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COMITÉ EJECUTIVO DEL FONDO MULTILATERAL
PARA LA APLICACIÓN DEL
PROTOCOLO DE MONTREAL
Octogésima quinta reunión
Montreal, 25 – 29 de mayo de 2020
Pospuesta: 19 – 22 de julio de 2020*

INFORMES DE SITUACIÓN Y SOBRE PROYECTOS CON REQUISITOS ESPECÍFICOS DE PRESENTACIÓN DE INFORMES

1. El presente documento hace el seguimiento de las cuestiones planteadas en los últimos informes anuales financieros y sobre la marcha de las actividades presentados a la 84ª reunión,[1] y con respecto a los proyectos y las actividades para los cuales se pidieron informes específicos en reuniones anteriores.

2. El documento está compuesto de las cinco secciones siguientes:

Sección I: Proyectos con demoras de ejecución y para los cuales se pidieron informes de situación especiales

Sección II: Informes sobre proyectos con requisitos específicos de presentación de informes para los cuales no hay política, costo u otras cuestiones pendientes, y para los cuales el Comité Ejecutivo podría tomar decisiones en base de las recomendaciones de la Secretaría sin más deliberaciones ("aprobación general"). El informe de la reunión del Comité Ejecutivo presentará individualmente cada informe que figura en esta sección, así como la decisión adoptada por el Comité

Sección III Informes sobre proyectos con requisitos específicos de presentación de informes para consideración individual del Comité Ejecutivo

Sección IV: Lista de empresas financiadas bajo los planes de gestión de eliminación de los HCFC con retrasos y/o sujetas a cambios del plan de ejecución y a empresas para conversión a tecnologías con bajo potencial de calentamiento atmosférico con

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[1] UNEP/OzL.Pro/ExCom/84/16-21

retrasos debidos a cuestiones relacionadas con su disponibilidad en el mercado local y/o costos más elevados (decisiones 84/27 y 84/42)

Sección V: Proyectos de inversión relacionados con HFC y actividades de facilitación financiadas usando las contribuciones adicionales de un grupo de 17 Partes que no operan al amparo del Artículo 5 (decisión 84/12 b))

SECCIÓN I: PROYECTOS CON DEMORAS DE EJECUCIÓN Y PARA LOS CUALES SE PIDIERON INFORMES DE SITUACIÓN ESPECIALES

Demoras en la ejecución

3. En la 84ª reunión, cinco proyectos en curso (uno bajo la ejecución del PNUMA y cuatro bajo la ejecución de la ONUDI) fueron clasificados como proyectos con retrasos en la ejecución. Estos proyectos, que figuran en el Anexo I del presente documento, están sujetos al procedimiento de cancelación y no pueden sacarse de la lista de supervisión antes de la terminación, conforme a la decisión 32/4.

4. Tanto el PNUMA como la ONUDI habían indicado que se había alcanzado un cierto progreso desde el último informe sobre la marcha de las actividades y que continuarían supervisando estos proyectos hasta su terminación.

Proyectos para los cuales se pidieron informes de situación adicionales[2]

5. En su 84ª reunión, el Comité Ejecutivo pidió informes de situación adicionales para 58 proyectos (decisión 84/12 a) iii)). Conforme a la decisión 84/12 a) iii), los organismos de ejecución y bilaterales pertinentes presentaron los informes pedidos para la 85ª reunión. Durante el examen, la Secretaría observó que 27 proyectos habían progresado. De los 31 proyectos restantes, en la sección III del presente documento se estudian cinco proyectos con cuestiones pendientes relacionadas con la República Popular Democrática de Corea; los restantes 26 proyectos con cuestiones pendientes se enumeran en el Anexo II del presente documento.

Recomendación

6. El Comité Ejecutivo podría querer:

a) Tomar nota de:

i) Los informes sobre retrasos en la ejecución y los informes de situación presentados por organismos de ejecución y bilaterales, que figuran en el documento UNEP/OzL.Pro/ExCom/85/9;

ii) Que los organismos de ejecución y bilaterales informasen al Comité Ejecutivo en la 86ª reunión sobre cinco proyectos con retrasos en la ejecución y 26 proyectos recomendados para informes de situación adicionales que aparecen en los Anexos I e II del presente documento, respectivamente, como parte de los informes anuales financieros y sobre la marcha de las actividades de 2019 de los organismos de ejecución y bilaterales; y

[2] Los proyectos de fortalecimiento institucional, las actividades relacionadas con bancos de halones, la capacitación de oficiales de aduanas, la recuperación y reciclaje, y los proyectos de demostración no están sujetos a los procedimientos de cancelación de proyecto. No obstante, el Comité Ejecutivo decidió continuar supervisándolos según proceda (decisión 36/14 b)).

b) Aprobar las recomendaciones sobre los proyectos en curso con las cuestiones específicas enumeradas en la última columna de la tabla del Anexo II del presente documento.

INFORMES SOBRE PROYECTOS CON REQUISITOS ESPECÍFICOS DE PRESENTACIÓN DE INFORMES

7. El Cuadro 1 enumera los informes sobre proyectos con requisitos específicos de presentación de informes presentados a la 85ª reunión y recomendados para aprobación general.

Cuadro 1: Informes sobre proyectos con requisitos específicos de presentación de informes recomendados para aprobación general

País	Título del proyecto	Apartados
Proyectos de eliminación de desechos de SAO		
Líbano	Proyecto experimental de demostración sobre la gestión y eliminación de desechos de SAO: informe final	9 - 13
País	**Título del proyecto**	**Apartados**
Uso temporal de tecnología con alto potencial de calentamiento atmosférico en proyectos aprobados		
Líbano	Plan de gestión de eliminación de los HCFC (etapa II): informe sobre la situación de la conversión de las empresas beneficiarias restantes en los sectores de fabricación de espumas y aparatos de climatización	14 - 20
Informes relacionados con planes de gestión de eliminación de los HCFC		
Argentina	Plan de gestión de eliminación de los HCFC (etapa II): Actualización de la viabilidad financiera de la empresa Celpack	21 - 23
Brasil	Plan de gestión de eliminación de los HCFC (etapa I): informe sobre el uso temporal de la tecnología con alto potencial de calentamiento atmosférico en los proveedores de sistemas de UTech e informe final sobre la marcha de las actividades	24 - 44
Brasil	Plan de gestión de eliminación de los HCFC (etapa II): situación de ejecución de los proyectos en el sector de fabricación de aparatos de climatización autónomos (CA)	45 - 52
Costa Rica	Plan de gestión de eliminación de los HCFC (etapa I): informe sobre la marcha de las actividades	53 - 62
Honduras	Plan de gestión de eliminación de los HCFC (etapa I): informe sobre la marcha de las actividades relativo a la ejecución de actividades bajo los componentes del PNUMA	63 - 73
India	Plan de gestión de eliminación de los HCFC (etapa II): Actualización de la evaluación de los fabricantes de paneles continuos con respecto a observancia a la prohibición	74 - 78
Indonesia	Plan de gestión de eliminación de los HCFC (etapa I): Actualización de la situación de la conversión de los fabricantes de equipos de refrigeración y climatización y plan de acción revisado	79 - 93
Malasia	Plan de gestión de eliminación de los HCFC (etapa II): Cambio de tecnología en 14 empresas	94 - 100
Marruecos	Plan de gestión de eliminación de los HCFC (etapa I): Informe sobre la marcha de las actividades	101 - 115
República de Moldova	Plan de gestión de eliminación de los HCFC (etapa II): Informe detallado sobre la situación de ejecución de los proyectos de demostración para usar tecnología con CO_2 en el sector de refrigeración comercial	116 -126

País	Título del proyecto	Apartados
Proyectos de eliminación de desechos de SAO		
Líbano	Proyecto experimental de demostración sobre la gestión y eliminación de desechos de SAO: informe final	9 - 13
Proyectos de demostración para alternativas con bajo potencial de calentamiento atmosférico		
Argentina y Túnez	Proyecto de demostración para la introducción de tecnología de refrigeración con CO^2 transcrítico para supermercados: informe final	127 - 147 (informe en el Anexo III)
Mundial	Proyecto de demostración sobre calidad, confinamiento e introducción de refrigerantes sucedáneos con bajo potencial de calentamiento atmosférico (Región de África Oriental y del Caribe): informe final	148 - 168 (informe en el Anexo IV)
Regional: Europa y Asia Central	Desarrollo de un centro de excelencia regional para la capacitación y la acreditación, y demostración de posibles refrigerantes alternativos con bajo calentamiento atmosférico: informe final	169 - 180 (informe en el Anexo V)
Arabia Saudita	Proyecto de demostración para eliminar los HCFC usando HFO como agente de espumación en usos con espumas pulverizadas en temperatura ambiente elevada: informe final	181 - 193 (informe en el Anexo VI)
Arabia Saudita	Proyecto de demostración sobre la promoción de refrigerantes con HFO y bajo potencial de calentamiento atmosférico para el sector de climatización en temperatura ambiente elevada: informe sobre la marcha de las actividades	194 - 202
Asia Occidental	Proyecto de demostración sobre la promoción de refrigerantes alternativos en aparatos de climatización para los países de temperatura ambiente elevada (PRAHA II): informe final	203 - 217 (informe en el Anexo VII)
Informes de auditoría financiera para los sectores de producción de CFC, halones, espumas de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes en China		
China	Agente de procesos II - información adicional sobre las actividades que se emprenderán	218 - 230
Peticiones de prórroga de actividades de facilitación		231 - 233

8. El Cuadro 2 enumera los informes sobre proyectos con requisitos específicos de presentación de informes presentados a la 85ª reunión para consideración individual y da una breve explicación de los temas conexos.

Cuadro 2: Informes sobre proyectos con requisitos específicos de presentación de informes para consideración individual

País	Título del proyecto	Problema	Apartados
Informes relacionados con los HCFC para planes de gestión de eliminación de los HCFC			
República Popular Democrática de Corea	Plan de gestión de eliminación de los HCFC (etapa I): Informe sobre la marcha de las actividades relativo a la ejecución de actividades	Pedido de orientación debido a las dificultades en la ejecución de actividades a la luz de las resoluciones del Consejo de Seguridad de las Naciones Unidas	234 - 244
Informes de auditoría financiera para los sectores de producción de CFC, halones, espumas de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes en China			
China	Informes de auditoría financiera para los sectores de producción de CFC, halones, espumas de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes	Devolución de saldos de los sectores de producción de CFC, espumas de poliuretano, servicio de equipos de refrigeración y solventes	245 - 250

SECCIÓN II: INFORMES SOBRE PROYECTOS CON LOS REQUISITOS ESPECÍFICOS DE INFORMACIÓN, RECOMENDADOS PARA APROBACIÓN GENERAL

Proyectos de eliminación de desechos de SAO

Líbano: Proyecto experimental de demostración sobre la gestión y eliminación de desechos de SAO (informe final) (ONUDI)

Antecedentes

9. En su 73ª reunión, el Comité Ejecutivo aprobó el proyecto experimental de demostración sobre la gestión y eliminación de desechos de SAO para Líbano, por un monto de $EUA 123 475, más los gastos de apoyo del organismo de $EUA 11 113, para la ONUDI.

10. En su 79ª reunión, el Comité Ejecutivo pidió, entre otras cosas, a los organismos de ejecución y bilaterales que presentasen informes finales sobre proyectos experimentales pendientes de eliminación de SAO, con excepción de los de Brasil y Colombia, y devolviesen a la 82ª reunión los saldos restantes de los proyectos para los cuales no se habían presentado informes a la reunión 80ª o 81ª (decisión 79/18 d)). Posteriormente la Secretaría preparó un informe de síntesis sobre los proyectos experimentales de eliminación de SAO estudiados por el Comité Ejecutivo en su 82ª reunión. En dicha reunión, el Comité Ejecutivo prolongó el proyecto experimental de demostración para Líbano hasta junio de 2019 con la presentación del informe final para la 84ª reunión y la devolución de los saldos en esa misma reunión (decisión 82/15 c)).[3]

Observaciones de la Secretaría

11. La Secretaría recibió el informe final del proyecto experimental de eliminación de SAO para Líbano para ser estudiado en la 85ª reunión el 5 de mayo de 2020, cinco semanas después del plazo de presentación. Debido al atraso de este documento, la Secretaría no pudo revisar la presentación y proporcionará un resumen de este informe en la 86ª reunión.

12. De acuerdo con la situación financiera proporcionada como parte del informe final, la ONUDI devolverá el saldo de $EUA 7 701 a la 85ª reunión.[4]

Recomendación

13. El Comité Ejecutivo podría tomar nota de la presentación hecha por la ONUDI del informe final para el proyecto experimental de demostración sobre la gestión y eliminación de desechos de SAO para Líbano, que la Secretaría examinará y presentará en la 86ª reunión.

[3] Aprobar la prórroga, al 30 de junio de 2019, del proyecto de demostración experimental sobre la gestión y eliminación de desechos de SAO para Líbano (LEB/DES/73/DEM/83), a condición de que el informe final y el informe de terminación de proyecto se presentasen a más tardar en la 84ª reunión y que los saldos fuesen devueltos conforme a la decisión 28/7.

[4] UNEP/OzL.Pro/ExCom/85/4

Uso temporal de una tecnología con alto potencial de calentamiento atmosférico en proyectos aprobados[5]

Líbano: Plan de gestión de eliminación de los HCFC (etapa II - Informe sobre la situación de la conversión de las empresas beneficiarias restantes en los sectores de fabricación de espumas y aparatos de climatización) (PNUD)

Antecedentes

14. En nombre del gobierno de Líbano, el PNUD, en calidad de organismo de ejecución asignado, presentó un informe sobre la marcha de las actividades relativo a la ejecución de las conversiones de empresas en los sectores de fabricación de espumas y aparatos de climatización, actualizaciones sobre el aseguramiento de la fuente de tecnología alternativa con bajo potencial de calentamiento atmosférico, y los resultados de las pruebas de dos alternativas en el sector de espumas, conforme a la decisión 84/29 b).[6]

Informe sobre la marcha de las actividades

15. Con respecto a conversión de las dos empresas restantes y a la asistencia técnica para la conversión de 11 empresas pequeñas en el sector de espumas, la disponibilidad de HFO sigue siendo un problema. Si bien se había identificado a un consultor técnico especializado en espumas, y se debían realizar los ensayos del metilal y formiato de metilo como agente espumante en empresas seleccionadas a principios de 2020, las condiciones reales de seguridad y la situación económica que prevalecían en el país han hecho imposible llevar a cabo estos ensayos. Además, la situación con el COVID-19 atrasó aún más su ejecución. Se espera empezar los ensayos con los diversos agentes espumantes, inclusive sistemas que utilizan HFO, una vez que la situación del país mejore con respecto al COVID-19; la conversión de 11 pequeñas empresas de espumas podría terminarse para el primer trimestre de 2021, y las empresas individuales restantes (SPEC y Prometal), para junio de 2021.

16. En la 84ª reunión, se informó que las dos empresas restantes del sector de fabricación de aparatos de climatización (es decir, CGI Halawany y ICR) todavía estaban decidiendo si utilizarían el HFC-32 u otra alternativa con bajo potencial de calentamiento atmosférico como refrigerante sucedáneo. Estas empresas finalmente se decidieron convertir al HFC-32. La conversión comenzará durante el tercer trimestre de 2020 y se espera que termine para el primer trimestre de 2021; no se prevé ningún problema con la tecnología seleccionada y el costo de la conversión.

Observaciones de la Secretaría

17. El PNUD reiteró que el gobierno de Líbano se comprometió a prohibir las importaciones de HCFC-141b para el 1 de enero de 2021. Esto permitiría terminar los ensayos con los diversos agentes espumantes y la conversión de todos los fabricantes de espumas para fines de 2020; en caso de que la conversión se termine durante el primer trimestre de 2021 (principalmente debido al COVID-19), se podría permitir a las empresas importar y almacenar el HCFC-141b antes de que la prohibición entre en vigencia.

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[5] El informe relacionado con el uso temporal de una tecnología con alto potencial de calentamiento atmosférico en los proyectos aprobados para Cuba se incluye en la propuesta de proyecto (UNEP/OzL.Pro/ExCom/85/23).

[6] Decisión 84/29 b): Pedir al PNUD que siga ayudando al gobierno de Líbano en asegurar el abastecimiento de tecnología alternativa de bajo potencial de calentamiento atmosférico, e informe, en la 85ª reunión, los resultados de las pruebas de dos alternativas en el sector de espumas y, en la misma reunión y en cada reunión posterior hasta que se haya introducido completamente la tecnología seleccionada originalmente u otra tecnología con bajo potencial de calentamiento atmosférico, sobre la situación de la conversión de las empresas beneficiarias restantes del sector de fabricación de espumas (SPEC, Prometal y las pequeñas empresas) y del sector de fabricación de aparatos de climatización (CGI Halawany y ICR).

18. Con respecto a las dos empresas restantes de aparatos de climatización (CGI Halawany y ICR), el PNUD mencionó que el gobierno confía en que estas empresas terminarían su conversión para el primer trimestre de 2021.

19. La Secretaría observó los esfuerzos realizados por el PNUD para ayudar a los restantes fabricantes de espumas y a las dos empresas de aparatos de climatización a terminar sus conversiones a alternativas sin SAO.

Recomendación

20. El Comité Ejecutivo podría:

a) Tomar nota del informe proporcionado por el PNUD y el gobierno de Líbano, que figura en el documento UNEP/OzL.Pro/ExCom/85/9, y describe las constantes dificultades con las que se enfrenta el gobierno para la obtención de suministros de alternativas con bajo potencial de calentamiento atmosférico y comercialmente disponibles, como HFO, y los esfuerzos realizados por el gobierno y el PNUD para facilitar el abastecimiento de tecnología con bajo potencial de calentamiento atmosférico a las empresas financiadas bajo la etapa II del plan de gestión de eliminación de los HCFC para Líbano; y

b) Pedir al PNUD que siga ayudando al gobierno de Líbano a asegurar el abastecimiento de tecnología alternativa con bajo potencial de calentamiento atmosférico, e informe en la 86ª reunión y en cada una de las reuniones posteriores hasta que se haya introducido completamente la tecnología original seleccionada u otra tecnología con bajo potencial de calentamiento atmosférico, sobre la situación de la conversión de las empresas beneficiarias restantes en el sector de fabricación de espumas (SPEC, Prometal y los pequeños fabricantes de espumas); y en el sector de fabricación de aparatos de climatización (CGI Halawany y ICR).

Informes relacionados con los planes de gestión de eliminación de los HCFC[7]

Argentina: Plan de gestión de eliminación de los HCFC (etapa II - actualización de la viabilidad financiera de la empresa Celpack) (ONUDI)

Antecedentes

21. En su 84ª reunión, el Comité Ejecutivo estudió la petición de financiamiento del segundo tramo de la etapa II del plan de gestión de eliminación de los HCFC para Argentina.[8] La petición del tramo incluyó un informe sobre la marcha de las actividades relativo a la ejecución de las actividades aprobadas bajo primer tramo; entre otras cosas el informe indicó que la conversión de la empresa Celpack, que fabrica espumas de poliestireno extruido, del HCFC-22 al CO_2, se había retrasado debido a las dificultades económicas con las que se enfrentaba, y a su interés en evaluar el butano como alternativa de los HCFC. Al aprobar el tramo de financiamiento, el Comité pidió a la ONUDI que presentase a la 85ª reunión una actualización de la viabilidad financiera de la empresa y si recibiría ayuda del Fondo Multilateral, a condición de que los fondos de la conversión se devolverían en caso de quitarse la empresa del proyecto (decisión 84/64 d) ii)).

22. En respuesta a la decisión 84/64 d) ii)), la ONUDI informó a la Secretaría que el gobierno de Argentina y la ONUDI no habían podido concluir la evaluación de la viabilidad financiera de Celpack. La

[7] El informe relacionado con el plan de gestión de eliminación de HCFC para Uruguay se incluye en la propuesta de proyecto (UNEP/OzL.Pro/ExCom/85/52).
[8] UNEP/OzL.Pro/ExCom/84/39

ONUDI explicó que ya se había iniciado el procedimiento para evaluar dicha viabilidad, que consiste en el nombramiento de un síndico y la verificación de las deudas y negociaciones con los acreedores; a fines de marzo de 2020, se estaban verificando las deudas de Celpack. Se pospuso una visita de seguimiento, planeada por la Dependencia Nacional del Ozono, hasta que se supriman las medidas de aislamiento establecidas por el gobierno debido al COVID-19. Se espera que las negociaciones con los acreedores terminen y la evaluación la viabilidad financiera se realice durante la segunda mitad de 2020. En consecuencia, el informe se presentaría a la 86ª reunión.

Recomendación

23. El Comité Ejecutivo podría solicitar al gobierno de Argentina, a través de la ONUDI, que proporcione a la 86ª reunión la actualización de la viabilidad financiera de la empresa Celpack, financiada bajo la etapa II del plan de gestión de eliminación de los HCFC, una decisión sobre si la empresa recibiría ayuda del Fondo Multilateral, conforme a la decisión 84/64 d) ii), y devolviese los fondos asociados a conversión a la 86ª reunión en caso de quitarse la empresa del proyecto.

<u>Brasil:</u> <u>Plan de gestión de eliminación de los HCFC (etapa I - informe sobre el uso temporal de la tecnología con alto potencial de calentamiento atmosférico en el proveedor de sistemas U-Tech e informe final sobre la marcha de las actividades)</u> (PNUD y el gobierno de Alemania)

Antecedentes

24. En nombre del gobierno de Brasil, el PNUD en calidad de organismo de ejecución principal, presentó a la 85ª reunión[9] el informe final sobre la ejecución del programa de trabajo asociado a la etapa I del plan de gestión de eliminación de los HCFC y el informe de terminación de proyecto,[10] conforme a la decisión 84/32 b) i).[11]

Consumo de HCFC

25. El gobierno de Brasil informó un consumo de 826,26 toneladas PAO de HCFC en 2018, lo que está 38 por ciento por debajo de la base para el cumplimiento de esas sustancias. El gobierno también informó que los datos de consumo sectorial de los HCFC, según el informe de ejecución del programa de país de 2018, coinciden con los datos informados en virtud del Artículo 7 del Protocolo. El consumo de los HCFC para 2019 no está disponible todavía.

Informe final sobre la ejecución de la etapa I del plan de gestión de eliminación de los HCFC

Sector de fabricación de espumas de poliuretano

<u>*Conversión de 12 fabricantes de espumas de poliuretano independientes (79,71 toneladas PAO)*</u>

26. Once empresas (con un consumo de 76,74 toneladas PAO de HCFC-141b) en fabricación de paneles continuos y revestimiento integral/usos moldeados flexibles terminaron sus conversiones (tres optaron por hidrocarburos, tres por formiato de metilo, tres por metilal, una por cloruro de metileno y una

[9] Según la carta del 26 de marzo de 2020, dirigida al PNUD por el Ministerio de Medio Ambiente de Brasil.
[10] El quinto y último tramo de la etapa I del plan de gestión de eliminación de HCFC se aprobó en la 75ª reunión por un costo total de $EUA 2 035 094, que consiste en $EUA 1 470 700, más los gastos de apoyo del organismo de $EUA 110 303, para el PNUD, y de $EUA 409 091, más los gastos de apoyo del organismo de $EUA 45 000, para el gobierno de Alemania. En su 80ª reunión, el Comité aprobó posponer la fecha de terminación de la etapa I al 31 de diciembre de 2019, a condición que no se pidiera otra prórroga (decisión 80/12 b)).
[11] Se pidió al gobierno de Brasil, el PNUD y el gobierno de Alemania que en la 85ª reunión presenten el informe final sobre la ejecución del programa de trabajo asociado a la etapa I del plan de gestión de eliminación de HCFC hasta su terminación y el informe de terminación de proyecto.

por tecnología a base de agua). Una empresa (Panisol), con un consumo total de 3,0 toneladas PAO de HCFC-141b, se retiró del plan de gestión de eliminación de los HCFC y, por lo tanto, el consumo asociado a la empresa no se eliminó según la etapa I. El saldo de financiamiento de $EUA 301 695 (más los gastos de apoyo del organismo de $EUA 22 627) deberá devolverse al Fondo Multilateral a más tardar en la 86ª reunión.

Conversión de 11 proveedores de sistemas y de 370 usuarios subsecuentes de espumas (89,1 toneladas PAO)

27. De los 11 proveedores de sistemas incluidos en el proyecto, 10 terminaron sus conversiones y elaboraron e introdujeron formulaciones con bajo potencial de calentamiento atmosférico en sus usuarios subsecuentes de espumas. En la 75ª reunión se devolvieron $EUA 179 300 más los gastos de apoyo del organismo de $EUA 13 448 correspondientes a una empresa (Arinos), que durante la ejecución del proyecto fue identificada como no admisible para el financiamiento. Además, $EUA 135 300, más los gastos de apoyo del organismo de $EUA 10 148 asignados a un proveedor de sistemas (Polysystem) que se retiró del plan de gestión de eliminación de los HCFC, deberán devolverse al Fondo Multilateral a más tardar en la 86ª reunión.

28. Conforme a la decisión 84/32 b) ii), el PNUD incluyó en el informe la lista de usuarios subsecuentes de espumas bajo la etapa I, junto con su consumo eliminado de HCFC-141b, subsector, equipos básicos y tecnología adoptada. El informe indica lo siguiente:

a) 225 empresas terminaron sus conversiones a las alternativas con bajo potencial de calentamiento atmosférico, eliminando 85,11 toneladas PAO de HCFC-141b;

b) 39 empresas subsecuentes de espumas (8,48 toneladas PAO) se retiraron del plan de gestión de eliminación de los HCFC; el consumo de HCFC-141b asociado a estas empresas se eliminó;

c) 22 empresas subsecuentes de espumas se consideraron no admisibles para el financiamiento (consumo no disponible);

d) Durante la ejecución del proyecto, se descubrió que 84 empresas subsecuentes de espumas identificadas en el momento de la presentación de la etapa I del plan de gestión de eliminación de los HCFC sin querer se habían contabilizado más de una vez, porque compraban polioles de varios proveedores de sistemas; y

e) Un saldo de $EUA 1 597 282 correspondiente a las empresas subsecuentes de espumas que no se convirtieron debido a la falta de admisibilidad o a la no participación en el plan de gestión de eliminación de los HCFC.

29. De este modo, el saldo total proveniente de la ejecución de todos los proyectos grupales e individuales en el sector de espumas de poliuretano es $EUA 2 034 278, que se devolverá a más tardar en la 86ª reunión, conforme a la decisión 84/32 b) iii).

Sector de servicio de equipos de refrigeración

30. Se terminaron todas las actividades previstas en el sector de servicio de equipos de refrigeración como se detalla en informes anteriores y el monto total desembolsado fue de $EUA 4 090 909. No hay saldos para el Fondo Multilateral.

Oficina de gestión de proyectos

31. La oficina de gestión de proyectos siguió apoyando la Dependencia Nacional del Ozono en la ejecución de las actividades del plan de gestión de eliminación de los HCFC durante la finalización de la etapa I de dicho plan. Entre 2012 y 2019 la oficina de gestión de proyectos desembolsó un monto de $EUA 800 000.[12]

Desembolsos de fondos

32. En diciembre de 2019, de los $EUA 19 417 866 aprobados para la etapa I,[13] se habían desembolsado $EUA 17 323 588 (90 por ciento) (es decir, $EUA 13 292 679, para el PNUD, y $EUA 4 090 909, para el gobierno de Alemania). El PNUD todavía está haciendo pagos finales de menor importancia del saldo de $EUA 2 034 278 y se devolverá al Fondo un saldo del orden de $EUA 2 millones (Cuadro 3).

Cuadro 3: Informe financiero de la etapa I del plan de gestión de eliminación de los HCFC para Brasil

Organismo	**Fondos aprobados ($EUA)**	**Fondos desembolsados**		**Saldo ($EUA)**
		($EUA)	**(%)**	
PNUD	15 326 957	13 292 679	87	2 034 278
Gobierno de Alemania	4 090 909	4 090 909	100	0
Total	**19 417 866**	**17 383 588**	**90**	**2 034 278**

33. El PNUD confirmó que todas las actividades bajo la etapa I terminaron en diciembre de 2019, conforme a la decisión 80/12 b).

Observaciones de la Secretaría

Sector de espumas de poliuretano

Terminación del proyecto y devolución de saldos

34. La Secretaría toma nota con beneplácito del minucioso trabajo realizado por el gobierno de Brasil y el PNUD para verificar la admisibilidad de un gran número de pequeños y medianos fabricantes de espumas incluidos en la etapa I y terminar el proyecto para la fecha prorrogada de diciembre de 2019.[14]

35. Con respecto a las 84 empresas que no se contabilizaron en el informe final, el PNUD confirmó que durante la ejecución del proyecto, 76 empresas se contabilizaron efectivamente en la lista final; en el momento de preparar el plan de gestión de eliminación de los HCFC, algunas empresas se contabilizaron sin querer más de una vez porque compraban polioles de varios proveedores de sistemas. Esta incertidumbre se reconoció en el momento de aprobar el plan de gestión de eliminación de los HCFC y, por este motivo, una de las tareas clave durante la ejecución fue verificar la información *in situ* y hacer un inventario detallado de las empresas admisibles y equipos básicos en las empresas subsecuentes de espumas que participaban. Una vez verificados los casos repetidos, el PNUD fortaleció su consumo y las trató como una empresa subsecuente de espumas a través de un proveedor de sistemas únicamente. Esto explica la razón de que haya menos empresas en el inventario final.

36. Asimismo el PNUD confirmó que todos los pagos hechos a los usuarios subsecuentes de espumas siguieron estrictamente los niveles de financiamiento aprobados por el Comité Ejecutivo (es decir,

[12] Los detalles en la estructura de costos de la oficina de gestión de proyectos se proporcionarán en la 86ª reunión con el pedido del tramo siguiente de la etapa II del plan de gestión de eliminación de HCFC.
[13] Excepto $EUA 179 300 devueltos al Fondo Multilateral que se asociaron a una empresa inadmisible.
[14] La etapa I del plan de gestión de eliminación de HCFC para Brasil se prorrogó dos veces: hasta diciembre de 2017 (UNEP/OzL.Pro/ExCom/75/40) y hasta diciembre de 2019 (decisión 80/12 b)).

$EUA 15 000 para nuevos distribuidores o reconversión de distribuidores de alta presión, $EUA 10 000 para reconversión de distribuidores de baja presión, $EUA 3 000 para asistencia técnica, ensayos y capacitación para las empresas con consumo por encima de 500 kg/año, y $EUA 1 300 para las empresas por debajo de 500 kg/año). El tipo de equipos y su admisibilidad (particularmente con respecto a la fecha límite) en cada empresa participante fueron identificados durante la ejecución del proyecto tal como se acordó durante la preparación del proyecto. La lista final de empresas presentadas por el PNUD incluye los equipos básicos de cada empresa y la ayuda proporcionada (reconversión de distribuidor, distribuidor nuevo o ningún cambio).

37. El PNUD también destacó que aunque el número verificado de empresas subsecuentes de espumas del inventario final fuera inferior al del inventario inicial, las empresas asistidas subsecuentes de espumas eliminaron un total de 86,06 toneladas PAO, lo que representa más del 95 por ciento de las 89,1 toneladas PAO financiadas por eliminar, y hay un saldo de casi $EUA 1,6 millones proveniente de este componente. El consumo de HCFC-141b asociado a las empresas no admisibles se eliminará con financiación externa al Fondo Multilateral.

38. De acuerdo con los datos detallados y las explicaciones dadas por el PNUD, la Secretaría toma nota de que el PNUD siguió rigurosamente los principios acordados del proyecto y logró el objetivo de eliminación con una mejor relación costo-eficacia que la propuesta aprobada. El Cuadro 4 siguiente resume la ejecución de la etapa I del plan de gestión de eliminación de los HCFC para Brasil.

Cuadro 4: Resumen de la ejecución de la etapa I del plan de gestión de eliminación de los HCFC para Brasil

Actividad	**Según lo aprobado**				**Según lo ejecutado**				**Saldo ($EUA)**
	No. de empresas	**Toneladas PAO**	**Aprobado ($EUA)**	**Relación de costo a eficacia ($EUA/kg)**	**No. de empresas**	**Toneladas PAO**	**Desembolsado ($EUA)**	**Relación de costo a eficacia ($EUA/kg)**	
Revestimiento integral	11	47,34	2 238 819	5,20	11	47,34	2 238 819	5,20	-
Paneles continuos	4	32,35	2 218 791	7,54	3	29,39	1 917 095	7,18	301 696 **
Proyecto grupal	11 PS 370 USE	89,03	9 949 347*	12,29	10 SH 225 DSU	85,11	8 216 765	10,62	1 732 582 ***
Total de espumas	**396**	**168,73**	**14 406 957**	**9,39**	**249**	**161,84**	**12 372 680**	**8,41**	**2 034 278**
Medida reglamentaria	n/c	1,50	120 000	4,40	n/c	1,50	120 000	4,40	-
Sector de servicios	n/c	50,00	4 090 909	4,50	n/c	50,00	4 090 909	4,50	-
Oficina de gestión de proyectos	n/c		800 000		n/c		800 000		-
Total		**220,23**	**19 417 866**	**7,86**		**213,34**	**17 383 588**	**7,22**	**2 034 278**

PS: Proveedor de sistemas; USE: Usuarios subsecuentes de espumas.

* Incluye una deducción de $EUA 179 300 del quinto tramo (75ª reunión) correspondiente al proveedor de sistemas PS Arinos, considerada no admisible.

** Fondos de la empresa Panisol (3,0 toneladas PAO) que se retiró del plan de gestión de eliminación de los HCFC.

*** Este saldo incluye $EUA 135 300 proveniente del proveedor de sistemas Polysystem que se retiró del plan de gestión de eliminación de los HCFC, y unos $EUA 1 597 282 de usuarios subsecuentes de espumas.

39. El saldo restante se devolverá en la 86ª reunión. El PNUD aclaró que todavía se estaban haciendo pagos finales de menor importancia, pero aseguró que el monto que se devolverá será del orden de $EUA 2 millones.

Uso temporal de la tecnología con alto potencial de calentamiento atmosférico

40. En la 80ª reunión, el PNUD explicó que dos proveedores de sistemas (Shitmek y U-Tech) habían pedido usar temporalmente sistemas de polioles con HFC con los agentes espumantes de alto potencial de calentamiento atmosférico, dado que los HFO todavía no estaban disponible comercialmente dentro del país. Ambos proveedores de sistemas habían firmado un compromiso para dejar de usar temporalmente las mezclas de HFC una vez que los HFO estuviesen disponible en el comercio y los sistemas se hubiesen desarrollado y optimizado, sin costo adicional para el Fondo Multilateral.

41. En consecuencia, el Comité Ejecutivo pidió al PNUD para siguiera ayudando a Shitmek y a U-Tech a asegurar el abastecimiento de las tecnologías alternativas seleccionadas, a condición de que los costos de explotación adicionales no se pagarían hasta que se hubiese introducido completamente la tecnología alternativa seleccionada u otra tecnología con bajo potencial de calentamiento atmosférico. Asimismo, se pidió al PNUD que informase sobre la situación del uso de la tecnología provisional hasta que se hubiese introducido completamente la tecnología alternativa seleccionada u otra tecnología con bajo potencial de calentamiento atmosférico (decisión 80/12 e)), junto con una actualización proveniente de los proveedores sobre el avance realizado para asegurar que en el país se disponía comercialmente de las tecnologías seleccionadas, inclusive los componentes conexos (decisión 81/9). En la 83ª reunión, el PNUD informó que Shitmek había optado por una tecnología a base de agua para sustituir el uso de los HFO en la producción de espumas flexible, usando los recursos propios de los proveedores de sistemas para los ajustes necesarios de las formulaciones, dado que los precios de HFO en el mercado seguían siendo muy altos, rechazando el suministro de sistemas a precios competitivos. La empresa ya no usa más HFC.

42. Conforme a la decisión 84/32 c), el PNUD reconfirmó que concluyó la reconversión del proveedor de sistemas U-Tech y se había eliminado el uso de los HCFC en sus polioles. La empresa U-Tech adoptó el formiato de metilo para sustituir el HCFC-141b en todas sus aplicaciones, a excepción de la producción de Froth System, donde se proponía sustituir el HCFC-22 por HFO, pero usa temporalmente el HFC-134a. Durante un semestre U-Tech probó formulaciones con HFO (basado en muestras recibidas a un precio de $EUA 22,00/kg) para evaluar la estabilidad del producto, y U-Tech y el proveedor (Honeywell) tratan los arreglos finales para el abastecimiento de agente espumante y los componentes químicos conexos. Sin embargo, sobre la base de un precio final de HFO estimado en $EUA 19,75/kg, según lo informado verbalmente por el proveedor, el costo de los sistemas de polioles aumentará el 33 por ciento, haciendo su cuota de mercado inviable.

43. La Secretaría toma nota de que la etapa I del plan de gestión de eliminación de los HCFC está terminada y, por lo tanto, no se pagará ningún costo de explotación adicional a los usuarios subsecuentes asociados a conversión de Froth System a la tecnología con bajo potencial de calentamiento atmosférico suministrada por U-Tech. Al observar que U-Tech también está incluida en la etapa II del plan de gestión de eliminación de los HCFC, la Secretaría recomienda que el PNUD siga informando sobre el todo progreso adicional realizado por U-Tech para introducir una tecnología alternativa con bajo potencial de calentamiento atmosférico en la producción de Froth System.

Recomendación

44. El Comité Ejecutivo podría:

a) Tomar nota de:

i) El informe final sobre la ejecución del plan de gestión de eliminación de los HCFC (etapa I) para Brasil, presentado por el PNUD y que figura en el documento UNEP/OzL.Pro/ExCom/85/9;

ii) Que hay un saldo estimado de $EUA 2 034 278 proveniente de la ejecución de proyectos en el sector de espumas de poliuretano, y que el PNUD devolverá el saldo real del financiamiento al Fondo Multilateral en la 86ª reunión; y

b) Pedir al PNUD que siga ayudando al gobierno de Brasil para asegurar el abastecimiento de tecnologías alternativas con bajo potencial de calentamiento atmosférico al proveedor de sistemas U-Tech, a condición de que no pagar ningún costo de explotación adicional relacionado con conversión de los usos de sistema de espumas bajo la etapa II hasta que se hubiese introducido completamente la tecnología seleccionada originalmente u otra tecnología con bajo potencial de calentamiento atmosférico, y proporcione, en cada reunión, hasta que se hubiese introducido completamente la tecnología seleccionada originalmente u otra tecnología con bajo potencial de calentamiento atmosférico, un informe sobre la situación de la conversión, junto con una actualización proveniente de los proveedores sobre el progreso realizado para asegurar que en el país se disponía comercialmente de las tecnologías seleccionadas, inclusive los componentes conexos.

Brasil: Plan de gestión de eliminación de los HCFC (etapa II - situación de ejecución de los proyectos en el sector de fabricación de aparatos de climatización autónomos) (ONUDI, PNUD, los gobiernos de Alemania e Italia)

Antecedentes

45. En la 82ª reunión, el gobierno de Brasil y la ONUDI informaron al Comité Ejecutivo que las tres empresas de aparatos de climatización autónomos, incluidas en la etapa II del plan de gestión de eliminación de los HCFC no habían comenzado sus conversiones al R-290, debido a la incertidumbre sobre las reglamentaciones relativas al uso de refrigerantes inflamables, la aceptación en el mercado de esos refrigerantes, el miedo de precios más elevados de los aparatos convertidos y la posible falta de disponibilidad de componentes de aparatos de climatización en el mercado. En consecuencia, al aprobar el tercer tramo de la etapa II, el Comité Ejecutivo pidió entre otras cosas a la ONUDI que informase en la 84ª reunión sobre la situación de ejecución de los proyectos en el sector de fabricación de aparatos de climatización autónomos (decisión 82/62 c)).

46. En respuesta a la decisión 82/62 c), en la 84ª reunión la ONUDI informó que, para abordar las preocupaciones de las empresas de aparatos de climatización autónomos con respecto a la introducción de la tecnología del R-290, en marzo 2019 ese organismo realizó un taller para más de 60 representantes de ese sector sobre el uso de refrigerantes alternativos en esos aparatos. Además, en coordinación con el Ministerio de Medio Ambiente, la ONUDI planeó realizar un segundo taller para fines de 2019 y un estudio de mercado en 2020 que aborde, entre otras cosas, la capacidad de aceptación del mercado, la evaluación de la opinión del consumidor, la evaluación de las normas de seguridad existentes, el costo y la disponibilidad de componentes, y los posibles obstáculos.

47. El Comité Ejecutivo tomó nota del informe presentado por la ONUDI sobre la situación de ejecución de los proyectos en el sector de fabricación de aparatos de climatización autónomos[15] y pidió a ese organismo que informase nuevamente en la 85ª reunión sobre la situación de ejecución de los proyectos en el sector de fabricación de dichos aparatos.

[15] Decisión 84/33 a) i) y c). El informe figura en el documento UNEP/OzL.Pro/ExCom/84/22

Informe sobre la marcha de las actividades

48. La ONUDI presentó a la 85ª reunión un informe sobre la marcha de las actividades que recuerda que las preocupaciones más pertinentes para las tres empresas de aparatos de climatización autónomos estaban relacionadas con la capacidad de aceptación de equipos con líquidos inflamables en el mercado brasileño; la dificultad de rastrear el producto en la etapa del mercado de postventa, afirmando que los accidentes podrían ocurrir debido a una mala instalación y mantenimiento, dañando la imagen de la empresa; y la necesidad de establecer programas de capacitación y de creación de capacidad para lidiar con los nuevos equipos.

49. Con el fin de tratar estas cuestiones, en noviembre de 2019 la ONUDI organizó el segundo taller para los fabricantes de aparatos de climatización autónomos sobre experiencias y perspectivas relacionadas con el uso del R-290 como refrigerante en esos aparatos. La reunión incluyó sesiones sobre las experiencias *in situ* de las empresas que trabajaban ya en equipos convertidos (por ej., Midea, en China y Godrej, en India) y contribuyó a sensibilizar a los interesados directos respecto de la tecnología. El gobierno y la ONUDI también llamaron a licitación para contratar una empresa para hacer el estudio de mercado planeado para 2020, que abordase la capacidad de aceptación del mercado, la evaluación de la opinión del consumidor, la evaluación de las normas de seguridad existentes, el costo y la disponibilidad de componentes, y los posibles obstáculos. Se espera que el estudio esté terminado en septiembre de 2020.

Observaciones de la Secretaría

50. La Secretaría toma nota con beneplácito de los esfuerzos adicionales hechos por el gobierno de Brasil y la ONUDI para ayudar a las empresas de aparatos de climatización autónomos a abordar sus preocupaciones de seleccionar una tecnología con bajo potencial de calentamiento atmosférico para su conversión.

51. Al tomar nota de que persisten las preocupaciones sobre la adopción de un refrigerante inflamable en las empresas de aparatos de climatización y al considerar los esfuerzos del gobierno de Brasil y la ONUDI para evitar la adopción de la tecnología con R-410A, la Secretaría recomienda que el gobierno y la ONUDI sigan trabajando con las empresas de aparatos de climatización para introducir la tecnología seleccionada y presenten a la 86ª reunión un informe sobre la marcha de las actividades relativas a la situación de la selección de las tecnologías por los fabricantes de dichos equipos.

Recomendación

52. El Comité Ejecutivo podría:

a) Tomar nota del informe sobre la situación de ejecución de los proyectos en el sector de fabricación de aparatos de climatización autónomos de la etapa II del plan de gestión de eliminación de los HCFC para Brasil, presentado por la ONUDI y que figura en el documento UNEP/OzL.Pro/ExCom/85/9; y

b) Pedir a la ONUDI que en la 86ª reunión informe sobre la situación de ejecución de los proyectos en el sector de fabricación de aparatos de climatización autónomos de la etapa II del plan de gestión de eliminación de los HCFC para Brasil.

Costa Rica: Plan de gestión de eliminación de los HCFC (etapa I - informe sobre la marcha de las actividades) (PNUD)

Antecedentes

53. En su 83ª reunión, el Comité Ejecutivo aprobó el quinto y último tramo de la etapa I del plan de gestión de eliminación de los HCFC para Costa Rica y solicitó al gobierno y al PNUD, en calidad de organismo de ejecución asignado, que en la 85ª reunión presenten un informe sobre la marcha de las actividades relativas a la ejecución del programa de trabajo asociado al último tramo de la etapa I del plan de gestión de eliminación de los HCFC y en la primera reunión del Comité Ejecutivo, en 2022, presenten el informe de terminación de proyecto (decisión 83/49).

54. En consecuencia, en nombre del gobierno de Costa Rica, el PNUD presentó el informe sobre la marcha de las actividades a la 85ª reunión.

Informe sobre la marcha de las actividades

Consumo de HCFC

55. El gobierno de Costa Rica informó en el informe de ejecución del programa de país un consumo de 6,31 toneladas PAO de HCFC para 2019, lo que está el 55 por ciento por debajo de la base para el cumplimiento de esas sustancias. En el Cuadro 5 se indica el consumo de HCFC correspondiente al período de 2015-2019.

Cuadro 5: Consumo de HCFC en Costa Rica (datos de 2015-2019, conforme al Artículo 7)

HCFC	2015	2016	2017	2018	2019*	Base
Toneladas métricas						
HCFC-22	155,69	155,40	152,56	138,20	92,96	181,88
HCFC-123	19,93	0,00	0,00	(0,64)	0,00	0,36
HCFC-124	2,10	1,50	0,48	0,48	0,00	3,95
HCFC-141b	2,45	20,30	15,22	10,88	10,88	32,59
HCFC-142b	0,67	0,45	0,14	0,14	0,00	6,17
HCFC-225ca	0,00	0,00	0,00	0,00	0,00	-
HCFC-225cb	0,00	0,00	0,00	0,00	0,00	-
Total (tm)	**180,84**	**177,65**	**168,40**	**149,06**	**103,84**	**224,94**
HCFC-141b en polioles premezclados importados*	10,00	11,50	4,49	3,66	3,31	164,64 **
Toneladas PAO						
HCFC-22	8,56	8,55	8,39	7,60	5,11	10,00
HCFC-123	2,19	0,00	0,00	(0,01)	0,00	0,01
HCFC-124	0,14	0,10	0,03	0,03	0,00	0,09
HCFC-141b	0,05	2,23	1,67	1,20	1,20	3,58
HCFC-142b	0,01	0,01	0,00	0,00	0,00	0,40
HCFC-225ca	-	0,00	0,00	0,00	0,00	-
HCFC-225cb	-	0,00	0,00	0,00	0,00	-
Total (toneladas PAO)	**10,96**	**10,89**	**10,10**	**8,82**	**6,31**	**14,10**
HCFC-141b en polioles premezclados importados*	1,10	1,27	0,49	0,40	0,36	18,11 **

* Datos del Programa de país.
** Punto de partida establecido en el Acuerdo con el Comité Ejecutivo.

56. El consumo de los HCFC ha estado disminuyendo debido a la aplicación del sistema de otorgamiento de licencias y cuotas, la ejecución de actividades de eliminación en el sector de servicio de equipos de refrigeración, conforme al plan de gestión de eliminación de los HCFC, la conversión del más

grande usuario de HCFC-141b en sistemas de polioles premezclados importados, y la introducción de equipos de refrigeración y climatización sin HCFC-22.

Actividades ejecutadas para el quinto y último tramo de la etapa I del plan de gestión de eliminación de los HCFC

57. Entre julio de 2019 y marzo de 2020 se ejecutaron las siguientes actividades:

a) Se está estudiando un proyecto de reglamentación que regiría las actividades de los técnicos de servicio de refrigeración y climatización y haría obligatoria la acreditación de técnicos en este campo; el Instituto Nacional de Aprendizaje (INA) actualmente expide un certificado de prácticas idóneas a aquellos técnicos en refrigeración y climatización que han terminado satisfactoriamente la capacitación en prácticas idóneas de mantenimiento;

b) El Comité Técnico Nacional, en cooperación con la Dependencia Nacional del Ozono, prepara un nuevo sistema de normas para el uso seguro del amoníaco y los hidrocarburos en el sector de refrigeración y climatización;

c) Con el Comité Técnico Nacional se realizó una gira técnica para estudiantes, técnicos y dueños de equipos de refrigeración y climatización, para mostrar tecnologías alternativas en diversos usos de refrigeración y climatización que se introdujeron en el país (por ej., NH_3/CO_2 en Pinova, enfriadores con R-290); para demostrar la eficacia energética más alta, menos intervenciones de mantenimiento, índices más bajos de fugas de refrigerantes y bajos costos de refrigerantes asociados a las tecnologías; y para apoyar la adopción de la norma nacional para el amoníaco;

d) Ejecución continua del programa para la destrucción de gases refrigerantes, donde el Acuerdo entre el Ministerio de Ambiente y Energía (MINAE) y el horno de cemento adaptado para la destrucción de los refrigerantes (Holcim) se prolongó dos años más; y coordinación con una red de compañías autorizadas para juntar los gases refrigerantes recolectados de posibles clientes para la destrucción por Holcim; y

e) Selección de dos consultores técnicos que ayudarán a la Dependencia Nacional del Ozono en la supervisión de la ejecución de las actividades del plan de gestión de eliminación de los HCFC, como parte de la oficina de gestión de proyectos.

Desembolsos de fondos

58. En diciembre de 2019, del total de fondos aprobados de $EUA 1 153 523 (es decir, $EUA 593 523 para del proyecto de conversión de espumas y $EUA 560 000 para las actividades en el sector de servicios), se habían desembolsado todos los fondos para el sector de espumas y $EUA 491 000 para el sector de servicios (91 por ciento de los fondos totales). El saldo de $EUA 69 000 se desembolsará en 2020.

Observaciones de la Secretaría

59. El PNUD tomó nota de que la contracción de la economía que tuvo lugar en la segunda mitad de 2019 y el impacto de COVID-19 podrían retrasar la terminación de algunas actividades del plan de gestión de eliminación de los HCFC, particularmente la adopción de tecnologías con bajo potencial de calentamiento atmosférico y ecoenergéticas.

60. El plan de trabajo para el último tramo incluyó la capacitación de los oficiales de aduanas y de los técnicos de servicio, y los talleres para los usuarios finales que aún no se han ejecutado. El PNUD mencionó que la capacitación de técnicos y los talleres para usuarios finales estaban programados para el primer trimestre de 2020; sin embargo, debido al COVID-19 estas actividades se retrasaron. Si bien no hubo ninguna capacitación para oficiales de aduanas, se coordinó con el Ministerio de Finanzas, la Dirección General de Aduanas, el Ministerio de Salud y la Dirección de Gestión de Calidad Ambiental del MINAE para planear la realización de la capacitación cuando la situación se normalice. El PNUD también indicó que las partes interesadas y los socios están listos para facilitar la terminación eficaz de estas actividades, cuando sea necesario.

61. La Secretaría tomó nota de los esfuerzos del PNUD por asegurar que se ejecutarían las actividades previstas bajo el último tramo del plan de gestión de eliminación de los HCFC, y que se llevó a cabo la planificación y la coordinación requeridos para asegurar que todas las actividades puedan terminarse cuando vuelva a normalizarse la situación.

Recomendación

62. El Comité Ejecutivo podría:

a) Tomar nota del informe sobre la marcha de las actividades relativas a la ejecución del quinto y último tramo de la etapa I del plan de gestión de eliminación de los HCFC para Costa Rica, presentado por el PNUD y que figura en el documento UNEP/OzL.Pro/ExCom/85/9; y

b) Pedir al gobierno de Costa Rica y el PNUD que presenten a la primera reunión del Comité Ejecutivo en 2022 un informe final sobre la ejecución de la etapa I del plan de gestión de eliminación de los HCFC, junto con el informe de terminación de proyecto requerido.

Honduras: Plan de gestión de eliminación de los HCFC (etapa I - informe sobre la marcha de las actividades ejecutadas bajo los componentes del PNUMA) (PNUMA)

Antecedentes

63. En su 81ª reunión, el Comité Ejecutivo aprobó (conforme a la lista de proyectos presentados para aprobación general) el cuarto tramo de la etapa I del plan de gestión de eliminación de los HCFC para Honduras, y el plan de ejecución del tramo correspondiente a 2018-2020, quedando entendido que: el PNUMA y el gobierno de Honduras intensificarían sus esfuerzos por ejecutar las actividades de capacitación de técnicos en refrigeración; el PNUMA presentaría un informe sobre la marcha de las actividades en cada reunión sobre la ejecución de las actividades bajo los componentes del PNUMA, inclusive los desembolsos realizados, hasta la presentación del quinto tramo de la etapa I; y que los objetivos de desembolsos para el monto total de fondos aprobados para los componentes del PNUMA del primero, segundo y tercer tramo eran del 50 por ciento al 30 de septiembre de 2018, el 80 por ciento al 31 de marzo de 2019, y el 100 por ciento en diciembre de 2019, y que los objetivos de desembolsos para el componente del PNUMA del cuarto tramo fueron un desembolso del 20 por ciento para el 31 de marzo de 2019 y 50 por ciento para diciembre de 2019.

64. En consecuencia, el PNUMA presentó informes sobre la marcha de las actividades a las reuniones 82ª, 83ª y 84ª. Si bien el gobierno de Honduras y el PNUMA habían ejecutado algunas actividades de capacitación para técnicos en refrigeración, otras actividades no avanzaron como se esperaba, y no se lograron los objetivos de desembolsos fijados en la 81ª reunión. Dado que todavía había compromisos que requerían otras medidas, en su 84ª reunión el Comité tomó nota de que el quinto tramo de la etapa I podría presentarse sólo cuando se hubiesen cumplido las siguientes condiciones:

a) Terminación de la capacitación para oficiales de aduanas y responsables de aplicar las reglamentaciones, cubriendo 31 puntos de entrada aduaneros, sobre el control de importaciones de los HCFC y de equipos que utilizan esas sustancias;

b) Terminación del establecimiento de un sistema electrónico para el registro de importadores, proveedores y usuarios finales;

c) Progreso importante en la revisión de normas técnicas, inclusive medidas de seguridad para refrigerantes inflamables; y

d) Desembolso del 100 por ciento del total de los fondos aprobados para los componentes del PNUMA del primero, segundo y tercer tramo de la etapa I del plan de gestión de eliminación de los HCFC y desembolso del 70 por ciento para el componente del PNUMA del cuarto tramo.

65. Asimismo, el Comité pidió al PNUMA que siga presentando en cada reunión hasta la presentación del quinto tramo de la etapa I del plan de gestión de eliminación de los HCFC, un informe sobre la marcha de las actividades relativo a la ejecución de todas las actividades bajo los componentes del PNUMA, inclusive los desembolsos (decisión 84/18).

66. Conforme a la decisión 84/18, el PNUMA presentó a la 85ª reunión un informe financiero y sobre el avance de la ejecución de las actividades del PNUMA bajo la etapa I.[16]

Informe sobre la marcha de las actividades

67. Desde la 84ª reunión se realizaron las siguientes actividades:

a) Un consultor internacional preparó un programa de capacitación para oficiales de aduanas y responsables de aplicar las reglamentaciones;

b) Se tomaron medidas para contratar a un experto regional para abril de 2020 con el fin de desarrollar el sistema electrónico para el registro de importadores, proveedores y usuarios finales; se preparó el contenido para los módulos de formación en línea; y se espera que la base de datos esté terminada y funcione plenamente en agosto de 2020;

c) En Colombia se acreditó a tres empleados de la Dependencia Nacional del Ozono y a nueve instructores del instituto nacional de formación (INFOP) en prácticas idóneas para el manejo de refrigerantes y lubricantes;[17] la Dependencia Nacional del Ozono y el INFOP realizaron un taller para continuar delineado el sistema de acreditación nacional para los técnicos en refrigeración, conforme a la norma laboral pertinente de Honduras;[18] y se realizaron actividades de sensibilización del público en prácticas idóneas de refrigeración, inclusive la preparación de materiales informativos, para los técnicos en el proceso de acreditación;

d) En total, se formó a 129 estudiantes y a 98 técnicos en prácticas idóneas de refrigeración y manejo seguro de las alternativas de SAO; y

[16] El quinto y último tramo de la etapa I del plan de gestión de eliminación de HCFC para Honduras, presentado a la 85ª reunión por la ONUDI, en calidad de organismo de ejecución principal, se retiró durante el proceso de estudio de proyecto, dado que no se habían cumplido todas las condiciones de la decisión 84/18.
[17] Norma laboral 280501022 de Colombia.
[18] En septiembre de 2019 se aceptó la norma laboral (código B712703) de Honduras sobre “Buenas prácticas en refrigeración y climatización”.

e) Durante los seminarios y los talleres se fomentó el uso de los centros de reciclado y regeneración; y se deliberó sobre el establecimiento de otros tres centros de recuperación en refrigeración que cubrían áreas geográficas que cuentan con el más alto consumo de refrigerantes.

Desembolsos de fondos

68. Al 15 de marzo de 2020, del monto total aprobado de $EUA 175 000 para los tres primeros tramos para el PNUMA, se habían desembolsado $EUA 144 514 (82,6 por ciento); y del monto total aprobado de $EUA 50 000 para el cuarto tramo, para el PNUMA, se habían desembolsado $EUA 8 213 (16,4 por ciento),[19] como se indica en el Cuadro 6.

Cuadro 6: Informe financiero de la etapa I del plan de gestión de eliminación de los HCFC para Honduras ($EUA)

Tramo	Aprobado	Desembolsado*	Índice de desembolso (%)	Avance **	Total	Desembolso + avance (%)
Primero	75 000	67 047	89,4	7 953	75 000	100,0
Segundo	50 000	49 467	98,9	0	49 467	98,9
Tercero	50 000	28 000	56,0	22 000	50 000	100,0
Subtotal	**175 000**	**144 514**	82,6	**29 953**	**174 467**	**99,7**
Cuarto	50 000	8 213	16,4	25 900	34 113	68,2

* Registrado en Umoja.
** Fondos avanzados al gobierno de Honduras provenientes del PNUMA, y todavía no registrados en Umoja.

69. Se planean las siguientes actividades hasta diciembre de 2020:

a) Terminación de capacitación para oficiales de aduanas y responsables de aplicar las reglamentaciones, cubriendo 31 puntos de entrada aduaneros, sobre el control de las importaciones de los HCFC y de equipos que utilizan esas sustancias;

b) Finalización del sistema electrónico para el registro de importadores, proveedores y usuarios finales, y elaboración de módulos de formación en línea;

c) Ejecución de los lineamientos de acreditación para los técnicos de refrigeración y promoción de su uso, y actualización del material informativo técnico y de sensibilización del público;

d) Formulación de una norma de acreditación para manejar refrigerantes inflamables;

e) Acreditación de 100 técnicos en refrigeración en prácticas idóneas de servicio; y

f) Concientización sobre el valor de regenerar refrigerantes, capacitación en el uso de refrigerantes naturales, mejoramiento del programa de acreditación para técnicos en refrigeración, establecimiento de un programa para usuarios finales destinado a fomentar el confinamiento de refrigerantes, el control de fugas y las prácticas idóneas de refrigeración, y actualizaciones técnicas para el centro de recuperación y reciclado.

[19] Inclusive los fondos destinados o avanzados por el PNUMA a Honduras (fondos aún no registrados en Umoja - el software de planificación de recurso usado por el PNUMA). El 15 de marzo de 2020, el monto de los fondos desembolsados y avanzados o comprometidos proveniente de los primeros tres tramos es $EUA 174 el 467 (99,6 por ciento) y del cuarto tramo es de $EUA 18 107 (68 por ciento).

Observaciones de la Secretaría

70. Aún no se satisficieron las condiciones fijadas en la decisión 84/18 b) para la presentación del quinto tramo de la etapa I del plan de gestión de eliminación de los HCFC; específicamente, el programa de capacitación para oficiales de aduanas y responsables de aplicar las reglamentaciones que debía comenzar en marzo de 2020 se retrasó debido al brote de COVID-19; se espera que en agosto de 2020 funcione la base electrónica de datos para el registro de importadores, proveedores y usuarios finales; se planea empezar la aplicación de la formulación de una norma para manejar refrigerantes inflamables para agosto de 2020; y aún no se ha establecido el programa de usuarios finales para promover el confinamiento de refrigerantes.

71. Además, no se alcanzaron los índices de desembolsos para los primeros tres tramos (100 por ciento) y el cuarto tramo (70 por ciento). El PNUMA tiene $EUA 55 853 comprometidos para desembolsar al completar las actividades en curso, y otros $EUA 16 420 que no están comprometidos.

72. Asimismo la ONUDI pidió a la 85ª reunión financiamiento para el quinto tramo de la etapa I del plan de gestión de eliminación de los HCFC para Honduras. Sin embargo, al observar que varios de los compromisos establecidos en la decisión 84/18 no se cumplieron, el Comité Ejecutivo no pudo considerar el financiamiento del tramo. El PNUMA y la ONUDI esperan poder presentar a la 86ª reunión el último tramo de financiamiento de la etapa I junto con la etapa II del plan de gestión de eliminación de los HCFC para Honduras.

Recomendación

73. El Comité Ejecutivo podría tomar nota de:

a) El informe sobre la marcha de las actividades relativo a la ejecución de actividades dentro de los componentes del PNUMA de la etapa I del plan de gestión de eliminación de los HCFC para Honduras, presentado por el PNUMA, y que figura en el documento UNEP/Ozl.Pro/ExCom/85/9; y

b) Que el quinto y último tramo de la etapa I del plan de gestión de eliminación de los HCFC podría presentarse sólo cuando se hubiesen cumplido las condiciones establecidas en la decisión 84/18 b).

India: Plan de gestión de eliminación de los HCFC (etapa II - actualización de la evaluación de los fabricantes de paneles continuos con respecto a la observancia de la prohibición) (PNUD, PNUMA y el gobierno de Alemania)

Antecedentes

74. El 1 de enero de 2015 gobierno de India prohibió el uso de los HCFC, inclusive el HCFC-141b puro y en polioles premezclados, en la fabricación de espumas aislantes para refrigeradores domésticos y paneles sándwich continuos. No obstante, en la 82ª reunión,[20] el PNUD pidió financiamiento para el segundo tramo de la etapa II del plan de gestión de eliminación de los HCFC,[21] e informó que dos fabricantes de paneles sándwich continuos habían firmado un memorando de acuerdo con el gobierno. Debido a eso, el PNUD aclaró que el gobierno estaba evaluando si esas empresas cumplieron con la prohibición.

75. Por consiguiente, el Comité Ejecutivo solicitó al gobierno de India, a través del PNUD, que proporcionase a la 83ª reunión una actualización de la evaluación sobre si los fabricantes de paneles

[20] 3-7 de diciembre de 2018.
[21] La etapa II del plan de gestión de eliminación de los HCFC se aprobó en la 77ª reunión.

continuos de espumas habían respetado la prohibición de los HCFC, observando que si el gobierno determinase que las empresas no habían cumplido con la prohibición, se rendiría el memorando de acuerdo firmado con las empresas y toda financiación desembolsada se devolvería al Fondo Multilateral, conforme a la decisión 77/43 d) ii).[22] Asimismo se observó que no se incluiría ninguna de estas empresa en la etapa II hasta que el Comité Ejecutivo hubiese evaluado su admisibilidad.[23]

76. En la 83ª reunión, el PNUD informó que la evaluación del gobierno todavía continuaba; por lo tanto, el Comité solicitó al gobierno, a través del PNUD, que presentase la evaluación en la 84ª reunión.[24] De manera similar, en la 84ª reunión, el PNUD indicó que la evaluación todavía se estaba llevando a cabo, y confirmó que no se había hecho ningún desembolso a estas empresas, y que los fondos se devolverían en caso se determinara que las dos empresas habían violado los objetivos de eliminación del 1 de enero de 2015. Además, el PNUD mencionó que la evaluación debía pasar por los debidos procesos legales y gubernamentales de India y que no era posible determinar cuándo terminaría. Por consiguiente el Comité Ejecutivo solicitó al gobierno de India, a través del PNUD, que proporcionase para la 85ª reunión su evaluación sobre si las empresas habían respetado la prohibición, conforme a la decisión 82/74 b) y c).[25]

77. Al prepararse para la 85ª reunión, el PNUD informó que no era posible confirmar la situación de la evaluación y que una situación actualizada no podría presentarse a tiempo debido al COVID-19.

Recomendación

78. El Comité Ejecutivo podría solicitar al gobierno de India, a través del PNUD, que proporcionase para la 86ª reunión, la evaluación del gobierno sobre la observancia de la prohibición del uso del HCFC-141b por parte de los fabricantes de paneles continuos desde el 1 de enero de 2015, conforme a la decisión 82/74 b) y c).

Indonesia: Plan de gestión de eliminación de los HCFC (etapa I - actualización de la situación de la conversión de los fabricantes de equipos de refrigeración y climatización y plan de acción revisado) (PNUD)

79. En nombre del gobierno de Indonesia, el PNUD, en calidad de organismo de ejecución principal, presentó a la 85ª reunión:

a) Un informe sobre la situación de empresas que fabricaban temporalmente equipos de refrigeración y climatización con elevado potencial de calentamiento atmosférico en las empresas que recibieron financiación para convertirse a alternativas con bajo potencial de calentamiento atmosférico, conforme a las decisiones 77/35, 81/11 c), y 83/22 c); y

b) Un plan de acción revisado para la conversión de las empresas Gita Mandrin Teknik, Fata Sarana Makmur y Sumo Elco Mandiri, y otra petición para prorrogar la fecha de terminación de la etapa I del plan de gestión de eliminación de los HCFC, conforme a la decisión 84/35 d) ii).

Antecedentes

80. La etapa I del plan de gestión de eliminación de los HCFC incluyó la conversión de 48 empresas en el sector de fabricación de equipos de refrigeración y climatización a tecnologías con bajo potencial de calentamiento atmosférico. Sin embargo, durante la ejecución, 28 empresas (16 en el sector de

[22] Decisión 82/74 b) i)
[23] Decisión 82/74 c)
[24] Decisión 83/21
[25] Decisión 84/34 b) ii)

climatización y 12 en el sector de refrigeración comercial) decidieron convertirse a tecnologías con alto potencial de calentamiento atmosférico mediante sus propios recursos, y devolvieron $EUA 3 134 216, más los gastos de apoyo del organismo, al Fondo Multilateral.

81. En la 83ª reunión, se informó que de las 20 empresas restantes, sólo una (Panasonic) fabricaba aparatos de climatización con tecnología del HFC-32. Ocho empresas de tamaño mediano y grande habían fabricado prototipos con HFC-32; ocho empresas pequeñas no habían recibido los pedidos para equipos que utilizan HFC-32; y las tres empresas restantes todavía esperaban que el mercado de equipos que utilizan HFC-32 mejorase antes de emprender su conversión. En ese momento, las 19 empresas fabricaban equipos basados en refrigerantes con alto potencial de calentamiento atmosférico.

82. En la 84ª reunión, el PNUD informó que once empresas[26] habían decidido retirarse del proyecto. Además, un fabricante de equipos de refrigeración comercial (Aneka Cool) había decidido subcontratar externamente su proceso de espumas de poliuretano para aislamiento que utilizan el HCFC-141b. Por lo tanto, el Comité Ejecutivo tomó nota del retiro del proyecto de las once empresas, y que la financiación conexa ($EUA 764 842, más los gastos de apoyo del organismo de $EUA 57 363, para PNUD) se devolvería a la 85ª reunión (decisión 84/35 b) i)); y que la financiación ($EUA 60 500, más los gastos de apoyo del organismo de $EUA 4 538, para PNUD) asociada a la empresa que subcontrató externamente su proceso de espumas de aislación se devolvería a la 85ª reunión (decisión 84/35 b) ii)).

83. Asimismo el PNUD informó que las dos empresas siguientes experimentaron dificultades técnicas durante su conversión:

a) Metropolitan Bayu Industri, un fabricante de aparatos de climatización comercial, había construido un prototipo basado en el refrigerante con HFC-32; sin embargo, fue necesario hacer otras mejoras de diseño. Por lo tanto, el PNUD propuso seguir proporcionando asistencia técnica y desembolsando los costos de explotación adicionales, cuando se iniciase la fabricación con HFC-32; y

b) Rotaryana Prima, un fabricante de refrigeradores y congeladores, había construido los prototipos basados en el refrigerante con HFC-32, pero con un bajo desempeño. De acuerdo con las actualizaciones recientes de la norma 60335-2-89 de la Comisión Electrotécnica Internacional, que permite una carga de hasta 500 g de refrigerantes A3,[27] la empresa decidió convertirse al refrigerante con R-290. Sobre esta base, el Comité aprobó el cambio de tecnología sin costo adicional para el Fondo (decisión 84/35 c)).

84. El PNUD informó, además, que otras tres empresas, a saber, Gita Mandrin Teknik, Fata Sarana Makmur y Sumo Elco Mandiri, fabricaron con la marca de su empresa y con una marca de fabricante de equipo original (OEM, por su sigla en inglés), para la cual usó refrigerantes con alto potencial de calentamiento atmosférico, si bien para la suya usó el HFC-32. Por lo tanto, el PNUD había propuesto que la proporción de costos de explotación adicionales aprobados y asociados a la fabricación con marca de la empresa se liberaría una vez se hubiese confirmado su fabricación con HFC-32, mientras que la proporción asociada a la marca de OEM se devolvería al Fondo Multilateral en la 85ª reunión. Finalmente, otras tres empresas, a saber, Industri Tata Udari, Alpine Cool, y Aneka Cool, habían decidido permanecer en el proyecto y convertir su fabricación al HFC-32; esas empresas no fabricaban para fabricantes de equipo original.

[26] Tres empresas del sector de refrigeración comercial (Mentari Metal Pratama, Polysari Citratama e Inti Tunggal) y ocho del subsector de montaje de equipos refrigeración comercial (Sabindo Refrigeration, Global Technic, AVIS Alpin Servis Tr, Aneka Froze Triutama, Graha Cool Technic, United Refrigeration, Gaya Technic Supply and Ilthabi Mandiri Tech).

[27] Los refrigerantes A3 exhiben propagación de llama a 60°C y 101,3 kPa, y tienen un límite de inflamabilidad más bajo o igual a 0,1 kg/m^3 o calor de combustión mayor o igual a 19 000 kJ/kg.

85. Tras las deliberaciones oficiosas entre los miembros interesados, el Comité Ejecutivo decidió entre otras cosas:

a) Tomar nota de que Gita Mandrin Teknik, Fata Sarana Makmur y Sumo Elco Mandiri habían decidido convertir sus líneas de montaje a la tecnología con HFC-32, fabricarían equipos que utilizan esa sustancia para marcas de sus empresas y fabricarían temporalmente equipos que usan refrigerantes con alto potencial de calentamiento atmosférico a pedido de los fabricantes de equipos originales;

b) Prolongar la fecha de terminación de la etapa I del plan de gestión de eliminación de los HCFC para Indonesia hasta el 30 de junio de 2020, a condición de que, entre otras cosas, el PNUD presentase, en la 85ª reunión, un plan de acción revisado para la conversión de esas empresas, y otra posible petición de extender la fecha de terminación de la etapa I del plan de gestión de eliminación de los HCFC; y

c) Considerar en la 85ª reunión el impacto potencial en el punto de partida para las reducciones acumulativas sostenidas para el consumo de HFC, conforme a la decisión 82/30 g) ii) (decisión 84/35).

Progreso alcanzado en fecha de la 85ª reunión

86. El PNUD suministró la actualización siguiente sobre la situación de la conversión de las cinco empresas de refrigeración y climatización que no fabricaron para los fabricantes de equipo original:

a) Conversión en Industri Tata Udari, terminada, inclusive la conversión con los intercambiadores de calor y las líneas de procesamiento de hojas y la adaptación requerida de la línea de montaje. Se fabricaron los aparatos prototípicos y fueron aprobados por los clientes, y la empresa comercializa aparatos que utilizan HFC-32. Se prevé que los costos de explotación adicionales ($EUA 14 161) se desembolsarán en diciembre de 2020;

b) Metropolitan Bayu Industri había mejorado el diseño del intercambiador de calor, con los prototipos previstos para utilizarse en diciembre de 2020y el desembolso del costo de explotación adicionales ($EUA 14 287) para la misma fecha;

c) Rotaryana terminó su conversión de la línea de fabricación al R-290; se utilizaron los prototipos y se informó que eran plenamente funcionales. La empresa trabajaba para mejorar el diseño a fin de aumentar la eficacia energética de los aparatos, y para proporcionar capacitación adicional al personal y a los usuarios finales en el uso seguro y el mantenimiento de los equipos. Se espera que los costos de explotación adicionales ($EUA 25 296) se desembolsen en diciembre de 2020; y

d) Alpine Cool y Aneka Cool terminaron su conversión al refrigerante HFC-32, diseñaron los prototipos y los probaron en los clientes, y los aparatos se comercializan. Se prevé que los costos de explotación adicionales ($EUA 40 160 para Alpine Cool y $EUA 17 510 para Aneka Cool) se desembolsarán en diciembre de 2020.

87. Con respecto a las tres empresas que también habían fabricado para los fabricantes de equipos originales, el PNUD informó:

a) Debido a la disminución de la cuota de mercado de equipos de fabricantes de equipos originales fabricados por Gita Mandiri Teknik y a los costos más elevados de esos equipos, la empresa se comprometió a dejar de fabricar para esos fabricantes y fabricar exclusivamente equipos con su propia marca que usa HFC-32;

b) Debido a la falta de demanda de fabricantes de equipos originales, Fata Sarana Makmur no fabrica actualmente equipos con alto potencial de calentamiento atmosférico para dichos fabricantes, y el contrato con ellos, que vence en junio de 2020, no se renovará. La empresa fabricará exclusivamente equipos bajo su propia marca que usa HFC-32; y

c) Sumo Elco Mandiri fabricó equipos para dos fabricantes de equipos originales. Uno de ellos en un país que no estaba al amparo del Artículo 5 que había ratificado la Enmienda de Kigali; dado la reducción de los HFC en ese país, y las dificultades que habrían resultado de continuas exportaciones de equipos con alto potencial de calentamiento atmosférico a ese país, el fabricante de equipo original decidió terminar el contrato con la empresa; el otro fabricante de equipo original cerró sus operaciones en Indonesia en enero de 2020 dado las restricciones del mercado de exportación, si bien la sociedad matriz mantiene el comercio de abastecimiento de piezas y componentes en Indonesia a través de sus distribuidores. Desde enero de 2020 la empresa sólo fabrica para su propia marca y usa HFC-32.

88. Las tres empresas habían terminado su conversión al refrigerante HFC-32. Gita Mandiri y Sumo Elco ya comercializan aparatos que utilizan HFC-32 en Indonesia, si bien Fata Sarana Makmur prevé comenzar a comercializar aparatos que utilizan esa sustancia en junio de 2020, fecha de vencimiento del contrato con el fabricante de equipo original. Se propone usar los costos de explotación adicionales ($EUA 249 738) para las tres empresas en diciembre 2020 con la terminación de proyecto. Para permitir que las empresas restantes fabriquen equipos con bajo potencial de calentamiento atmosférico, el gobierno de Indonesia propuso prolongar la ejecución de la etapa I del plan de gestión de eliminación de los HCFC al 31 de diciembre de 2020.

89. Conforme a la decisión 84/35 b), y como se explica en el informe sobre saldos y disponibilidad de recursos,[28] el PNUD devolvió a la 85ª reunión $EUA 825 342, más los gastos de apoyo del organismo de $EUA 61 901.

Observaciones de la Secretaría

90. La Secretaría tomó nota con beneplácito los esfuerzos del gobierno, la industria y el PNUD destinados a abordar las dificultades de la introducción en el mercado de equipos con bajo potencial de calentamiento atmosférico, y en particular tomó nota de que las empresas que decidieron permanecer en el proyecto no fabricaban equipos de refrigeración y climatización con alto potencial de calentamiento atmosférico. La Secretaría observó que la liberación de costos de explotación adicionales restantes se basarían en la fabricación con la tecnología acordada, y recomienda la prórroga propuesta de la etapa I del plan de gestión de eliminación de los HCFC al 31 de diciembre de 2020.

91. Con respecto al impacto potencial en el punto de partida para las reducciones acumulativas sostenidas para el consumo de HFC (decisión 82/30 g) ii)), la Secretaría recomienda que no se cambie el el punto de partida, dado que las empresas que decidieron permanecer en el proyecto no fabricaron equipos de refrigeración y climatización con alto potencial de calentamiento atmosférico.

[28] UNEP/OzL.Pro/ExCom/85/4.

92. Al tomar nota de que las empresas que permanecieron en el proyecto se habían convertido a las tecnologías con bajo potencial de calentamiento atmosférico, la Secretaría recomendó que, en lugar de presentar informes anuales sobre la marcha de las actividades, el PNUD presentase a la 88ª reunión un solo informe final exhaustivo sobre la marcha de las actividades, quedando entendido que incluiría datos agregados sobre las ventas de equipos de refrigeración y climatización que utilizan HFC-32 y R-290 fabricados por las empresas que permanecieron en el proyecto.

Recomendación

93. El Comité Ejecutivo podría:

94. Tomar nota de la actualización sobre la situación de la conversión de los fabricantes de equipos de refrigeración y climatización y el plan de acción revisado para la etapa I del plan de gestión de eliminación de los HCFC para Indonesia, presentado por el PNUD, que figura en el documento UNEP/OzL.Pro/ExCom/85/9;

a) Prorrogar la fecha de terminación de la etapa I del plan de gestión de eliminación de los HCFC para Indonesia hasta el 31 de diciembre de 2020; y

b) Pedir el gobierno de Indonesia y el PNUD que presenten un informe final sobre la marcha de las actividades relativo a la ejecución de la etapa I del plan de gestión de eliminación de los HCFC que incluiría la información agregada sobre las ventas de equipos con bajo potencial de calentamiento atmosférico fabricados por las empresas que participan en el proyecto, y el informe de terminación de proyecto, el 30 de junio de 2021.

Malasia: Plan de gestión de eliminación de los HCFC (etapa II - cambio de tecnología en 14 empresas) (PNUD)

Antecedentes

95. En su 77ª reunión, el Comité Ejecutivo aprobó en principio, la etapa II del plan de gestión de eliminación de los HCFC para Malasia[29] para el período de 2016 a 2022, destinado a reducir el consumo de los HCFC en el 42,9 por ciento de su base, por un monto de $EUA 6 138 063, más los gastos de apoyo del organismo de $EUA 429 665, para el PNUD.

96. La etapa II incluyó financiamiento para la conversión de 67 fabricantes de espumas de poliuretano, de los cuales 57 son pequeñas y medianas empresas (PyME), a las alternativas con bajo potencial de calentamiento atmosférico; las otras 10 empresas que no son admisibles eliminarán su consumo sin ayuda del Fondo Multilateral, lo que llevará a la eliminación del HCFC-141b en el sector de espumas de poliuretano para el 1 de enero de 2022. Se utilizó un enfoque por etapas, en el que las empresas con consumo de un mínimo de 20 toneladas métricas (tm) se convertirían al ciclopentano o sistemas de polioles premezclados con ciclopentano, y las empresas más pequeñas se convertirían en el segundo y tercer tramo a formulaciones reducidas de hidrofloroolefinas (HFO), aunque algunas podrían convertirse al metilal.

97. En la 84ª reunión, el PNUD informó que se firmaron memorandos de acuerdo con 12 empresas, dos de las cuales han terminado su conversión al ciclopentano, con una eliminación asociada de 12,32 toneladas PAO de HCFC-141b; la conversión de otras ocho empresas avanzaba y resultaría en una eliminación de 28,99 toneladas PAO de HCFC-141b; y se preveía que dos empresas más pequeñas, con un consumo de 2,54 toneladas PAO de HCFC-141b, terminaran su conversión en 2020.

[29] UNEP/OzL.Pro/ExCom/77/54

98. El PNUD informó, además, que dado las preocupaciones sobre abastecimiento estable de agentes espumantes con HFO a corto plazo y la disponibilidad comercial inmediata del sistemas de polioles premezclados con ciclopentano, provenientes de cuatro proveedores de sistemas en el país, siete empresas (Allied Foam, Astino, Century, Gai Hin, Hewgant, Insulated Box y Roto Speed) consideraban el cambio de tecnología de HFO al ciclopentano premezclado; no obstante, esas empresas todavía no habían tomado una decisión dado que todavía se estaban realizando las pruebas de diversas formulaciones . La Secretaría evaluó los costos adicionales admisibles para convertirse a sistemas de polioles premezclados con ciclopentano, que confirmaron que no habría ahorros asociados a ese cambio de tecnología. Asimismo el PNUD confirmó que las empresas cofinanciarían cualquier costo adicional asociado al cambio de tecnología. Por lo tanto, el Comité Ejecutivo decidió que esas empresas tendrían flexibilidad para cambiar la tecnología al ciclopentano premezclado durante la ejecución, a condición de que las conversiones no se retrasaran y todo costo adicional fuese cubierto por ellas; y el PNUD informaría sobre este asunto al presentar el pedido del tercer tramo del plan de gestión de eliminación de los HCFC (decisión 84/77 b)). Pedido de cambio de tecnologíaDe acuerdo con el apartado 7 a) v) del Acuerdo suscrito entre el gobierno de Malasia y el Comité Ejecutivo, el gobierno presentó a la 85ª reunión a través del PNUD una petición para cambiar la tecnología en 14 empresas de HFO a sistemas de polioles premezclados con ciclopentano, indicadas en el Cuadro 7. El PNUD confirmó que las empresas cofinanciarían cualquier costo adicional asociado al cambio de tecnología.

Cuadro 7: Empresas que se convertirán de HFO a los sistemas de polioles premezclados con ciclopentano

Empresa	Uso	HCFC-141b (tm)	Financiación aprobada ($EUA)
Komiya Roofing (M) Sdn Bhd	paneles discontinuos	9,00	55 731
Power Cool Engineering S/B	refrigeración comercial	8,40	52 393
Coolaxis sdn Bhd	paneles discontinuos	7,80	49 054
CoolMax Refrigeration Industries	paneles discontinuos	7,00	44 603
SJ Classic Industries Sdn Bhd	paneles discontinuos	6,91	44 092
PS Coldroom Panels Supplies	paneles discontinuos	6,80	43 491
Hi-tech Preinsulated Pipes S/B	tubos	6,11	39 652
Ngui Soon ColdRoom & Refrigeration (Snowfall)	transporte	6,00	39 040
P.K.T Insulation Trading	paneles discontinuos	6,00	39 040
NYC Products Sdn bhd	paneles discontinuos	5,75	37 649
Top Amity Sdn Bhd	paneles discontinuos	5,01	33 532
Chong Brothers Coldroom Eng. Sdn Bhd	paneles discontinuos	5,00	33 476
Perniagaan Nam Sing S/B	refrigeración comercial	3,00	22 349
Lian Pang Refrigeration & Electrical S/B	refrigeración comercial	1,20	12 334
Total		**83,98**	**546 436**

Observaciones de la Secretaría

100. Las siete empresas que habían pedido flexibilidad para cambiar de tecnología al ciclopentano premezclado en la 84ª reunión terminaron las pruebas y decidieron cambiar al ciclopentano premezclado. La Secretaría realizó una evaluación detallada de los costos adicionales admisibles para convertir las 14 empresas a los sistemas de polioles premezclados con ciclopentano, que confirmó que no habría ahorros asociados al cambio de tecnología. Por lo tanto, y tomando nota de la disponibilidad comercial de los sistemas premezclados del ciclopentano de los cuatro proveedores de sistemas en el país y de la exitosa conversión de otros fabricantes de espumas a esa alternativa, la Secretaría recomendó la aprobación del cambio de tecnología.

Recomendación

101. El Comité Ejecutivo podría:

a) Tomar nota del pedido presentado por el PNUD en nombre del gobierno de Malasia para el cambio de tecnología en 14 fabricantes de espumas, de hidrofloroolefinas a sistemas de polioles premezclados con ciclopentano en el contexto de la etapa II del plan de gestión de eliminación de los HCFC que figura en el documento UNEP/OzL.Pro/ExCom/85/9; y

b) Aprobar el cambio de tecnología para esos 14 fabricantes de espumas, de HFO a los sistemas de polioles premezclados con ciclopentano, a condición de que las conversiones no se retrasaran y que todo costo adicional fuese cubierto por las empresas.

Marruecos: Plan de gestión de eliminación de los HCFC (etapa I - informe sobre la marcha de las actividades) (ONUDI y PNUD)

Antecedentes

102. En nombre del gobierno de Marruecos, la ONUDI, en calidad de organismo de ejecución principal, presentó el informe anual sobre la marcha de las actividades relativo a la ejecución del programa de trabajo asociado al tercero y último tramo del plan de gestión de eliminación de los HCFC,[30] conforme a la decisión 83/57 d).[31]

Consumo de HCFC

103. El gobierno de Marruecos estimó un consumo de HCFC de 25,50 toneladas PAO para 2019, que está el 38 por ciento por debajo del objetivo establecido en su Acuerdo con el Comité Ejecutivo para el mismo año, y el 50 por ciento por debajo de la base de HCFC de 51,35 toneladas PAO.

Informe de verificación

104. Antes de presentar el informe sobre la marcha de las actividades asociado al tercer tramo de financiamiento del plan de gestión de eliminación de los HCFC, se planeó la verificación del consumo de los HCFC para 2019; no obstante, debido a las contingencias asociadas a la pandemia del COVID-19, en el momento de expedir el presente documento, la verificación todavía no se había realizado.

[30] Aprobado en la 83ª reunión, por un costo total de $EUA 35 000, más los gastos de apoyo del organismo de $EUA 2 625 para la ONUDI.

[31] Pedir al gobierno de Marruecos y la ONUDI que presenten informes sobre la marcha de las actividades relativos a la ejecución del programa de trabajo asociado al tercero y último tramo, anualmente y hasta la terminación del proyecto, informes de verificación hasta la aprobación de la etapa II del plan de gestión de eliminación de HCFC y el informe de terminación de proyecto a la primera reunión del Comité Ejecutivo en 2022.

Sector de fabricación

105. La conversión de la fabricación de espumas en Manar Company se ha terminado, resultado en una eliminación de 11,00 toneladas PAO de HCFC-141b. La prohibición sobre la importación de HCFC-141b puro entró en vigencia el 1 de enero de 2015; y desde 2014 no se ha importado esa sustancia.

Situación de ejecución de las actividades previstas para el tercer tramo

106. Conforme al plan de ejecución del tercer tramo, se suministraron otros 26 identificadores de refrigerantes para entregarse en abril de 2020, a fin de ser distribuidos en las aduanas, la Asociación de Refrigeración y el centro de capacitación de la capital (Rabat). Se planeó realizar un taller de capacitación sobre el uso de identificadores de refrigerantes cuando lleguen los identificadores.

107. Se identificaron dos consultores internacionales para llevar a cabo la capacitación teórica y práctica de los técnicos de mantenimiento. La capacitación se centrará en las últimas tecnologías y la penetración de mercado, cuestiones de seguridad y la gestión apropiada de refrigerantes inflamables durante el mantenimiento, y mejores prácticas de mantenimiento, inclusive la recuperación y el reciclado.

108. Ya se había iniciado la adquisición de herramientas y equipos de servicio para equipos de refrigeración para la distribución entre los técnicos capacitados, inclusive los aparatos de recuperación y reciclado, pero se ha detenido debido a la pandemia del COVID-19. Una vez que se reanude, el proceso de la adquisición se terminará en pocas semanas. Se prevé que los equipos se distribuirán a más tardar a finales de 2020.

109. Se está actualizando el material de sensibilización sobre la calidad de refrigerantes, y se traducirá al idioma local y se distribuirá entre las partes interesadas.

110. La etapa I del plan de gestión de eliminación de los HCFC para Marruecos terminará a fines de 2020, según lo previsto.

Desembolsos de fondos

111. En marzo de 2020, de los $EUA 335 000 aprobados, se habían desembolsado $EUA 192 635 (58 por ciento). Como se indica en el Cuadro 8, en diciembre de 2020 se desembolsará un saldo de $EUA 142 365.

Cuadro 8: Informe financiero de la etapa I del plan de gestión de eliminación de los HCFC para Marruecos, a marzo de 2020 ($EUA)

Tramo	Aprobado	Desembolsado	Porcentaje desembolsado (%)	Saldo
Primero	80 000	77 078	96	2 922
Segundo	220 000	115 557	53	104 443
Tercero	35 000	0	0	35 000
Total	**335 000**	**192 635**	**58**	**142 365**

Observaciones de la Secretaría

112. A la hora de la presentación del pedido de financiamiento del tercer tramo del plan de gestión de eliminación de los HCFC, el consumo de los HCFC para 2018 se basó en el consumo informado conforme al informe de verificación (es decir, 23,24 toneladas PAO),[32] dado que el consumo no se había informado en virtud del Artículo 7 del Protocolo de Montreal ni en virtud del programa de país, el informe de ejecución no se había presentado. Posteriormente, el gobierno de Marruecos informó el consumo de los HCFC de 25,66 toneladas PAO en virtud del Artículo 7 y bajo el informe del programa

[32] UNEP/OzL.Pro/ExCom/83/32

de país. Para explicar la discrepancia de los datos, la ONUDI indicó que los datos informados en virtud del Artículo 7 y el informe del programa de país eran el total de las cuotas expedidas para 2018, lo que era más alto que la cantidad importada realmente, como se confirma en el informe de verificación. La ONUDI informó al gobierno sobre la necesidad de revisar los datos del Artículo 7 y del programa de país para 2018. El PNUMA (organismo de ejecución para el fortalecimiento institucional) ayudará al gobierno a presentar una petición para corregir los datos de consumo de 2018, basado en el informe de verificación 2018.

113. El informe sobre la marcha de las actividades del tercer tramo de la etapa I del plan de gestión de eliminación de los HCFC requiere la presentación de un informe de verificación. Al tomar nota de que la terminación del informe de verificación se retrasaría dado las restricciones creadas por la pandemia del COVID-19, y que el consumo de HCFC de 2019 estaba 50 por ciento por debajo de la base, la Secretaría recomienda la aprobación de este informe sobre la marcha de las actividades, en forma excepcional y sin sentar un precedente, a condición de que:

a) La ONUDI se comprometiese a presentar a más tardar doce semanas antes de la 87ª reunión el informe de verificación y el informe sobre la marcha de las actividades de la ejecución del tercer tramo;

b) Las recomendaciones incluidas en el informe de verificación se abordarían durante la ejecución del tercer tramo y las medidas tomadas hacia ese fin se incluirían en el informe sobre la marcha de las actividades de la etapa I del plan de gestión de eliminación de los HCFC; y

c) En el caso improbable de incumplimiento por parte del gobierno de Marruecos con su Acuerdo con el Comité Ejecutivo, el Comité Ejecutivo tomaría las medidas pertinentes.

114. La Secretaría preguntó sobre la incorporación de la capacitación para la protección del ozono en el plan de estudios de la capacitación rutinaria de los oficiales de aduanas. La ONUDI informó que se preveía incluir esto en la etapa II del plan de gestión de eliminación de los HCFC. El gobierno también planea fortalecer los institutos de capacitación profesional y desarrollar un programa de acreditación durante la etapa II para sostener la capacitación de técnicos en refrigeración y climatización.

115. Con respecto al progreso realizado en la elaboración de un inventario de equipos que utilizan HCFC-22 y la introducción de normas de eficiencia energética, la ONUDI informó que se han publicado esas normas para el etiquetado de equipos de refrigeración y climatización; las normas para el etiquetado de otros productos, como termotanques, secadores y termotanques de almacenamiento, se están formulando actuamente. Se espera que éstas contribuyan a mejorar la eficiencia energética de los equipos que utilizan HCFC-22.

Recomendación

116. El Comité Ejecutivo podría tomar nota del informe sobre la marcha de las actividades relativo a la ejecución de la etapa I del plan de gestión de eliminación de los HCFC para Marruecos, presentado por la ONUDI y que figura en el documento UNEP/OzL.Pro/ExCom/85/9, a condición de que:

a) La ONUDI se hubiese comprometido a presentar el informe de verificación a la Secretaría a más tardar con doce semanas de antelación de la 87ª reunión, que las recomendaciones incluidas abordarían la ejecución del tercer tramo de la etapa I del plan de gestión de eliminación de los HCFC, y que las medidas aplicadas hacia ese fin se incluirían en el informe sobre la marcha de las actividades de la etapa I del plan de gestión de eliminación de los HCFC; y

b) En caso de que el informe de verificación confirmara que Marruecos no había cumplido con el Protocolo de Montreal y su Acuerdo con el Comité Ejecutivo, la Secretaría informaría al Comité Ejecutivo de modo que pudiese tomar en consideración, por consiguiente, las medidas pertinentes, entre otras cosas, la aplicación de la cláusula de sanción económica.

República de Moldova: Plan de gestión de eliminación de los HCFC (etapa II – Informe detallado sobre la situación de la ejecución de los proyectos de demostración para la utilización de tecnología basada en CO_2 en el sector de refrigeración comercial) (PNUD)

Antecedentes

117. En su 84ª reunión, el Comité Ejecutivo aprobó la financiación del segundo tramo de la etapa II del programa de gestión de la eliminación de los HFC para la República de Moldova, en el entendimiento de que el Gobierno, por conducto del PNUD, presentará en la 85ª reunión un informe detallado sobre la situación de la ejecución de los proyectos de demostración para la utilización de tecnología basada en el CO_2 en el sector de refrigeración comercial (Decisión 84/55.a)). Posteriormente, el PNUD ha presentado el informe sobre la situación de la ejecución de los proyectos de demostración.

118. Los objetivos de los proyectos de demostración consisten en: promover el ahorro de energía y de costos relacionados, entre otras cosas, con la reducción del consumo de refrigerantes; demostrar el uso seguro de la tecnología innovadora; concienciar a los usuarios finales acerca de las tecnologías disponibles y de cómo el uso de la tecnología basada en el CO_2 se traduce en un aumento de la disponibilidad de espacio en el interior de la instalación; y demostrar al mismo tiempo los beneficios ambientales relacionados con el ozono y con el clima inherentes a la tecnología.

119. Tras un proceso de licitación, se seleccionaron las dos empresas a continuación:

a) Forward International SRL, dedicada a operaciones de almacenamiento en frío. La capacidad de refrigeración del equipo que se instalará es de 189,6 kW para enfriar aproximadamente 11.000 metros cúbicos de espacio de almacenamiento; y

b) STS Trading SRL, dedicada a operaciones de venta al por menor de comestibles, fueron seleccionadas. La capacidad de refrigeración del equipo que se instalará es de 5 kW en una sala con cuatro mostradores.

120. La empresa Forward International SRL ya ha importado el equipo y está finalizando todos los trabajos de construcción y acondicionamiento. El equipo será probado y se prevé que entre en funcionamiento a finales de marzo de 2020. En lo que respecta a STS Trading SRL, se ha firmado el contrato para la adquisición del equipo, el montaje in situ, la puesta en marcha y el mantenimiento inicial, se están llevando a cabo las obras de renovación y se estima que el equipo se importará a mediados de marzo de 2020.

121. Se prevé que ambos proyectos estarán en fase operativa y se completarán a finales de junio de 2020; no obstante, podría haber retrasos ocasionados por el COVID-19, lo que afectaría a la disponibilidad de los componentes. La difusión de los resultados y la impartición de las clases sobre los proyectos de demostración, junto con la celebración de un seminario, se realizarán en la segunda mitad de 2020.

Recomendaciones **de la Secretaría**

122. En respuesta a una pregunta sobre las normas para promover la utilización de refrigerantes naturales, el PNUD explicó que el Gobierno de la República de Moldova armoniza gradualmente su

marco reglamentario con la legislación de la Unión Europea, incluido el marco reglamentario del sector de refrigeración y aire acondicionado; el Gobierno también se propone ratificar la Enmienda de Kigali al Protocolo de Montreal en 2021. El Gobierno elaborará un plan de acción para la reducción de los HFC y seguirá fortaleciendo el marco normativo para apoyar la transición gradual a tecnologías basadas en refrigerantes de bajo potencial de calentamiento atmosférico, como los hidrocarburos, el amoníaco y el CO_2, y tecnologías alternativas como las de enfriamiento gratuito por aire y sin compuestos orgánicos halogenados.

123. Respecto de la eficiencia energética, se esperan mejoras de alrededor del 20%; sin embargo, los verdaderos progresos se conocerán tras la medición de los resultados a lo largo de varias temporadas.

124. En cuanto a la expansión de la utilización de la tecnología, el PNUD explicó que el Gobierno tiene previsto introducir medidas de sensibilización y la divulgación de las experiencias de los beneficiarios, y desarrollar programas de capacitación y certificación obligatorios dirigidos a los técnicos que trabajan con refrigerantes naturales. La utilización a mayor escala de nuevas tecnologías será un proceso que requerirá más tiempo, a medida que se adquieran nuevos conocimientos y experiencias sobre los refrigerantes naturales y los costos sean comparables a los de la tecnología actual.

125. La secretaría pidió que se explicaran las diferencias observadas en los niveles de cofinanciación de las dos empresas, señalando que se asignaron 32 000 $EUA del proyecto a cada una de ellas, y que Forward International SRL y STS Trading SRL contribuyeron con 192 000 $EUA y 18 000 $EUA, respectivamente. El PNUD explicó que esas dos empresas fueron las únicas que decidieron participar en los proyectos de demostración; por lo tanto, la subvención prevista en el proyecto se dividió en partes iguales. Debido a la diferencia en la configuración del equipo y la infraestructura de los componentes de cada empresa, los costos totales de la conversión y los niveles de cofinanciación eran diferentes.

126. El PNUD también aclaró que el saldo de 2 000 $EUA. se utilizaría para brindar asistencia técnica y sensibilizar al público sobre los resultados de los proyectos de demostración.

Recomendación

127. El Comité Ejecutivo podría tomar nota del informe detallado sobre la situación de la ejecución de los proyectos de demostración para la utilización de la tecnología basada en CO_2, en el sector de refrigeración comercial de la etapa II del plan de gestión de eliminación de los HCFC en la República de Moldova, presentado por el PNUD, que figura en el documento UNEP/Ozl.Pro/ExCom/85/9.

Proyectos de demostración para alternativas con bajo potencial de calentamiento atmosférico

Argentina y Túnez: Proyecto de demostración para la introducción de tecnología de refrigeración con CO_2 transcrítico para supermercados (informe final) (ONUDI)

Antecedentes

128. En su 76ª reunión, el Comité Ejecutivo aprobó el proyecto de demostración para la introducción de tecnología de refrigeración con CO_2 transcrítico para supermercados (Argentina y Túnez)[33] por un monto de $EUA 846 300, más los gastos de apoyo del organismo de $EUA 59 241, para la ONUDI (decisión 76/27).

129. El proyecto se aprobó para ayudar a introducir la tecnología de refrigeración con CO_2 transcrítico en países al amparo del Artículo 5, mediante la eliminación de barreras como la falta de conocimientos sobre sistemas de refrigeración con CO_2 transcrítico, la disponibilidad limitada de los componentes de

[33] UNEP/OzL.Pro/ExCom/76/56

equipos, y el alto costo inicial de la conversión. Asimismo evaluaría el funcionamiento y la eficacia energética de la tecnología con CO_2 transcrítico en un escenario real y proporcionaría información sobre la viabilidad técnica, el costo de conversiones, los beneficios ambientales, y la eficacia energética del uso del CO_2 en sistemas de refrigeración centralizados de supermercados.

130. El proyecto de demostración incluye la introducción de sistemas de refrigeración con CO_2 transcrítico en dos supermercados seleccionados en Argentina y Túnez, situados en condiciones climáticas de calor moderado. Se espera utilizar el proyecto en otros países, promoviendo de este modo el uso de refrigerantes con bajo potencial de calentamiento atmosférico en el sector de montaje.

131. El subproyecto diseñado para el supermercado La Anónima, en Lincoln, Argentina, tuvo éxito; no obstante, el subproyecto diseñado para el supermercado Monoprix, en Túnez, se canceló después de la fase de diseño inicial debido a una falta de interés.[34] El saldo del financiamiento restante de ambos subproyectos se devolverá al Fondo a más tardar el 31 de diciembre de 2020.

132. En nombre del gobierno de Argentina, la ONUDI presentó el informe final del proyecto de demostración (el informe final se adjunta en el Anexo III del presente documento).

Ejecución del proyecto

133. El subproyecto en Argentina introdujo un sistema potenciado de CO_2 transcrítico con compresión paralela y un sistema de subenfriamiento que utiliza el R-290 en el supermercado La Anónima, que operó sistemas centrales de refrigeración con temperaturas bajas y altas usando el HCFC-22 y varios congeladores autónomos (islas y armarios verticales) usando el HFC-404A. El consumo de electricidad por los sistemas de refrigeración en La Anónima se midió por separado antes y después de la conversión para comparar el consumo de electricidad del sistema de referencia con el sistema convertido. También se tomaron datos sobre temperaturas y condiciones climáticas generales de la estación meteorológica más cercana mientras duró el período de medición.

134. EPTA desarrolló el diseño del sistema con CO_2 transcrítico[35] con la ayuda de su sedes sociales en Italia y el Reino Unido de Gran Bretaña e Irlanda del Norte, según los requisitos técnicos proporcionados por la ONUDI y la Dependencia Nacional del Ozono. EPTA Italia fabricó los equipos de los sistemas de refrigeración centrales del CO_2 transcrítico, los evaporadores y el subenfriador y los entregó *in situ*; y todos los cálculos de tuberías se ajustaron localmente.

135. La disposición del supermercado y la configuración de los nuevos sistemas de refrigeración son casi idénticas al sistema de referencia. Los aparatos autónomos con R-404A se sustituyeron e integraron en el sistema centralizado del CO_2. La capacidad de refrigeración del nuevo sistema es 78,32 kilovatios (68,79 kilovatios para el circuito de temperatura media y 9,53 kilovatios para el circuito de baja temperatura); lo cual es ligeramente más pequeño que el sistema original de 82,14 kilovatios (72,09 kilovatios para los armarios y cámara frigorífica con temperatura positiva de HCFC-22 y 10,05 kilovatios para los armarios y cámaras frigoríficas con temperatura baja de R-404A).

136. Se instaló un sistema de refrigeración central con multicompresores para cubrir la demanda de refrigeración. En una zona abierta y para aumentar la eficacia energética durante los períodos calurosos del año, se instaló un subenfriador de R-290 (carga refrigerante de 1,7 kg). Las tuberías se modificaron para soportar presiones de funcionamiento más altas en el lazo y para armonizar el sistema a la carga más baja de refrigerante. Para asegurar la seguridad asociada al uso del CO_2, se instalaron válvulas de seguridad para liberar la presión cuando ésta sobrepasa 120 bar. Se instalaron detectores de fugas y

[34] Párrafo 157 de UNEP/OzL.Pro/ExCom/82/20, y decisión 82/22 d).
[35] EPTA refrigeration: https://www.eptarefrigeration.com/en

alarmas para detectar las fugas del CO_2 y para activar el sistema que cierra las válvulas electrónicas para evitar peligros de asfixia por una acumulación de concentración del CO_2.

137. El nuevo sistema de refrigeración se instaló en diciembre de 2017 y funciona desde enero de 2018. Se recopilaron datos para evaluar el funcionamiento y el consumo de energía del sistema. Desde que empezó a funcionar el sistema con CO_2 no tuvo fugas. Si en el futuro ocurre una fuga, el refrigerante del CO_2 puede suministrarse localmente. La ejecución de la conversión terminó sin interrumpir la operación del supermercado. La maquinaria de referencia se desmanteló sólo después de la puesta en marcha y los ensayos exitosos del nuevo sistema.

138. El personal de La Anónima recibió la capacitación de los fabricantes de los equipos sobre la instalación, la puesta en marcha, la operación y el mantenimiento del sistema, inclusive los procedimientos de intervenir en un sistema del CO_2 bajo presión; los procedimientos de mantenimiento como cambio de filtro y control con mirillas de inspección; la gestión de los controles electrónicos del sistema en paralelo; y la operación del sistema de supervisión. Asimismo la Dependencia Nacional del Ozono llevó a cabo la capacitación en prácticas idóneas en el manejo de los refrigerantes con bajo potencial de calentamiento atmosférico inclusive el CO_2 y más de 700 técnicos recibieron esta formación. Para difundir los resultados del proyecto se organizó un taller en los márgenes de la reunión del Grupo de trabajo de composición abierta de las Partes en julio de 2019, en Bangkok.

Resultados de la demostración

139. La ejecución del subproyecto en Argentina tuvo los siguientes resultados:

a) El sistema de refrigeración del CO_2 transcrítico es técnicamente viable para usar en supermercados en condiciones climáticas similares a las de Lincoln, Argentina; y todos los componentes usados en el sistema están disponibles localmente o internacionalmente a un precio razonable;

b) De acuerdo con la experiencia industrial y la literatura técnica, la inversión inicial de un sistema de refrigeración del CO_2 transcrítico es más alta que la del sistema con HFC, debido a que la alta presión requiere una tubería más fuerte y una mejor soldadura durante la instalación; en los precios actuales, la inversión de un sistema similar que utiliza R-404A es un 20 por ciento más bajo que el CO_2 transcrítico, aproximadamente, y un 10-13 por ciento más bajo que un sistema con HFC/glicol;

c) El consumo de electricidad del sistema de CO_2 transcrítico fue el 27,64 por ciento más bajo que el sistema de referencia con HCFC-22/R-404A[36] según las medidas tomadas durante un período de 11 meses (de enero a noviembre), antes y después de la conversión, en 2017 y 2018. La factura de electricidad (incluyendo otros usos de energía) indicó ahorros anuales de unos $EUA 9 200;

[36] Calculado sobre la base del consumo acumulativo anual de electricidad en 2017 (antes de la conversión) y en 2018 (después de la instalación del sistema del CO_2 transcrítico); se midieron los datos de los primeros 11 meses (de enero a noviembre) y los datos del último mes fueron extrapolados usando las medidas de 11 meses.

d) La reducción en las emisiones de gases de efecto invernadero calculadas por la ONUDI ascendió a 856,33 tCO_2eq, proveniente de emisión directa,[37] reducción de 834,90 tCO_2eq proveniente del reemplazo de HCFC-22 y de R-404A, y 21,43tCO2eq de emisión indirecta[38] proveniente de ahorros de electricidad de 68 453kW;

e) El índice más bajo de fugas del sistema del CO_2, el precio más bajo del refrigerante del CO_2 comparado con los refrigerantes sintéticos, y el consumo más bajo de electricidad parece dirigirse a costos de explotación más bajos; y

f) La frecuencia del mantenimiento preventivo del sistema del CO_2 transcrítico es similar a la de los sistemas de HCFC-22/R-404A.

140. Basado en los buenos resultados del proyecto de demostración, La Anónima acordó con EPTA adoptar el CO_2 transcrítico como la tecnología predeterminada para las nuevas instalaciones y como tecnología sucedánea para sus 162 instalaciones existentes en 85 ciudades de Argentina. Hasta el momento, el número de supermercados que utilizan sistemas con CO_2 transcrítico en Argentina aumentó a 13 en siete cadenas de supermercados. En el nivel regional, desde 2017 EPTA instaló otros tres sistemas en Chile, uno en Colombia y 12 en Ecuador.

Informe financiero

141. De los $EUA 527 169 aprobados para el subproyecto en Argentina, se desembolsaron $EUA 508 135. El subproyecto de Túnez se canceló después de que movilizó a los expertos técnicos y se hubiese preparado el mandato y de que todos los socios lo hubiesen aprobado; este trabajo inicial de preparación tuvo un costo de $EUA 20 000. El saldo restante se devolverá al Fondo a fines de 2020, conforme a la decisión 82/22. Los gastos reales del proyecto de demostración comparado con el presupuesto previsto se presentan en el Cuadro 9.

Cuadro 9: Desglose de costos del proyecto de demostración para los sistemas de refrigeración con CO_2 transcrítico ($EUA)

Rúbrica	Presupuesto aprobado	Desembolsos	Saldo
Subproyecto en Argentina			
Equipos de refrigeración nuevos	389 866	484 372	
Armarios de presentación para alimentos	102 303		
Ingeniería y transporte	15 000		
Talleres para difundir los resultados del proyecto	20 000	23 763	
Subtotal Argentina	**527 169**	**508 135**	**19 034**
Subproyecto en Túnez			
Equipos de refrigeración nuevos	245 347	0	
Armarios de presentación de alimentos	43 784	0	
Ingeniería y transporte	10 000	0	
Talleres, consultor, reuniones y viajes	20 000	20 000	
Subtotal Túnez	**319 131**	**20 000**	**299 131**
Totales (Argentina + Túnez)	**846 300**	**528 135**	**318 165**

Observaciones de la Secretaría

142. La Secretaría observó que el proyecto se planeó originalmente para terminar en 30 meses. Para obtener los datos sobre la mejora de la eficiencia energética del sistema de refrigeración con el CO_2

[37] De no asumirse ninguna fuga del CO_2 y del R-290 en el sistema de refrigeración del CO_2 transcrítico.
[38] Con el uso de 313 tCO2eq/ KVH para la intensidad de generación energética en Argentina.

transcrítico, el consumo de electricidad del sistema de refrigeración se midió antes y después de la conversión. Éste es el primer proyecto que mide el consumo de electricidad real en un sistema de refrigeración y proporciona datos de primera mano sobre el aumento de la eficiencia energética de la conversión de un sistema con HCFC/HFC a un sistema de refrigeración del CO_2 transcrítico en supermercados.

143. La ejecución del proyecto aumentó notablemente los conocimientos técnicos del diseño, la instalación, la puesta en marcha, la operación y el mantenimiento del sistema de refrigeración transcrítico del CO_2 en supermercados. El proyecto demostró que la tecnología de refrigeración con CO_2 transcrítico es económica y técnicamente viable para los países del Artículo 5 con clima templado y ayudó a confiar en la adopción de la tecnología para sustituir los sistemas con HCFC y HFC en los supermercados que operen dentro de esos países.

144. De conformidad con la información del informe final, el costo más alto de la inversión inicial puede compensarse, a lo largo de un tiempo razonable, mediante los ahorros del consumo reducido de electricidad y de la posible reducción de fugas de refrigerantes durante las operaciones.

145. La adopción de la tecnología llevará a la reducción permanente de emisiones de los gases de efecto invernadero y tendrá un impacto positivo en el clima. La demostración proporcionó una opción tecnológica sostenible para la eliminación de los HCFC y HFC en supermercados y esta tecnología se está adoptando en varios países de la región, lo que contribuirá a la eliminación sostenible de esas sustancias en general.

146. La Secretaría preguntó sobre las medidas de seguridad necesarias para la instalación del subenfriador en una zona abierta. La ONUDI aclaró que es importante demarcar el área alrededor del subenfriador, donde no se permite calor, chispas, llamas abiertas, superficies calientes ni fumar; y diseñar medidas de seguridad apropiadas, según las normas nacionales de seguridad y el tamaño de la carga, en el sitio de instalación, dado que el R-290 es un refrigerante inflamable. Para el subproyecto de Argentina, el subenfriador se instaló en el tejado donde hay una buena ventilación natural y, por lo tanto, no hubo ninguna necesidad de instalar sensores especiales.

147. La Secretaría observó que el informe final proporcionó el costo de equipos de refrigeración, de armarios de presentación de alimentos, ingeniería y transporte en una cifra global sin un desglose detallado de costos como en el presupuesto propuesto. La ONUDI informó que se otorgó el contrato del proyecto a EPTA, que considera confidencial la información detallada de los costos y no la ha compartido con la ONUDI. La Secretaría observó que el proyecto de demostración es el primer proyecto de la región dirigido a cuantificar la mejora de la eficiencia energética de la tecnología; y el costo detallado podría cambiar a medida que se instalen más sistemas. Además, el costo total del sistema de refrigeración del CO_2 transcrítico del informe proporcionó un nivel indicativo de costo inicial.

Recomendación

148. El Comité Ejecutivo podría:

a) Tomar nota con beneplácito del informe final sobre el proyecto de demostración para la introducción de tecnología de refrigeración con CO_2 transcrítico para supermercados en Argentina y Túnez, presentado por la ONUDI, y que figura en el documento UNEP/OzL.Pro/ExCom/85/9; y

b) Invitar a organismos de ejecución y bilaterales a tener en cuenta el informe final del proyecto de demostración mencionado en el subpárrafo a) anterior, cuando ayudan a países del Artículo 5 en la preparación de proyectos de los sectores de refrigeración comercial.

Mundial (África Oriental y Caribe): Proyecto de demostración sobre la calidad, el confinamiento y la introducción de refrigerantes sucedáneos con bajo potencial de calentamiento atmosférico en el sector de equipos de refrigeración y climatización (informe final) (ONUDI)

Antecedentes

149. En su 76ª reunión, el Comité Ejecutivo aprobó el proyecto de demostración en las regiones de África Oriental y el Caribe sobre la calidad, el confinamiento y la introducción de refrigerantes sucedáneos con bajo potencial de calentamiento atmosférico, por un monto de $EUA 425 650, que consiste en $EUA 50 000, más los gastos de apoyo del organismo de $EUA 6 500, para el PNUMA y de $EUA 345 000, más los gastos de apoyo del organismo de $EUA 24 150, para la ONUDI, conforme a la decisión 72/40 (decisión 76/36).

150. En su 82ª reunión, el Comité Ejecutivo canceló el componente ejecutado por el PNUMA (dado que no se logró ningún progreso) y prorrogó al 31 de julio de 2019 la fecha de terminación para el componente ejecutado por la ONUDI, a condición de que no se pida otra prórroga, y pidió a la ONUDI que presentase el informe final a más tardar a la 84ª reunión (decisión 82/22 c)). En la misma reunión, el PNUMA devolvió el total de financiación de su componente (es decir, $EUA 56 500).

151. Conforme a la decisión 82/22 c), la ONUDI presentó a la 84ª reunión un informe sobre la marcha de las actividades del proyecto de demostración. Al examinar el informe sobre la marcha de las actividades, la Secretaría observó que se requería información adicional, entre otras cosas: aspectos de seguridad al adaptar equipos que utilizan HCFC-22 a los refrigerantes inflamables; resultados en el funcionamiento y el mantenimiento de aparatos que usan hidrocarburos instalados en cada uno de los países del Caribe; consideración del impacto de las reglamentaciones y normas sobre la implantación de la tecnología en esos países; conclusiones sobre las herramientas necesarias para operar con los refrigerantes inflamables basado en la experiencia del centro regional de Granada; importancia del problema con refrigerantes falsificados para Dependencias Nacionales del Ozono; lecciones aprendidas sobre medidas prácticas para asegurar la calidad del refrigerante en los mercados nacionales; supervisión y medidas de aplicación de las reglamentaciones necesarias para reducir el riesgo de las importaciones y de las ventas locales de refrigerantes falsificados; y un informe financiero detallado.

152. Al tomar nota del tiempo limitado disponible para abordar las observaciones planteadas por la Secretaría, el Comité Ejecutivo decidió observar que la ONUDI presentaría un informe final sobre el proyecto, además del informe de terminación de proyecto, a la 85ª reunión, y que los saldos no utilizados se devolverían en la 86ª reunión (decisión 84/24).

Informe final

153. Conforme a la decisión 84/24, la ONUDI presentó el informe final del proyecto de demostración, que se adjunta como Anexo IV del presente documento.

Componente de África Oriental

154. El componente del proyecto relacionado con la región africana que cubre Eritrea, Kenya, Rwanda, la República Unida de Tanzania, y Zambia era demostrar la disponibilidad de refrigerantes falsificados en los mercados locales, las lagunas reglamentarias y la falta de sensibilización sobre esta cuestión; y proponer una estrategia para asegurar la calidad del refrigerante en el mercado, dado que esto mejorará la eficacia de la operación de los equipos de refrigeración y climatización, prolongando de este modo la vida útil de los mismos y la reduciendo la necesidad de nuevos refrigerantes. Dado la ubicación geográfica, se seleccionó la República Unida de Tanzania, de tamaño mayor y una población más grande, como el país experimental para la ejecución de actividades técnicas específicas.

155. Las actividades realizadas bajo el proyecto comprendieron encuestas sobre la disponibilidad de refrigerantes; capacitación para técnicos en refrigeración, oficiales de aduanas, inspectores ambientales e importadores; suministro de identificadores de refrigerantes a las partes interesadas; establecimiento de centros de prueba de refrigerantes; y apoyo a las actividades de sensibilización. El proyecto logró su objetivo de hacer un inventario de los refrigerantes falsificados de la región, e identificó las lagunas que llevaban a la penetración de mercado regional de dichos refrigerantes. Se capacitó a las partes interesadas sobre el uso de analizadores de refrigerantes, la identificación de refrigerantes falsificados y la medida de desempeño de equipos de refrigeración y climatización, usando refrigerantes puros y falsificados. El proyecto fortaleció centros de prueba de refrigerantes a través del suministro de herramientas y equipos, y concientizó sobre la disponibilidad de refrigerantes falsificados en mercados locales y las consecuencias de usarlos.

156. Las consecuencias de usar los refrigerantes falsificados son: consumo de energía adicional con emisiones indirectas de CO_2 conexas; daño de los componentes de sistema inclusive del compresor; reducción del desempeño y la vida útil de los equipos; uso inadvertido de refrigerantes inflamables o tóxicos; probable expulsión del refrigerante durante el mantenimiento, dado que no puede reciclarse o regenerarse; aumento potencial del consumo del refrigerante virgen; aumento potencial de fugas si se carga un refrigerante con más alta presión; pérdida de credibilidad para los técnicos; y riesgos potenciales de seguridad.

157. Los resultados de este componente revelaron que el refrigerante falsificado se usa mucho en numerosos países del Artículo 5 y que había una falta de reglamentaciones para abordar el problema; había también una falta de concientización entre los oficiales de aduanas e importadores. Por lo tanto, estas cuestiones deberían abordarse durante la ejecución de los planes de gestión de eliminación de los HCFC y las actividades de facilitación para la reducción de los HFC, dado que toda clase de refrigerantes que se recupera se embotella y se vende o se exporta como nuevo.

158. El proyecto de demostración también detalló medidas para evitar que los refrigerantes falsificados/contaminados entren en los mercados locales, entre otras cosas, la interacción permanente entre las Dependencias Nacionales del Ozono y los importadores de refrigerantes para aumentar la transparencia y el intercambio de información; programas continuos de creación de capacidad para los oficiales de aduanas, las autoridades ambientales y los oficiales de la Dependencia Nacional del Ozono; colaboración entre organismos, como las Dependencias Nacionales del Ozono, las oficinas de normas, los departamentos de aduanas, las autoridades portuarias y otros responsables de la aplicación de las reglamentaciones; identificadores de refrigerantes en los puntos de entrada; uso del sistema de codificación armonizado por las aduanas, inclusive el uso del número de la O.N.U,[39] fórmula química y el número de ASHRAE[40] (por su sigla en inglés) entre otros; implicación de las asociaciones y los técnicos en refrigeración en campañas de concienciación para minimizar las importaciones y el uso de refrigerantes falsificados; incentivos/premios para los oficiales de aduanas que decomisan refrigerantes falsificados; y material de sensibilización, que se exhibirá en todos los puntos fronterizos para guiar a los oficiales de aduanas y las Dependencias Nacionales del Ozono en la composición química de los diversos refrigerantes durante el análisis.

Componente del Caribe

159. El componente del proyecto relacionado con la región del Caribe que abarca Bahamas, Granada, Santa Lucía, San Vicente y Granadinas y Suriname debía facilitar la introducción de refrigerantes con bajo potencial de calentamiento atmosférico en el sector de servicios mediante: mejoramiento de la pericia de técnicos y capacitación de instructores especializados; actualización de los planes de estudios

[39] Números de cuatro cifras, asignados por el Comité de expertos en transporte de mercancías peligrosas de las Naciones Unidas, que identifican los artículos y materiales peligrosos en el marco de transporte internacional.
[40] American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

de capacitación en los centros de formación profesional; suministro de equipos básicos a los centros de capacitación regionales (es decir, aparatos de climatización que usan HC, colectores con manómetros para HC, detectores de fugas electrónicos para refrigerantes inflamables, puestos de carga portátiles para HC, cilindros de gas propano y butano, y otras herramientas); sesiones de formación dentro del país e información a las partes interesadas sobre los últimos equipos con HC disponibles en el mercado.

160. Las actividades que se ejecutaron fueron: el diseño de un plan de estudios de capacitación en el manejo seguro de refrigerantes inflamables con bajo potencial de calentamiento atmosférico; un taller regional para los encargados de la adopción de políticas y los creadores del plan de estudios con representantes de Dependencias Nacionales del Ozono y los encargados de la capacitación; equipamiento del centro de capacitación regional en Granada con herramientas y equipos adecuados para refrigerantes inflamables con bajo potencial de calentamiento atmosférico; realización de un taller regional de capacitación de instructores en Granada, en el que los participantes se formaron sobre los aspectos teóricos de servicios de refrigeración, inclusive el manejo seguro de refrigerantes alternativos; diseño de un plan de estudios regional de capacitación y acreditación para asegurar que sólo los técnicos calificados manejan y prestan servicios de equipos y con refrigerantes inflamables; entrega de dos acondicionadores de aire con R-290; y celebración de una reunión regional del grupo de expertos que siguió a la reunión de los funcionarios de la dependencia del ozono en Suriname.

161. Como resultado del proyecto, en 2019 el centro de capacitación regional empezó a funcionar plenamente para los técnicos de refrigeración y climatización de Granada, y en 2020 se abrirá a técnicos de otros países de la región. Al final del curso de formación, se realizó una evaluación y los participantes exitosos recibieron acreditación en "gas fluorado" y "alternativas REAL".[41]

162. De acuerdo con observaciones provenientes de la ejecución del proyecto, las recomendaciones incluyen la adopción por parte de todos los países del plan de estudios elaborado por el proyecto; la evaluación regular de la capacidad regional del centro de capacitación de Granada; consideración de la necesidad de un segundo centro de capacitación regional en otro país, si las capacidades no son suficientes; creación de asociaciones y mecanismos para exhortar a los proveedores o a los fabricantes internacionales de equipos y de herramientas que utilizan HC a tener mayor una presencia en la región; consideración de la adquisición regional de equipos y herramientas que utilizan HC; consideración de creación de una asociación regional de refrigeración; atracción de más ayuda financiera de los organismos de financiación internacionales para la introducción de refrigerantes alternativos con bajo potencial de calentamiento atmosférico; consideración de creación de lineamientos de etiquetado ecológico para aparatos de enfriamiento y/o lineamientos de recompensa cuando los consumidores compran aparatos ecológicos; consideración de la imposición de aranceles a las importaciones de equipos con alto potencial de calentamiento atmosférico; consideración de requisitos técnicos obligatorios para diseñar, construir o adaptar edificios civiles (por ej., oficinas, hoteles, hospitales, escuelas, edificios de apartamentos, e instalaciones de servicios) con una superficie superior a determinado tamaño; realización de evaluaciones técnicas con aparatos que usan R-290 para examinar cómo actúan con electricidad de 110V/60Hz; y desarrollo de plataformas para la distribución de información entre los técnicos.

[41] Éstas son certificaciones reconocidas mundialmente del nivel de competencia de los técnicos para manejar los gases refrigerantes - en este caso, los gases fluorados y los refrigerantes inflamables.

Observaciones de la Secretaría

163. En base a las observaciones y los resultados del componente de África Oriental, la Secretaría pidió más información sobre el modo en que sería posible estimular a los técnicos y los usuarios finales a que informasen en condiciones de seguridad casos que utilicen refrigerantes falsificados, y cuáles podrían ser las medidas punitivas apropiadas para los importadores o distribuidores locales que venden esos refrigerantes.

164. La ONUDI explicó que se espera que los técnicos y otros interesados directos informen a través de la asociación de técnicos en refrigeración. Cuando no existe una asociación, se invitó a los técnicos que informen directamente a la Dependencia Nacional del Ozono del país. La ONUDI explicó los resultados del proyecto de demostración a otras Dependencias Nacionales del Ozono. Las medidas punitivas para los violadores varían según el país. Algunos países comienzan con campañas de sensibilización del público, inclusive la distribución de folletos de la ONUDI, y más adelante aplican las multas. Asimismo la ONUDI considera que la información sobre el tema se puede intercambiar durante las reuniones de la red regional organizadas por el Programa de Asistencia al Cumplimiento del PNUMA.

165. Respecto a si la ejecución de los planes de gestión de eliminación de los HCFC en países del Artículo 5 se había ajustado como resultado del proyecto, la ONUDI indicó que la cuestión de la calidad del refrigerante se incluye en la capacitación que se brinda a los técnicos; la capacitación incluye métodos básicos para identificar posibles refrigerantes falsificados y, en lo posible, una demostración del funcionamiento de equipos con el refrigerante puro y el falso, comprado localmente. Las Dependencias Nacionales del Ozono y los técnicos aprecian esta cuestión, pero se requiere más sensibilización.

166. Al explicar más la principal contribución del componente del Caribe del proyecto a los países participantes y de su impacto en la ejecución de sus planes de gestión de eliminación de los HCFC, la ONUDI informó que el proyecto demostró la necesidad de fortalecer la cooperación regional para que en los países participantes haya más equipos disponibles que usan HC. Más concretamente:

a) El desarrollo de un plan de estudios de capacitación con material de referencia sobre refrigerantes inflamables que se puedan incorporar en las estrategias del plan de gestión de eliminación de los HCFC una vez que se han adaptado a los países específicos, donde sea necesario;

b) La creación de un centro de formación bien equipado en Granada, disponible para que los técnicos de la región aprendan cómo manejar con seguridad los refrigerantes inflamables. Asimismo se reforzó la capacidad de los centros de capacitación en otros países. El centro regional y las instalaciones de capacitación actualizadas de cada país ya realizaron sesiones de formación para técnicos que complementan los talleres de capacitación llevados a cabo conforme a los planes de gestión de eliminación de los HCFC; y

c) El establecimiento de una reserva de instructores provenientes de cada país participante capaz de formar a técnicos en refrigeración y climatización como parte de los planes de gestión de eliminación de los HCFC, tal como ya se está haciendo en las Bahamas, Granada y Suriname.

167. Con respecto a la disponibilidad de las herramientas críticas y requeridas por los técnicos para manejar los refrigerantes inflamables,[42] la ONUDI indicó que, hasta la fecha, en los mercados regionales era imposible obtener estas herramientas y los países seguían siendo dependientes de los planes de gestión de eliminación de los HCFC y otras iniciativas para tener acceso al mercado internacional. También es

[42] Colector con manómetro para refrigerantes inflamables, detectores de fugas electrónicos para refrigerantes inflamables, y cilindros adecuados para refrigerantes inflamables.

necesario tener más aparatos que utilicen refrigerantes inflamables para usarlos como modelos de capacitación para aumentar y sustituir la capacidad instalada en los establecimientos de capacitación de la región. La ONUDI incluyó detalles sobre los equipos más necesarios para formar y hacer el servicio de los refrigerantes inflamables en el plan de estudios adjunto como Anexo I al componente del Caribe del informe final.

168. Conforme a la decisión 84/24, la ONUDI confirmó que había un saldo de $EUA 709, que sería devuelto a la 86ª reunión.

Recomendación

169. El Comité Ejecutivo podría:

a) Tomar nota del informe final sobre el proyecto mundial de demostración (África Oriental y el Caribe) sobre la calidad, el confinamiento y la introducción de alternativas con bajo potencial de calentamiento atmosférico en el sector de refrigeración y climatización, presentado por la ONUDI, y que figura en el documento UNEP/OzL.Pro/ExCom/85/9; e

b) Invitar a los organismos de ejecución y bilaterales a que tomen en cuenta el informe mencionado en el subpárrafo a) anterior cuando presten asistencia a países del Artículo 5 en la preparación y la ejecución de proyectos en el sector de servicio de equipos de refrigeración.

Regional (Europa y Asia Central): Desarrollo de un centro de excelencia regional para la capacitación y acreditación y la demostración de refrigerantes alternativos con bajo potencial de calentamiento atmosférico (informe final) (Federación de Rusia)

Antecedentes

170. En su 76ª reunión, el Comité Ejecutivo aprobó un proyecto de demostración para la región de Europa y Asia Central (ECA, por su sigla en inglés) para el desarrollo de un centro de excelencia regional para la capacitación y acreditación y la demostración de refrigerantes alternativos con bajo potencial de calentamiento atmosférico, por un monto de $EUA 591 600, más los gastos de apoyo del organismo de $EUA 75 076, para el gobierno de la Federación de Rusia (decisión 76/35).

171. El objetivo del proyecto era mejorar la capacidad técnica de sectores de refrigeración y climatización de los países en Europa Oriental y Asia Central para superar las barreras a la adopción de los refrigerantes con bajo potencial de calentamiento atmosférico; mejorar las prácticas de mantenimiento; reducir las emisiones de gas fluorado provenientes de los equipos de refrigeración y climatización; y hacer que los técnicos y los fabricantes de equipos comprendan el diseño ecoenergético y la operación de equipos de refrigeración y climatización. El gobierno de la Federación de Rusia pidió ayuda a la ONUDI para ejecutar este proyecto.

172. La ONUDI, en calidad de organismo asignado, presentó el informe final sobre el establecimiento de un centro de excelencia regional para la capacitación y acreditación y la demostración de los refrigerantes alternativos con bajo potencial de calentamiento atmosférico, conforme a la decisión 83/30 c). [43] El informe detallado se adjunta como Anexo V del presente documento.

[43] En la 83ª reunión se estudió un Informe sobre la marcha de las actividades del proyecto, y luego de tomar nota del progreso notable se prorrogó la fecha de terminación del proyecto al 31 de diciembre de 2019 (decisión 83/30 b)).

Informe final

173. El centro de excelencia regional se estableció en Armenia, en el complejo científico educativo internacional del "Liceo de Shirakatsy", bajo el Ministerio de Protección de la Naturaleza. Fue inaugurado en septiembre de 2019 en una ceremonia con más de 50 participantes en la que estuvieron presente ministros y secretarios de estado de países del Consejo Ecológico Interestatal de la Comunidad de Estados Independientes (CEI), representantes de la ONUDI, asociaciones y compañías de refrigeración y climatización, expertos técnicos y estudiantes.

174. Actualmente el centro regional funciona y brinda capacitación y asesoramiento a los países de la región de ECA, inclusive programas de capacitación, lineamientos de acreditación y capacitación de instructores; y proporciona un plan de estudios común para los estudios de formación profesional y académicos que podrían adoptar los países durante la ejecución de sus actividades del plan de gestión de eliminación de los HCFC.

175. A continuación se indican otras actividades terminadas bajo el proyecto:

a) Se formó y acreditó a cinco instructores con el sistema de acreditación del gas fluorado y alternativas REAL, y se firmó un acuerdo especial de cooperación con un centro de capacitación de Moscú para dictar cursos de capacitación y acreditación para principiantes, *entre otras cosas,* en seguridad eléctrica, trabajos en altura, receptáculos de presión y conocimientos de soldadura, válidas en el territorio de Rusia y de los estados Unión Económica Euroasiática;

b) Traducción al ruso del proyecto de reglamentación sobre gases fluorados armonizada con la reglamentación no. 517/2014 de la Unión Europea y desarrollo del sistema simplificado de acreditación de técnicos en reglamentaciones sobre gases fluorados para facilitar la aplicación de sistemas de acreditación en cada uno de los países de ECA;

c) Asesoramiento y asistencia técnica para la armonización de la legislación nacional y la reglamentación después de ratificar la Enmienda de Kigali a través del Consejo Técnico Interestatal de Asociaciones Nacionales de Refrigeración;

d) En la provincia de Kotayk', Armenia, se ejecutó un proyecto de demostración con refrigerantes inflamables usados para instalaciones de almacenamiento de frutas y verduras; y se establecieron los requisitos de seguridad para hacer funcionar y mantener los equipos y se demostró mediante la instalación y el funcionamiento de equipos. La mejora de la eficacia energética alcanzada a través de nuevos equipos fue de un 34 por ciento, y la réplica del proyecto de demostración podría dar lugar al reemplazo de unas 500 instalaciones por año en los países en la región de Europa Oriental y Asia Central;

e) Se llevaron a cabo nueve programas de asistencia técnica, como aprendizaje electrónico, sesiones prácticas en el centro de excelencia regional y demostración práctica sobre la función de nuevas tecnologías con la ayuda proveniente de fabricantes de equipos mediante un plan de estudios común para los estudios de formación profesional y académicos; se fomentó la participación de aprendices de género femenino en los programas de capacitación del centro y en el centro se formó a 77 profesionales de refrigeración y climatización; y

f) Se creó un sitio Web (http://hvaccenter.am/) para proporcionar un espacio de capacitación en línea y a distancia.

176. El desarrollo y la operacionalización del centro de capacitación se dieron a conocer mediante reuniones consultivas regionales del personal técnico, dependencias nacionales del ozono y otras reuniones consultivas; y el establecimiento del centro se anunció a través de medios impresos y electrónicos entre interesados directos de la región.

177. Los fondos aprobaron ascienden a $EUA 591 600 y se desembolsaron en su totalidad para desarrollar y operacionalizar el centro de capacitación ($EUA 184 044), la ejecución del proyecto de demostración ($EUA 188 261), la traducción de las reglamentaciones al inglés y ruso ($EUA 55 500), la creación del sitio Web para los programas de capacitación electrónicos y de divulgación ($EUA 92 795), y la divulgación de la información y las actividades de sensibilización y otras actividades relacionadas con la gestión del proyecto ($EUA 71 000).

Observaciones de la Secretaría

178. Sobre los retrasos del proyecto, la ONUDI aclaró que la razón principal se debía a la asignación de la financiación para la ejecución del proyecto y, en grado menor, para la modernización de la infraestructura de las instalaciones de capacitación del centro, el cambio de beneficiario para el proyecto de demostración, y los cambios de los responsables en el gobierno de Armenia.

179. A pedido de una aclaración, la ONUDI explicó que el proyecto de demostración implicó el reemplazo de equipos usados en el almacenamiento de frutas y verduras, dado que los equipos instalados previamente eran muy viejos. El beneficiario proporcionó la cofinanciación de unos $EUA 30 000, que incluyeron la preparación del sitio, las obras civiles y eléctricas para la instalación de equipos, las actividades de sensibilización del público y la obtención de permisos y certificados de seguridad/inspecciones nacionales. Se espera que el proyecto tenga potencial de escalabilidad en la región y sirva para una adopción más rápida de las tecnologías refrigerantes con bajo potencial de calentamiento atmosférico; los países adoptarían reglamentaciones nacionales para promover dichas tecnologías.

180. En general, el proyecto logró su objetivo de establecer un centro de excelencia regional para capacitación de técnicos e ingenieros en el manejo seguro de refrigerantes y la demostración de los usos de refrigerantes con bajo potencial de calentamiento atmosférico en sistemas de refrigeración y climatización en países de ECA.

Recomendación

181. El Comité Ejecutivo podría:

a) Tomar nota del informe final sobre el desarrollo de un centro de excelencia regional para la capacitación y acreditación y la demostración de refrigerantes alternativos con bajo potencial de calentamiento atmosférico para la región de Europa y Asia Central, presentado por el gobierno de la Federación de Rusia y la ONUDI, y que figura en el documento UNEP/Ozl.Pro/ExCom/85/9; y

b) Alentar a los organismos de ejecución y bilaterales a que utilicen plenamente los recursos proporcionados por el centro regional a los que se hace referencia en el subpárrafo a) para la ejecución de los proyectos de gestión de eliminación de HCFC y proyectos de reducción del consumo de HFC en ECA y las regiones vecinas.

Arabia Saudita: Proyecto de demostración para eliminar HCFC usando HFO como agente de espumación en espumas pulverizadas a temperatura ambiente elevada (informe final) (ONUDI)

Antecedentes

182. En su 76ª reunión, el Comité Ejecutivo aprobó entre otras cosas el proyecto de demostración para eliminar los HCFC usando HFO como agente de espumación en espumas pulverizadas a temperatura ambiente elevada, por un monto de $EUA 96 250, más los gastos de apoyo del organismo de $EUA 8 663, para la ONUDI, y pidió al gobierno de Arabia Saudita y a la ONUDI que terminasen el proyecto en el plazo de 16 meses, a partir de su aprobación, y presentasen un informe final exhaustivo poco después de la terminación de proyecto (decisión 76/31).[44]

183. En la 83ª reunión, la ONUDI presentó un informe sobre la marcha de las actividades del proyecto de demostración, observando que las actividades adicionales, inclusive las pruebas *in situ* (por ej., fuerza de adherencia, absorción de agua, contenido de célula cerrada, durabilidad de la resistencia térmica y fuerza de compresión contra el envejecimiento/degradación), necesitarían llevarse a cabo antes de que el proyecto pudiera terminarse. Para concluir las actividades restantes que proporcionarían información valiosa, y observando que se había logrado un progreso considerable, el Comité Ejecutivo acordó prorrogar la fecha de terminación de proyecto al 31 de octubre de 2019, a condición de que en el futuro no se solicitaran otras prórrogas de ejecución del proyecto. Además, el Comité pidió a la ONUDI que presentase, a más tardar en la 84ª reunión, el informe final del proyecto (decisión 83/35 b) y c)).

184. Conforme a la decisión 83/35 c), la ONUDI presentó el informe final del proyecto de demostración el 11 de noviembre de 2019. El Comité Ejecutivo tomó nota de la presentación, que la Secretaría examinaría y presentaría en la 85ª reunión.[45] Esta sección contiene el examen de la Secretaría del informe y de sus resultados.

Informe final

185. El proyecto se aprobó para demostrar los beneficios, la aplicabilidad y la replicación del uso de HFO-1233zd (E) y HFO-1336mzz (Z) cosoplado con agua en usos con espumas de poliuretano pulverizadas a temperatura ambiente elevada, y para analizar las reducciones de los costos de capital y de explotación obtenidas cosoplando con agua y considerando cambios en la densidad y conductividad térmica de las espumas.

186. El proyecto fue ejecutado en Sham Najd International, un productor local de poliuretano rígido y con espumas pulverizadas del poliisocianurato (PIR) para estructuras de aislantes e impermeabilizantes (por ej., paredes, cielo rasos, tejados y pisos). El único agente espumante que se probó fue el HFO-1233zd (E), porque el HFO-1336mzz (Z) no estaba disponible comercialmente.

187. En base de los resultados de las pruebas, la formulación con espumas pulverizadas con HFO-1233zd (E) parece ser una posible alternativa para sustituir las formulaciones con HCFC y con HFC, dado que tiene cualidades técnicas y físicas similares, combinadas con un potencial de calentamiento atmosférico bajo y cero PAO. A continuación se dan las conclusiones del proyecto de demostración:

[44] En la 80ª reunión, la fecha de terminación del proyecto se prorrogó al 31 de diciembre de 2018 (decisión 80/26 i)).
[45] Párrafo 120 de UNEP/OzL.Pro/ExCom/84/75.

a) El desempeño del HFO-1233zd (E) correspondió al del HCFC-141b en adherencia, conductividad térmica, estabilidad dimensional, pintabilidad, densidad total de espumas y resistencia a la compresión;

b) La superficie pulverizada con HFO-1233zd (E) exhibió más poros que la que usa HCFC-141b, pero aun así cumplió con las expectativas del cliente;

c) El HFO-1233zd (E) no requirió nuevos equipos de espumación; todas las pruebas se realizaron con los equipos existentes en Sham Najd (es decir, Graco E-XP1 Applicator);

d) Debido a su bajo punto de ebullición (19,5 °C), el HFO-1233zd (E) debería mezclarse en el reactor a una temperatura inferior a los 18 °C, preferiblemente a 15 °C, para evitar la pérdida de agente espumante durante el proceso de mezcla;

e) Una cantidad más pequeña de HFO-1233zd (E) puede mezclarse en el poliol, dado que el punto de ebullición de la mezcla del poliol también será más bajo que el punto de ebullición del HCFC-141b;

f) Los proveedores de sistemas y usuarios finales almacenaron el poliol premezclado con HFO-1233zd (E) durante cinco meses sin observar cambios en la reactividad. La mezcla tiene que ser almacenada a un máximo de 28 °C, debido al bajo punto de ebullición de HFO-1233zd (E), que causaría evaporación/ebullición de la sustancia química en temperaturas más altas;

g) El sistema de poliol premezclado con HFO-1233zd (E) requiere un paquete especial de aditivos (agentes tensioactivos y catalizadores) para evitar el deterioro de la mezcla del poliol; el paquete catalizador proporciona una vida útil que supera los ocho meses;

h) Los costos de explotación adicionales del sistema con HFO-1233zd (E) son $EUA 4,30/kg más altos que los del sistema con HCFC-141b. Sin embargo, con la conductividad térmica más baja (mejor aislación) y una densidad más baja de la espuma producida con HFO-1233zd (E), el costo de explotación adicionales se redujo a $EUA 0,33/kg; y

i) El precio de HFO-1233zd (E) pagado para la ejecución del proyecto fue de $EUA 9,50/kg; sin embargo, el precio real cuando se compran pequeñas cantidades es $EUA 15/kg; lo cual aumentaría los costos de explotación adicionales. Se espera que estos costos se reduzcan dentro de unos años, cuando disminuya el precio de HFO-1233zd (E) y aumente el del HCFC-141b, debido a una menor disponibilidad.

Resultados de las pruebas adicionales in situ

188. El informe final incluyó los resultados de las pruebas realizadas por un laboratorio independiente en Finlandia 18 meses después de usar espumas pulverizadas con HFO en condiciones de temperatura ambiente elevada. De acuerdo con los resultados, la ONUDI concluyó que la espuma basada en HFO-1233zd (E) demostró tener por lo menos un comportamiento similar a la espuma con HCFC-141b. Además, el período de envejecimiento de 18 meses de la espuma para pulverización aplicada a temperatura ambiente elevada no cambió notablemente ningún indicador de desempeño, y la espuma cumplió con todas las especificaciones.

189. En junio de 2019 se realizaron talleres en Jeddah, Riyadh y Dammam para informar sobre los resultados de los usos con espumas de poliuretano pulverizadas y vertidas con HFO-1233zd (E) en comparación con otras tecnologías y análisis de costos.

Observaciones de la Secretaría

190. Si bien la Secretaría observó algunas variaciones en los valores obtenidos en las pruebas de 18 meses en comparación con las pruebas originales, las propiedades físicas de las espumas siguieron siendo comparables a las de espumas con HCFC-141b. La ONUDI proporcionó una interpretación de los datos obtenidos en cada prueba, que la Secretaría encontró valiosa y sugirió el adjuntar al informe. El informe final revisado se adjunta como Anexo VI del presente documento.

Disponibilidad y adopción de la tecnología

191 Al aclarar el origen y la disponibilidad de las formulaciones usadas para probar el HFO-1233zd (E), la ONUDI indicó que la formulación utilizada para las primeras pruebas había sido totalmente desarrollada por Covestro (proveedor mundial de polímeros en los Emiratos Árabes Unidos) y no estaba disponible para cualquier otro proveedor de sistemas en el país. Todos los detalles de la formulación de espumas pertenecen a los proveedores de sistemas, que, por lo general, son secretos. Sin embargo, los proveedores de aditivos (es decir, Evonik y Momentive) y del agente espumante (es decir, Honeywell y Chemours) proporcionan activamente ayuda a los responsables de la formulación de los proveedores de sistemas. Dado que ahora en Arabia Saudita los sistemas con espumas pulverizadas están disponibles localmente, todos los aplicadores usarán más el sistema local de espumas pulverizadas.

191. En la descripción de los principales obstáculos a la integración de esta tecnología en Arabia Saudita, la ONUDI indicó que si bien se dispone actualmente de sistemas que utilizan HFO para espumas pulverizadas y pueden utilizarse para todos los usos de la construcción, los sistemas de espumación con HCFC-141b y plenamente formulados y las reservas de HCFC-141b puro son ampliamente accesibles en los proveedores de sistemas. La aceptación en el mercado de las nuevas formulaciones con espumas pulverizadas con bajo potencial de calentamiento atmosférico es limitada, debido a la publicidad negativa sobre el mal desempeño previsto de estas formulaciones. Bajo el plan de gestión de eliminación de los HCFC, la ONUDI y el PNUMA están planeando un programa de acreditación y norma de calidad dirigido al uso de sistemas certificados de espumas únicamente, que podría ayudar a superar los obstáculos actuales y lograr una adopción más amplia de la tecnología.

Cofinanciación

193. El costo total del proyecto de demostración para el Fondo Multilateral fue de $EUA 94 000, de los cuales $EUA 28 000 se utilizaron en servicios de asesoría y viajes; $EUA 48 000, en equipos y sustancias químicas; y $EUA 18 000, en las pruebas de laboratorio y el taller de divulgación. A pedido de una aclaración, la ONUDI informó que, según la información disponible, los proveedores de sistemas beneficiarios contribuyeron con una inversión de $EUA 250 000 en equipos y sustancias químicas.

Recomendación

194. El Comité Ejecutivo podría:

a) Tomar nota del informe final sobre el proyecto de demostración para la eliminación de los HCFC mediante el uso de HFO como agente de espumación en espumas pulverizadas a temperatura ambiente elevada en Arabia Saudita, presentado por la ONUDI y que figura en el documento UNEP/OzL.Pro/ExCom/85/9; e

b) Invitar a los organismos de ejecución y bilaterales a tomar en cuenta el informe mencionado en el subpárrafo a) anterior cuando asisten a países del Artículo 5 en la preparación y la ejecución de proyectos de espumas de poliuretano.

Arabia Saudita: Proyecto de demostración sobre la promoción de refrigerantes con HFO y bajo potencial de calentamiento atmosférico para el sector de climatización en temperatura ambiente elevada (Informe sobre la marcha de las actividades) (ONUDI)

Antecedentes

195. En nombre del gobierno de Arabia Saudita, la ONUDI presentó a la 85ª reunión un informe sobre la marcha de las actividades del proyecto de demostración sobre la promoción de refrigerantes potenciales con hidrofloroolefina (HFO) con bajo potencial de calentamiento atmosférico para el sector de climatización a temperatura ambiente elevada.

196. El proyecto se aprobó en la 76ª reunión para fabricar, probar y optimizar modelos experimentales de acondicionadores de aire con mezclas de HFO/HFC y con bajo potencial de calentamiento atmosférico así como el R-290, hacer una demostración de la producción y convertir una línea de producción, por un monto de $EUA 1 300 000, más los gastos de apoyo del organismo de $EUA 91 000, para la ONUDI.

197. En su 80ª reunión, el Comité Ejecutivo acordó prorrogar el proyecto, de mayo de 2018 al 31 de diciembre de 2018, a condición de que no se solicite otra prórroga y pedir a los organismos de ejecución que presenten el informe final a más tardar a la 83ª reunión (decisión 80/26 g)). Posteriormente, en la 82ª reunión se presentó un informe sucinto sobre la marcha de las actividades que documentaba un progreso notable en muchas actividades, como la adquisición de equipos y ejecución de los componentes (por ej., compresores), con entrega de equipos de producción y la producción de los primeros aparatos con R-290 todavía pendiente. Se esperaba que esas actividades terminasen en diciembre de 2018.

198. En la 83ª reunión, se informó que si bien se entregaron equipos de fabricación, quedaba pendiente todavía la instalación, dado que la empresa había decidido a mover la línea de fabricación. No obstante, la empresa planeaba instalar los equipos en forma preliminar para que se pudiera hacer una prueba y formar al personal; la línea se movería en septiembre 2019. Se requirió hacer más pruebas y optimizar los aparatos. La terminación de esas actividades, así como la realización de un taller para difundir los resultados del proyecto, se previeron para diciembre de 2019. En consecuencia, el Comité Ejecutivo decidió prolongar, de manera excepcional, la fecha de terminación de proyecto al 31 de diciembre de 2019, observando el progreso avanzado en la ejecución y la capacidad potencial de replicación de los resultados en varios países del Artículo 5, a condición de que en el futuro no se pidieran otras prórrogas para la ejecución del proyecto; y pidió a la ONUDI que presentara el informe final del proyecto a más tardar en la 85ª reunión y devolviera todos los saldos restantes para la 86ª reunión (decisión 83/33).

Informe sobre la marcha de las actividades

199. Se realizaron otras pruebas y optimización de los aparatos, como la optimización del condensador con diámetro externo de 5 milímetros y tubos de cobre con estriado interno, para lo cual la empresa aumentó su línea de fabricación del intercambiador de calor para permitir la producción en fábrica, proporcionando una ventaja económica con respecto a los intercambiadores de calor con microcanales que deberían comprarse de los proveedores. Se elaboró un prototipo totalmente funcional de aparatos de climatización con mini condensador separado y R-290 con una capacidad de 18 000 BTU (1,5 toneladas de refrigeración) que utiliza condensador con tubos estriados internos de 5 milímetros; no fue necesaria otra optimización del condensador. El aparato sobrepasó los requisitos locales de normas de eficiencia energética mínima (MEPS, por su sigla en inglés) con un grado de eficacia energética de 12,5 en 35 °C (T1) y 9,36 en 46 °C (T3). Sin embargo, la prueba de terceros todavía no se ha realizado a la espera del recibo de un nuevo lote de compresores prototípicos y de encontrar un laboratorio adecuado. El aparato

desarrollado con mini condensador separado y R-290 responde a las nuevas normas de eficiencia energética mínima propuestas por la Organización de Calidad, Metrología y Normas de Saudi Arabia, y se emprenderán otras optimizaciones. A tal efecto, se pidió un nuevo lote de 48 compresores de R-290 con diseños mejorados para hacer más pruebas con prototipos de condensador separado de R-290.

200. Se movió la línea de fabricación, concluyeron las obras civiles y se instalaron todos los equipos, inclusive un sistema completo de control de calidad. Sin embargo, la puesta en marcha de la línea, prevista para febrero de 2020, se retrasó debido a la pandemia del COVID-19; la prueba de la línea de fabricación se planea para cuando se supriman las restricciones de viajes impuestas por dicha pandemia. De manera similar, si bien los laboratorios y los cuartos de prueba reales se actualizaron con equipos e instrumentos necesarios, la puesta en marcha se retrasó. Otras actividades pendientes son la capacitación de los técnicos en la línea de fabricación y el último taller para difundir los resultados del proyecto entre las partes interesadas.

Observaciones de la Secretaría

201. Dado la pandemia del COVID-19, el proyecto aún no pudo terminarse. La ONUDI suministró una cronología provisional para la terminación de proyecto que incluyó el viaje de un experto en mayo de 2020 para la puesta en marcha y llevar a cabo la capacitación, hacer las pruebas de los prototipos basados en un nuevo lote de 48 compresores de R-290 con diseño mejorado en junio-agosto de 2020, y la realización del último taller en septiembre de 2020.

202. Al tomar nota de que la cronología propuesta era provisional y dependería de la situación del COVID-19, por ejemplo si se permitiría el viaje internacional, la Secretaría recomienda prorrogar el proyecto al 15 de diciembre de 2020, y pedir a la ONUDI que presente el informe final del proyecto a más tardar el 1 de enero de 2021, y devuelva todo saldo restante para la 87ª reunión.

Recomendación

203. El Comité Ejecutivo podría:

a) Tomar nota del informe sobre la marcha de las actividades del proyecto de demostración sobre la promoción de refrigerantes con hidrofloroolefina y bajo potencial de calentamiento atmosférico para el sector de climatización a temperatura ambiente elevada en Arabia Saudita, presentado por la ONUDI, y que figura en el documento UNEP/OzL.Pro/ExCom/85/9;

b) Prorrogar la fecha de terminación del proyecto mencionado en el subpárrafo a) anterior al 15 de diciembre de 2020, de manera excepcional, dado la pandemia del COVID-19 y el progreso alcanzado; y

c) Pedir a la ONUDI que presente el informe final del proyecto mencionado en el subpárrafo a) anterior a más tardar el 1 de enero de 2021 y devuelva todo saldo restante para la 87ª reunión.

<u>Región de Asia Occidental: Proyecto de demostración sobre la promoción de refrigerantes alternativos en aparatos de climatización para los países de temperatura ambiente elevada (PRAHA-II) (informe final)</u> (PNUMA y ONUDI)

204. En su 76ª reunión, el Comité Ejecutivo aprobó el proyecto de demostración sobre la promoción de refrigerantes alternativos en aparatos de climatización para los países de temperatura ambiente elevada

en Asia Occidental,[46] más conocido como PRAHA-II, con un costo total de $EUA 771 500, que consiste en $EUA 375 000, más los gastos de apoyo del organismo de $EUA 48 750, para el PNUMA, y en $EUA 325 000, más los gastos de apoyo del organismo de $EUA 22 750, para la ONUDI. El PNUMA y la ONUDI presentaron el exhaustivo informe final del proyecto que se incluye en el Anexo VII del presente documento.[47]

205. El proyecto tuvo como objetivo basarse en el progreso del proyecto de demostración para promover alternativas con bajo potencial de calentamiento atmosférico para la industria de aparatos de climatización en países de temperatura ambiente elevada en Asia Occidental (PRAHA-I).[48] PRAHA-II tenía tres elementos principales: crear capacidad de la industria local en el diseño y la prueba de aparatos de climatización que utilizan refrigerantes inflamables con bajo potencial de calentamiento atmosférico; evaluar y optimizar los prototipos construidos para PRAHA-I; y construir un modelo de evaluación de riesgos para los países de temperatura ambiente elevada.

206. Para la creación de capacidad local, se analizaron los prototipos de aparatos de climatización que se elaboraron en PRAHA-I y se optimizaron adquiriendo los planos de desempeño para los componentes (compresores, ventiladores); evaluando las configuraciones de diseño del intercambiador de calor, inclusive los intercambiadores de calor con microcanales; optimizando la ingeniería para igualar o sobrepasar el desempeño del aparato de referencia, que incluyó la instalación de nuevos compresores mejorados, para los mismos refrigerantes usados en PRAHA-I, y que no estaban disponibles en el momento que se habían construido los prototipos del PRAHA I; o compresores para refrigerantes no probados bajo PRAHA-I. Los aparatos optimizados se probaron con refrigerantes con bajo potencial de calentamiento atmosférico (es decir, R-290, HFC-32, y ciertas mezclas de HFO), y se analizó el efecto de la recarga con fugas en el desempeño de alternativas de alto-deslizamiento.[49] Se organizaron talleres de capacitación para diseñar prototipos, consultas entre los fabricantes de equipos de aparatos de climatización y los abastecedores locales de tecnología, visitas *in situ* en los centros de industria e investigación en China y Japón, y un viaje de estudio a los Estados Unidos de América. Se creó un modelo de evaluación de riesgos adecuado para patrones de uso y condiciones de desempeño prevalecientes en países con temperatura ambiente elevada en cooperación con los institutos locales y la Asociación de la Industria de Refrigeración y Climatización de Japón (JRAIA, por su sigla en inglés).

Resultados y recomendaciones

207. Los resultados de la optimización de los prototipos de PRAHA-I demostraron que las mejoras en desempeño del sistema se pueden alcanzar con el modelado, el diseño y la selección de componentes. El rediseño de componentes se centró en el compresor, el condensador y la válvula de expansión. Los prototipos de PRAHA-I utilizaron sobre todo los compresores clasificados específicamente para R-410A o HCFC-22, lo que presentó una oportunidad para una mejor selección del compresor dado que un compresor diseñado para un refrigerante en particular mejorará la eficacia energética (EE) del aparato. La reducción del diámetro del tubo/canal del intercambiador de calor permite una reducción en el tamaño de la carga, dado que los coeficientes de transferencia de calor son inversamente proporcionales a los diámetros del tubo; sin embargo, diámetros reducido aumentan la caída de la presión. Además, si bien las reducciones en diámetro u otros cambios al diseño del intercambiador de calor permitirían una mayor

[46] Bahrein, Egipto, Kuwait, Qatar, Omán, Arabia Saudita, y los Emiratos Arabes Unidos. No se proporcionó ninguna financiación para los Emiratos Árabes Unidos, y la industria local construyó los prototipos y asistió a las sesiones de PRAHA por cuenta propia.

[47] El informe se presentó en la 84ª reunión, pero debido al tiempo limitado disponible, la Secretaría pudo estudiar el informe y presentar sus resultados a la 85ª reunión (apartado 122 del documento UNEP/OzL.Pro/ExCom/84/75).

[48] Aprobado en la 69ª reunión para la puesta en práctica por el PNUMA y la ONUDI (UNEP/OzL.Pro/ExCom/69/19). El informe final de ese proyecto se puede encontrar en el documento UNEP/OzL.Pro/ExCom/76/10.

[49] El deslizamiento de temperatura es la diferencia térmica entre el vapor saturado y las temperaturas de líquidos saturados a una presión constante.

eficacia del sistema y una carga reducida, los cambios del diseño de un intercambiador de calor están limitados por las dimensiones permitidas de la envoltura: un completo rediseño del sistema proveería una oportunidad para diseñar intercambiadores de calor con una eficacia todavía mayor. Si bien la selección de ventiladores y sopladores puede mejorar la eficacia energética de manera similar, esos componentes no se consideraron dado el costo y el tiempo, y dado que el 80-90 por ciento del consumo de energía viene del compresor.

208. Las pruebas de aparatos optimizados mostraron una considerable reducción en el consumo de energía al probarse en temperatura ambiente elevada (46 °C). El análisis de simulación mostró que el refrigerante con curvas más anchas de saturación tiende a dar lugar a sistemas con una eficacia más alta y una carga menor cuando no se modifica el hardware. No obstante, los resultados indicaron que haciendo una selección de componentes apropiada, como compresores con volúmenes más grandes de desplazamiento y una masa de flujo más alta, las capacidades de enfriamiento y el desempeño total de los otros refrigerantes estaban en el mismo orden de magnitud.

209. Los resultados de pruebas de las alternativas de alto deslizamiento descubrieron que el fraccionamiento del refrigerante, tal como se evidenció en las pruebas de hermeticidad, no parece ser una preocupación significativa, dado que se observó menos de 2 por ciento de cambio en la capacidad de enfriamiento después de la recarga del sistema y se espera que los cambios a la eficiencia energética sean mínimos.

210. El trabajo sobre la evaluación de riesgos requirió la consideración de diferentes usos de aparatos de climatización y prácticas de servicio en temperatura ambiente elevada, relacionado con la instalación y prácticas de servicio y los niveles de competencia de los técnicos; la temperatura no tiene ningún efecto directo sobre el riesgo. En cooperación con expertos de JRAIA, y con la colaboración de expertos del Comité de Opciones Técnicas de Refrigeración y del Comité de Opciones Técnicas de Halones, se creó un modelo de evaluación de riesgos, que se aplicó posteriormente como ejemplo de un sistema de aparatos de climatización con condensador separado de 5,3 kW (1 tonelada de refrigeración) que utiliza un refrigerante A2L con lo siguiente:

a) Durante el uso en una oficina donde las fuentes de ignición incluyen carbón de leña y un encendedor usado para el incienso, una vela con aroma, y cigarrillos y encendedores. Se evaluó la probabilidad de ignición proveniente de actos en 10^{-9} aproximadamente; y

b) Durante la etapa de reparación durante la soldadura con fuentes de ignición, inclusive el soplete, un cigarrillo y un encendedor. La probabilidad de ignición fue 10^{-3}, aproximadamente, destacando la importancia de prácticas de servicio seguras (incluida la prohibición de fumar en el área de servicio).

211. Las recomendaciones clave de PRAHA-II son:

a) La creación de capacidad proporcionó una plataforma de cooperación entre los gobiernos, los institutos de investigación, las asociaciones industriales y la industria; se convirtió en una plataforma para compartir información y los resultados del diseño, colocando en los mercados aparatos de climatización que trabajaban con refrigerantes con bajo potencial de calentamiento atmosférico y haciendo el servicio de los mismos; ayudó a los interesados directos a adquirir conocimientos sobre el modo de trabajar con dichos refrigerantes; ayudó a los fabricantes a construir o a involucrarse en proyectos de investigación colaborativos, permitió que la industria evaluara alternativas a largo plazo, y aumentó la sensibilización sobre la necesidad de seleccionar alternativas. Los viajes de estudio expusieron a interesados directos a la última tecnología de refrigeración. En la medida de lo posible, este proceso debe continuar;

b) El reemplazo de los refrigerantes es viable y puede ser competitivo con los refrigerantes con alto potencial de calentamiento atmosférico, pero su realización requiere el diseño y la selección de componentes apropiados (en particular, compresor y dispositivo de expansión). No se recomienda nunca el uso de productos sucedáneos de uso inmediato sin cambio de soporte físico. Las simulaciones numéricas y algunos tenues análisis de optimización proporcionarán la información para el rediseño a costos mucho más bajos que los cambios graduales con métodos por aproximación;

c) Una evaluación de riesgos adaptada a las necesidades es esencial para comprender mejor las implicaciones de seguridad asociadas con la utilización de refrigerantes alternativos, considerando las características específicas de diversos tipos de equipos y vida útil, inclusive el transporte, almacenamiento, instalación, uso, mantenimiento y desmantelamiento. Deberían estudiarse las evaluaciones de riesgos de otras etapas que corresponden a aspectos culturales y formas de vida. Las medidas para atenuar los riesgos dependerían del tipo de normas y de códigos de cada país, así como las prácticas de mantenimiento. Los países al amparo del Artículo 5 podían beneficiarse de la experiencia del PRAHA-II en el desarrollo del modelo de evaluación de riesgos para superar las dificultades técnicas y para desarrollar rápidamente un modelo; y

d) La optimización de los prototipos de PRAHA-I mostró que los componentes y, en particular, los compresores, diseñados para alternativas con bajo potencial de calentamiento atmosférico no estaban disponibles en ese momento y en muchos casos todavía no se encuentran ampliamente disponibles. Un proceso para asegurar que los fabricantes están informados constantemente de las novedades les ayudará a tomar una decisión fundamentada.

Observaciones de la Secretaría

212. En su 83ª reunión, el Comité Ejecutivo decidió prolongar, entre otras cosas, de manera excepcional, la fecha de terminación de proyecto al 15 de noviembre de 2019 para concluir la prueba de los prototipos los aparatos de climatización, validar los resultados de la prueba de optimización y el modelo de evaluación de riesgo y difundir los resultados del proyecto, y pidió al PNUMA y la ONUDI que devolviesen todos los saldos restantes para la 85ª reunión. Todas esas actividades concluyeron, excepto que el sexto simposio internacional sobre refrigerantes alternativos para los países de temperatura ambiente elevada, que se había programado para marzo de 2020 en Dubai, tuvo que posponerse debido a la pandemia del COVID-19. Ese simposio se volvió a programar para diciembre de 2020 o el primer trimestre de 2021, dependiendo de la situación del COVID-19. Mientras tanto, el PNUMA y la ONUDI planean difundir los resultados del proyecto entre los países de temperatura ambiente elevada con un seminario web especial, programado provisionalmente para junio de 2020. El PNUMA y la ONUDI han comprometido todos los fondos necesarios para el 15 de noviembre de 2019. Si bien los fondos no comprometidos podrían ser devueltos, queda pendiente un pago no liquidado que todavía no se desembolsó, debido al aplazamiento del simposio. Por lo tanto, se acordó pedir al PNUMA y la ONUDI, de manera excepcional, devolver todos los saldos restantes para la 86ª reunión.

213. El descubrimiento de que el fraccionamiento del refrigerante de alternativas de alto deslizamiento en el ciclo de recarga es probable que tenga un pequeño efecto sobre la capacidad de refrigeración de los equipos y la eficiencia energética es significativa y puede facilitar la implantación de tales refrigerantes.

214. Uno de los resultados clave de PRAHA-I, que se confirmó con PRAHA-II, es que el proceso de mejorar normas de eficiencia energética para aparatos de climatización en países de temperatura ambiente elevada progresa más rápidamente que el proceso de evaluar y seleccionar los refrigerantes alternativos; por lo tanto, hay una necesidad urgente de abordar en forma conjunta las alternativas de eficiencia energética y con bajo potencial de calentamiento atmosférico para evitar la promoción de alternativas con

alto potencial de calentamiento atmosférico. PRAHA creó un proceso que permite a la industria involucrarse en la investigación y el desarrollo, y compartir la información y las mejores prácticas relacionadas con la transición a equipos de climatización ecoenergéticos y con bajo potencial de calentamiento atmosférico. Asimismo, el PNUMA creó una plataforma para la cooperación interna entre las Dependencias Nacionales del Ozono y las autoridades de energía con el programa del hermanamiento de ozono/energía que se ejecutó durante 2018-2019, e hizo arreglos de cooperación locales en muchos países. Además, se tomó en consideración nacionalmente la diferencia en la tasa de actualización de las normas de eficiencia energética comparada con el proceso de desarrollar y de utilizar refrigerantes con bajo potencial de calentamiento atmosférico en la fabricación de aparatos de climatización (por ej., el proyecto de conversión de aparatos de climatización en Egipto aprobado en la 84ª reunión). [50]

215. La Secretaría tomó nota de que el PNUMA y la ONUDI se proponen transformar la iniciativa PRAHA en un proceso dinámico con intercambio de información continuo y ayuda para los países de temperatura ambiente elevada y trató de comprender de qué manera PRAHA sería sostenible. PRAHA incluyó funciones de creación de capacidad que involucraron a países con y sin temperatura ambiente elevada, por ejemplo:

a) Viajes de estudio a China y Japón en los que participaron expertos de Argelia, Bahrein, Egipto, Jordania, Kuwait, Pakistán, Arabia Saudita y los Emiratos Árabes Unidos;

b) Sesiones especiales en las reuniones de la red regional para compartir conocimientos e información sobre PRAHA;

c) Participación en una serie de cinco simposios de temperatura ambiente elevada con numerosos asistentes de los países con y sin temperatura ambiente elevada, así como expertos de la industria, y un sexto simposio, si bien ha sido pospuesto, documentación y materiales se compartirán a través de un seminario web especial, y las lecciones del proyecto se pondrán a disposición en los sitios web del PNUMA y la ONUDI; y

d) Sesiones especiales en los Grupo de trabajo de composición abierta y en conferencias internacionales pertinentes sobre calefacción, ventilación, aparatos de climatización y refrigeración (HVACR, por su sigla en inglés).

216. Hasta la fecha, PRAHA se centró en países de temperatura ambiente elevada con fabricación de aparatos de climatización; sin embargo, la mayoría de países de temperatura ambiente elevada carece de fabricación local de esos aparatos, pero se beneficia con esa tecnología. El PNUMA y la ONUDI se proponen abordar este problema a través de:

a) Uso continuo de los recursos generados por PRAHA para ayudar a países y aumentar sus conocimientos sobre alternativas; y

b) Presentación al Comité Ejecutivo de un nuevo proyecto que se centrará en el suministro de asistencia técnica para la utilización de alternativas, como la evaluación de riesgos para los países de temperatura ambiente elevada sin fabricación de aparatos de climatización, soporte técnico en la elaboración de una estrategia de aceptación en el mercado y un plan de utilización para equipos que usan refrigerantes con bajo potencial de calentamiento atmosférico, diseñando un código de HVACR y las herramientas de aplicación de las reglamentaciones para facilitar el buen uso de los refrigerantes con bajo potencial de calentamiento atmosférico, y un programa de capacitación para las autoridades locales que regulan, autorizan o supervisan equipos y proyectos que utilizan refrigerantes con bajo potencial de calentamiento atmosférico.

[50] UNEP/OzL.Pro/ExCom/84/49.

217. La Secretaría observó, sin embargo, que el Comité Ejecutivo no ha abierto un marco adicional para otros proyectos de demostración de HCFC.

Recomendación

218. El Comité Ejecutivo podría:

a) Tomar nota con beneplácito del informe final de la demostración sobre la promoción de los refrigerantes alternativos en aparatos de climatización para los países de temperatura ambiente elevada en Asia Occidental (PRAHA-II), presentado por el PNUMA y la ONUDI, que figura en el documento UNEP/OzL.Pro/ExCom/85/9;

b) Pedir al PNUMA y la ONUDI que devuelvan todos los saldos restantes para la 86ª reunión en lugar de la 85ª reunión, dada el retraso de la celebración del sexto simposio internacional sobre refrigerantes alternativos para los países de temperatura ambiente elevada, debido a la pandemia del COVID-19; e

c) Invitar a los organismos de ejecución y bilaterales a compartir el informe final del proyecto de demostración mencionado en el subpárrafo a) arriba, cuando ayudan a países del Artículo 5 en la preparación de proyectos en sectores de aparatos de climatización en países de temperatura ambiente elevada.

Informes de auditoría financiera para sectores de producción de CFC, halones, espumas de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes en China

China: agente de procesos II - información adicional sobre las actividades que se emprenderán (Banco Mundial)

Antecedentes

219. En la 84ª reunión, el gobierno de China había propuesto realizar las siguientes actividades para aumentar la supervisión y la gestión a largo plazo de las SAO, dado saldos no asignados de unos $EUA 1,24 millones en el plan sectorial de agente de procesos II:

a) Construcción y actualización del sistema de supervisión en línea sobre la producción del tetracloruro de carbono (CTC). Este sistema complementaría el sistema de información de la gestión de SAO centrándose en la producción de CTC, conversión, ventas y reservas entre todos los productores del clorometano;

b) Investigaciones sobre los usos de producción y como materia prima de los CTC. Esta actividad complementará el estudio sobre la producción de CTC y su uso como materia prima, que se presentó conforme a la decisión 75/18, e incluirá una encuesta y una verificación *in situ* para los usos de producción y como materia prima de CTC. Las plantas del percloroetileno (PCE) no estarían incluidas;

c) Ayuda a las empresas en el desarrollo y el abastecimiento del reactivo necesario (sustituto de CTC) que se aplica mediante la norma nacional enmendada. Esta actividad apoyaría las fábricas de reactivos para poner instalaciones de purificación del percloroetileno para cumplir con los requisitos de la nueva norma y demanda del mercado;

d) Capacitación y creación de capacidad en la supervisión y la aplicación de las reglamentaciones sobre SAO para las oficinas locales de Ecología y Medio Ambiente. La actividad es realizar cursos de formación regulares para el personal de las oficinas provinciales, municipales y de condado sobre la gestión, inspección, supervisión y aplicación de las reglamentaciones sobre las SAO;

e) Supervisión del mercado y recopilación de información sobre ventas de SAO. Se contratará a una empresa de consultoría para recopilar información sobre las ventas y el mercado de SAO, y para identificar ventas ilícitas sospechosas. La información relacionada con tales ventas se informará al Ministerio de Ecología y Medio Ambiente para otras medidas; y

f) Ayuda técnica, de políticas y jurídica sobre la gestión, inspección, supervisión, aplicación y eliminación de SAO. Se contratará a expertos individuales para proporcionar dicha ayuda a las instituciones pertinentes.

220. Además, el gobierno de China planeó utilizar los saldos restantes de $EUA 250 000 para un sistema de gestión en línea de SAO, y de $EUA 750 000 para la creación de capacidad con la Autoridad Aduanera.

221. En la 84ª reunión, la Secretaría observó lo siguiente:

a) El sistema de gestión en línea de SAO permitirá a todas las empresas que utilicen SAO solicitar y registrarse como usuarios de SAO, y difundirá datos. Si bien la Secretaría apoyó la propuesta no estaba familiarizada con los detalles del sistema de gestión en línea y no podía evaluar el nivel de financiación para esta actividad. Por otra parte, el financiamiento proveniente de otros proyectos, inclusive la producción del metilbromuro, los planes sectoriales de refrigeración industrial y comercial y aparatos de climatización autónomos, bajo el plan de gestión de eliminación de HCFC, y el plan de gestión de eliminación de la producción de los HCFC, se habían utilizado para fortalecer el sistema de gestión en línea de SAO; ese agrupamiento del financiamiento probablemente es un uso eficaz de recursos, pero hace dificulta la supervisión del progreso financiero y la ejecución;

b) De manera similar se propone financiación bajo el sector de producción de metilbromuro para la creación de capacidad con la Autoridad Aduanera. La Oficina de Cooperación Económica Extranjera aclaró que el contrato bajo el sector de producción de metilbromuro se centra en esta sustancia utilizada para cuarentena y aplicaciones previas al envío, mientras que la creación de capacidad bajo el plan sectorial de agente de procesos II se centraría en actividades de anticontrabando; y

c) Si bien las seis actividades propuestas serán útiles, la Secretaría no tenía claro cuánta financiación se asignaría a cada actividad. Además, la Secretaría consideraba que sería útil presentar otros informes sobre el resultado de algunas de las actividades. Por ejemplo, la actividad relacionada con la supervisión del mercado podría proporcionar una mejor comprensión de cómo las instalaciones de producción del CFC-11 podían comprar CTC. La Secretaría sugirió que la actividad de supervisión del mercado seguiría siendo útil después de la terminación de proyecto, y que se asignase un presupuesto dentro del Ministerio de Medio Ambiente para ese fin. La construcción y la mejora del sistema de supervisión en línea de la producción de CTC facilitaría la supervisión del mercado. La Secretaría sugirió que el gobierno de China, a través del Banco Mundial, proporcione la información adicional sobre las actividades propuestas, su presupuesto, y un informe sobre la marcha de las actividades relativo a su ejecución, a la 85ª reunión; y que el Comité Ejecutivo puede también querer suministrar orientación adicional sobre el $EUA 1 millón asignado al sistema de gestión en línea de SAO y a la creación de capacidad de la Autoridad Aduanera.

222. Después de deliberar bilateralmente, el Comité Ejecutivo pidió al gobierno de China, a través del Banco Mundial, que suministre información adicional sobre las actividades propuestas que se emprenderán bajo el plan sectorial de agente de procesos II, su presupuesto y un informe sobre la marcha de las actividades relativa a su ejecución en la 85ª reunión (decisión 84/39 d)).

Información adicional proporcionada a la 85ª reunión

223. El presupuesto para el sistema de gestión en línea de SAO se aumentó a $EUA 280 000; se seleccionó y contrató a una empresa de consultoría con un contrato de $EUA 272 238. Durante la ejecución de la etapa I del plan de gestión de eliminación de producción de los HCFC, se estableció un sistema en línea a través del cual se pidió a las empresas que solicitaran las cuotas de producción y consumo de HCFC el registro de las ventas y del uso como materia prima, e informasen los datos pertinentes en línea. El propósito de esta actividad es desarrollar un sistema que extienda el mecanismo de presentación de datos y gestión de los HCFC a todas las SAO.

224. Para la creación de capacidad para las aduanas, la Oficina de Cooperación Económica Extranjera y la Autoridad Aduanera han estado llevando a cabo la formación habitual de los oficiales de aduana, tanto de las oficinas centrales como de las locales. El presupuesto para esta actividad permaneció en $EUA 750 000.

225. Con respecto a las seis actividades restantes, dado las fluctuaciones en el tipo de cambio, el presupuesto se aumentó a $EUA 1,26 millones para las cuatro actividades siguientes:

a) *Construcción y actualización del sistema de supervisión en línea sobre la producción de CTC*: El proyecto, con un presupuesto de $EUA 450 000, mejorará el método de transmisión de datos usado por el sistema para supervisar y gestionar el CTC, inclusive usando Internet para dicha trasmisión; ampliará la capacidad del software y del soporte físico existente del sistema de supervisión en línea de CTC; y establecerá una página web del sistema. La plataforma central de supervisión supervisa los datos para todos los aspectos de la producción y el uso de CTC, inclusive ventas, destrucción e inventario, permitiendo el control dinámico de los datos de producción, análisis de datos y otras funciones. Se seleccionó al consultor y éste ha comenzado a preparar el concepto técnico, el marco, la interfaz del software y el protocolo de transferencia de datos que son compatibles con los sistemas de la base de datos de los productores de CTC;

b) *Creación de capacidad para las aduanas sobre supervisión y gestión de SAO*: Esta actividad de creación de capacidad, con un presupuesto de $EUA 650 000, incluye la continuación de la ejecución de los programas de capacitación realizados en el extranjero para el personal de aduanas, promoviendo la capacidad de gestión de la importación y exportación de China y la cooperación transfronteriza de la aplicación de las reglamentaciones; asistiendo a la Autoridad Aduanera a establecer un sistema judicial y de investigación de las datos sobre comercio ilícito, estableciendo un mecanismo para compartir inteligencia e información multisectorial y fortaleciendo las capacidades conjuntas de aplicación de las reglamentaciones, lo que puede combatir las violaciones de la importación y exportación de SAO, y rastrear las fuentes de producción y ventas ilícitas nacionales. La Oficina de Cooperación Económica Extranjera y la Autoridad Aduanera prepararon un plan de trabajo y se ha elaborado el mandato para el establecimiento de un sistema judicial y de investigación de la información de datos de comercio ilícito;

c) *Investigaciones de la producción y usos como materia prima de CTC, ayuda a las empresas para el desarrollo y suministro del reactivo necesario (sucedáneo de CTC) que se aplica mediante la norma nacional enmendada*: Esta actividad, con un presupuesto de

$EUA 120 000, se propone seguir supervisando la producción y el uso como materia prima de CTC; incluye una encuesta y una verificación de la producción y los usos como materia prima de CTC, y una ayuda *in situ* para los fabricantes del reactivo para que hagan las instalaciones de purificación necesarias del percloroetileno. Se ha seleccionado al consultor y se iniciaron los exámenes documentales de la producción de CTC y el consumo de materia prima; sin embargo, la encuesta *in situ* aún no ha comenzado debido a las restricciones de viaje causadas por la pandemia del COVID-19. Con la asociación de la industria se discute la actividad para apoyar el abastecimiento del percloroetileno de calidad de laboratorio; y

d) *Ayuda técnica, de políticas y jurídica sobre n la gestión, inspección, supervisión, a aplicación de las reglamentaciones y eliminación de SAO*: Ayuda técnica, de política y jurídica en la gestión, inspección, supervisión, aplicación de las reglamentaciones y eliminación de SAO. El presupuesto para esta actividad es $EUA 40 000. El Ministerio de Medio Ambiente y Ecología está terminando el mandato, y para fines de 2020 se seleccionarán y contratarán los expertos; la actividad terminará a fines de 2020.

Observaciones de la Secretaría

226. En contraste con el sector de producción de metilbromuro, donde hubo retrasos para concluir la modalidad de cooperación entre la Oficina de Cooperación Económica Extranjera y la Autoridad Aduanera, el Banco Mundial explicó que el sólido mecanismo de cooperación que existe entre el Ministerio de Medio Ambiente y Ecología, la Autoridad Aduanera y el Ministerio de Comercio desde que se estableció la oficina de importación/exportación, se seguirá utilizando y que no se prevé ningún retraso en concluir las actividades en curso relacionadas con el plan sectorial de agente de procesos II con la Autoridad Aduanera.

227. La supervisión del mercado y la recopilación de información sobre las ventas de SAO que se propusieron en la 84ª reunión, se realizarán bajo el programa de supervisión, presentación de informes y verificación ejecutado por el Ministerio de Medio Ambiente y Ecología, conforme a la decisión 83/41 c) v). Se ha asignado a un oficial para mantener el enlace con la industria para supervisar las ventas de SAO y los productos las utilizan. Por lo tanto, esta tarea se quitó del programa de trabajo de agente de procesos.

228. Con respecto al nexo entre el sistema de gestión en línea de SAO ($EUA 280 000) y el sistema de supervisión en línea de la producción de CTC ($EUA 450 000), el Banco Mundial aclaró que el sistema de gestión en línea existente se diseñó para supervisar la producción y ventas de los HCFC únicamente; los productores deben informar trimestralmente la producción y ventas mensuales; esos datos son compilados por Oficina de Cooperación Económica Extranjera y utilizados como base para el ejercicio anual de la verificación independiente de la producción y consumo de los HCFC realizada por el Banco Mundial. La Oficina de Cooperación Económica Extranjera encargó a los consultores que ampliaran el sistema en línea existente de los HCFC para incluir otras SAO, como CTC; esta actividad terminará para fines de 2020. El sistema de supervisión en línea de la producción de CTC debe asegurar la transferencia en tiempo real de los datos de producción de CTC (medidos por los medidores de caudal y almacenados en los sistemas del control de proceso de las empresas) provenientes de cada productor de CTC a las autoridades gubernamentales; la información recopilada se utilizará para verificar la producción y los registros de ventas mensuales, que las empresas presentarán cada trimestre en el sistema de gestión en línea, separado y ampliado, de SAO.

229. En relación con la distinción entre la creación de capacidad con la Autoridad Aduanera ($EUA 750 000) y la creación de capacidad para las aduanas sobre supervisión y gestión de SAO ($EUA 650 000), el Banco Mundial explicó que la anterior era para una capacitación habitual de funcionarios de alto nivel de la oficina central de aduanas y las locales, llevada a cabo por FECO y la Autoridad Aduanera, y que la segunda es para ayudar a la Autoridad Aduanera a establecer un sistema judicial y de investigación

de la información de los datos sobre el comercio ilícito, establecer un mecanismo para compartir inteligencia e información multisectorial, y fortalecer las capacidades de aplicación de la ley en forma conjunta.

230. La Secretaría apoya las actividades propuestas que se ejecutarán bajo el plan sectorial de agente de proceso II; sin embargo, con la información adicional proporcionada por el gobierno de China no pudo evaluar los costos de las actividades propuestas.

Recomendación

231. El Comité Ejecutivo puede querer tomar nota de la información adicional sobre las actividades propuestas que se emprenderán bajo el plan sectorial de agente de proceso II para China, su presupuesto y el informe sobre la marcha de las actividades relativo a su ejecución (decisión 84/39 d)) que figura en el documento UNEP/OzL.Pro/ExCom/85/9.

Solicitud de prórroga para las actividades de facilitación (PNUD, PNUMA y ONUDI)

232. Conforme a la decisión 81/32 a),[51] en nombre de nueve países del Artículo 5, los organismos de ejecución y bilaterales presentaron peticiones oficiales para prorrogar las actividades de facilitación para la eliminación de los HFC, como se indica en el Cuadro 10.

Cuadro 10: Solicitudes de prórroga para las actividades de facilitación para la reducción de HFC presentada a la 85ª reunión

País	Organismo principal	Fecha de terminación	Prórroga
Bahamas	PNUMA	30 de junio de 2020	30 de junio de 2021
Bolivia (Estado Plurinacional de)	PNUMA	30 de junio de 2020	30 de junio de 2021
Brunei Darussalam	PNUMA	30 de junio de 2020	30 de junio de 2021
Cabo Verde	PNUMA	30 de junio de 2020	30 de junio de 2021
Islas Cook	PNUMA	30 de junio de 2020	30 de junio de 2021
Jordania	ONUDI	30 de junio de 2020	30 de junio de 2021
Mauricio	PNUMA	30 de junio de 2020	30 de junio de 2021
Qatar*	ONUDI	30 de junio de 2020	30 de junio de 2021
Timor-Leste	PNUMA	30 de junio de 2020	30 de junio de 2021

*El PNUMA como organismo de cooperación

Observaciones de la Secretaría

233. Las razones de los pedidos de prórroga para las actividades de facilitación son, entre otras cosas, el tiempo adicional necesario para comenzar la ejecución prevista originalmente, la coordinación entre las Dependencias Nacionales del Ozono, los interesados directos y el PNUMA, y la necesidad de terminar todas las actividades previstas. La Secretaría tomó nota de que todas las cuestiones que habían retrasado el comienzo de la ejecución, se habían tratado y se había logrado un avance. Los gobiernos de los países en cuestión son conscientes de que las actividades de facilitación deben terminarse a más tardar el 30 de junio de 2021, y que los saldos deben devolverse una vez que se hayan terminado dichas actividades.

Recomendación

234. El Comité Ejecutivo puede querer:

a) Tomar nota de los pedidos de prórroga de las actividades de facilitación para la reducción

[51] El Comité decidió mantener el período de dieciocho meses para la ejecución de las actividades de facilitación y, si es necesario, prolongar ese período otros 12 meses más (lo que suman 30 meses desde la aprobación del proyecto), cuando la Secretaría recibió una petición oficial de prórroga.

de los HFC presentada por los organismos de ejecución respectivos para los nueve países del Artículo 5 indicados en el cuadro 10 del documento UNEP/OzL.Pro/ExCom/85/9; y

b) Prorrogar la fecha de terminación de las actividades de facilitación para la reducción de los HFC al 30 de junio a 2021, para Bahamas, Bolivia (Estado Plurinacional de), Brunei Darussalam, Cabo Verde, Islas Cook, Jordania, Mauricio, Qatar y la República Democrática de Timor-Leste, a condición de que no se pidiese ninguna otra prórroga y que los organismos de ejecución presentasen, dentro de los seis meses de la fecha de terminación del proyecto, un informe final de actividades de facilitación terminadas, conforme a la decisión 81/32 (b).

SECCIÓN III: INFORMES SOBRE PROYECTOS CON REQUISITOS ESPECÍFICOS DE INFORMACIÓN PARA CONSIDERACIÓN INDIVIDUAL

Informes relacionados con planes de gestión de eliminación de HCFC

República Popular Democrática de Corea: plan de gestión de eliminación de los HCFC (etapa I - informe sobre la marcha de las actividades de ejecución) (ONUDI)

Antecedentes

235. En su 73ª reunión, el Comité Ejecutivo aprobó, en principio, la etapa I del plan de gestión de eliminación de los HCFC para la República Popular Democrática de Corea, con la ONUDI como organismo de ejecución principal, y el PNUMA como organismo de ejecución cooperante, para reducir el consumo de HCFC a un nivel sostenido de 66,30 toneladas PAO para el 1 de enero de 2018 (es decir, el 15 por ciento por debajo de la base para el cumplimiento de 78,00 toneladas PAO). La aprobación se hizo una vez que los organismos de ejecución confirmaron que la etapa I del plan de gestión de eliminación de los HCFC se podría ejecutar de acuerdo con las resoluciones del Comité del Consejo de Seguridad de las Naciones Unidas [52] sobre la República Popular Democrática de Corea.

236. Desde la aprobación de la etapa I, el Comité Ejecutivo aprobó tres de cuatro tramos de financiamiento por un nivel total de $EUA 808 550 (es decir, el 95,3 por ciento de los fondos totales de $EUA 848 550, aprobados en principio), así como la transferencia a la ONUDI de todas actividades de eliminación que ejecutará el PNUMA. Conforme al Acuerdo entre el gobierno y el Comité Ejecutivo, el último tramo de la etapa I del plan de gestión de eliminación de los HCFC, por un monto de $EUA 40 000, se programó para presentarse a la 81ª reunión. En la 84ª reunión, la ONUDI había no podido presentar la petición del tramo, debido a las resoluciones del Consejo de Seguridad.

Informe sobre la marcha de las actividades

237. La ONUDI presentó a la 85ª reunión un Informe sobre la marcha de las actividades relativo a la ejecución de la etapa I del plan de gestión de eliminación de los HCFC, enumerando las actividades ejecutadas hasta el momento, el nivel de desembolso alcanzado, las dificultades encontradas para continuar la ejecución de actividades de acuerdo con las resoluciones del Consejo de Seguridad, y pidió orientación al Comité Ejecutivo.

238. El informe indica que, a pesar de dificultades provenientes de las resoluciones del Consejo de Seguridad, las actividades principales realizadas durante el primero y segundo tramo son:

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[52] El Consejo de Seguridad de la ONU, establecido conforme a la resolución 1718, fue consultado antes de la presentación de la etapa I del plan de gestión de eliminación de HCFC para determinar si se podría proporcionar al país equipos u otros servicios conforme al plan de gestión de eliminación de HCFC.

a) Adquisición de tres identificadores de refrigerantes para la oficina de aduanas del país;

b) Compra de una máquina de espumación para pulverización para Puhung Building Material, una vez recibida la aprobación del Comité del Consejo de Seguridad en 2015, y preparación de un contrato equipos auxiliares y su envío para facilitar la instalación/puesta en marcha de los equipos de pulverización;

c) Adquisición equipos para espumas poliuretano (formiato de metilo), aprobada el Comité del Consejo de Seguridad, conforme a los procedimientos establecidos en la resolución 2270 (2016) de dicho Consejo; se expidió un contrato de compra a los proveedores de equipos; los equipos se enviaron a través de China, pues no podían enviarse directamente a la República Popular Democrática de Corea, pero las autoridades aduaneras chinas los rechazaron y volvieron al proveedor;

d) Adquisición de equipos de capacitación para técnicos en servicio de equipos de refrigeración y climatización, una vez aprobada por el Comité del Consejo de Seguridad, enviado y distribuido a los técnicos de servicios de equipos de refrigeración en junio de 2016;

e) Organización de un taller de capacitación de instructores para 35 técnicos de servicio de equipos de refrigeración y climatización, realizado en agosto y septiembre de 2016;

f) Sesión de formación adicional para cinco instructores sobre mejores prácticas en servicio de equipos de refrigeración y climatización, realizada en India en diciembre de 2016; y

g) Primer taller de capacitación de instructores para 40 oficiales de aduanas en mayo de 2017.

Desembolsos de los fondos

239. Al 30 de marzo de 2020, del monto total de $EUA 808 550 de los fondos aprobados, se habían desembolsado $EUA 303 313 (36 por ciento), como se indica en el Cuadro 11.

Cuadro 11: Informe financiero de la etapa I del plan de gestión de eliminación de los HCFC para la República Popular Democrática de Corea ($EUA)

Tramo	Aprobado	Desembolsado	Índice de desembolsos (%)
Primero	134 003	87 386	65,2
Segundo	506 680	211 110	41,7
Tercero	167 867	1 817	1,1
Total	**808 550**	**300 313**	**36,0**

Actualización del plan de ejecución para la etapa I del plan de gestión de eliminación de los HCFC

240. Las actividades que todavía no se han ejecutado son:

a) Seguimiento de los talleres de capacitación para técnicos de servicio de equipos de refrigeración y climatización y oficiales de aduanas;

b) Trazado de los centros existentes de regeneración y recuperación y adquisición de otros equipos; y

c) Establecimiento de la oficina de gestión de proyectos, una vez aprobado y puesto en funcionamiento el canal de transferencia de financiamiento.

241. Además, los equipos de espuma de poliuretano que las autoridades aduaneras chinas devolvieron al proveedor no se podían volver reimportar, dado que la resolución adicional 2397 prohíbe en 2017 específicamente "toda maquinaria industrial (códigos 84 y 85 del sistema armonizado), vehículos de transporte (códigos 86 a 89 del sistema armonizado), y hierro, acero y otros metales (códigos 72 a 83 del sistema armonizado)". Con posterioridad a esta resolución, se informó a la ONUDI que presentara al Consejo de Seguridad una nueva petición de exención, así como una lista actualizada de equipos para importar al país. La ONUDI presentó una petición oficial de exención el 8 de mayo de 2019 y el Comité del Consejo de Seguridad negó dicha exención el 18 de junio de 2019. Debido a lo antedicho, la ONUDI no ha podido proceder con la entrega de los equipos

242. Las actividades sin inversión también se vieron afectadas por la imposibilidad de transferir fondos dentro del país, dificultada aún más por la introducción de sanciones más estrictas que siguieron a la adopción de la resolución 2397 (2017).

243. Debido al antedicho, la ONUDI indicó en su informe que no está en condiciones de continuar la ejecución del plan de gestión de eliminación de los HCFC para la República Popular Democrática de Corea y pide al Comité Ejecutivo que la oriente.

Observaciones de la Secretaría

244. La Secretaría toma nota de que la ONUDI ha continuado ejercitando diligencia debida y supervisando la ejecución del proyecto. Luego de la adopción de una resolución adicional del Consejo de Seguridad en 2017, se presentó al Comité del Consejo de Seguridad, conforme a la resolución 1718, una petición de exención, y una lista actualizada de equipos para ser importados en el país, y ha permanecido en estrecha colaboración con los estados miembros pertinentes de la O.N.U con respecto a la adquisición y la exportación de equipos diseñados para eliminar el uso de sustancias controladas en el país.

Recomendación

245. El Comité Ejecutivo podría querer considerar la información sobre la ejecución de las actividades bajo la etapa I del plan de gestión de eliminación de los HCFC para la República Popular Democrática de Corea, presentado por la ONUDI.

Informes de auditoría financiera para los sectores de producción de CFC, halones, espuma de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes en China

China: Informes de auditoría financiera para los sectores de producción de CFC, halones, espuma de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes (PNUD, ONUDI y Banco Mundial)

Antecedentes

246. En su 84ª reunión, el Comité Ejecutivo examinó los informes de auditoría financiera para los sectores de producción de CFC, halones, espuma de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes sobre los cuales también se proporcionó una actualización de las

actividades ejecutadas en cada plan sectorial.[53] Posteriormente, el Comité Ejecutivo pidió entre otras cosas al gobierno de China, a través del organismo de ejecución pertinente, que presentase en la 85ª reunión los informes de auditoría financiera al 31 de diciembre de 2019 para los planes sectoriales de la producción de CFC, halones, espuma de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes, y los informes de proyectos terminados para los planes sectoriales de producción de CFC, espuma de poliuretano, servicio de equipos de refrigeración y solventes; y que devolviese al Fondo Multilateral en la 85ª reunión los saldos de financiamiento disponibles al 31 de diciembre 2019 asociados con los planes sectoriales de la producción de CFC, espumas de poliuretano, servicio de equipos de refrigeración y solventes (decisión 84/39 c) i) y c) ii)).

247. Conforme a la decisión 84/39 c) i), los organismos de ejecución pertinentes, en nombre del gobierno de China, presentaron los informes de auditoría financiera al 31 de diciembre de 2019 y los informes de proyectos terminados para los sectores de producción de CFC, espuma de poliuretano, servicio de equipos de refrigeración y solventes. Se presentaron informes finales suplementarios para los sectores de servicio de equipos de refrigeración y solventes. Una actualización sobre el progreso del sector de agente de procesos II se proporciona en los apartados 218 a 230 del presente documento.

248. Los datos financieros del presente informe se basan en el informe de auditoría presentado por el gobierno de China al 31 de diciembre de 2019, que reflejan saldos restantes de $EUA 11 309 628 (Cuadro 12). Los saldos restantes de los planes sectoriales terminados (es decir, producción de CFC, espuma de poliuretano, servicio de equipos de refrigeración y solventes), ascienden a $EUA 792 215 (es decir, $EUA 311 653 de saldos y $EUA 480 561 de interés acumulativo). Conforme a la decisión 84/39 c) ii), los saldos que se devuelven la 85ª reunión son $EUA 792 215.

Cuadro 12: Saldos restantes e interés para los planes sectoriales de producción de CFC, halones, espuma de poliuretano, agente de procesos II, servicio de equipos de refrigeración y solventes del sector ($EUA)

Actividad	Saldo al 30 de junio de 2019	Saldo al 31 de diciembre de 2019	Interés acumulativo	Fecha de terminación
Producción de CFC (Banco Mundial)	179 878	33 907	22 119	Dec-19
Halones (Banco Mundial)	9 154 827	8 913 167		Dec-20
Agente de procesos II (Banco Mundial)	3 076 109	2 084 808		Dec-20
Espuma de poliuretano (Banco Mundial)	897 009	280 108		Dec-19
Servicio y mantenimiento (Japón, PNUMA, ONUDI)	735 791	752	99 178	Dec-19
Solventes (PNUD)	708 822	*-3 114	*359 265	Dec-19
Total	**14 752 436**	**11 309 628**	**480 561**	

*El saldo total que el PNUD devolverá se calcula en $EUA 356 151.

Observaciones de la Secretaría

249. Se terminaron los planes sectoriales de producción de CFC, espuma de poliuretano, servicio de equipos de refrigeración, y solventes. Si bien se han presentado los informes preliminares de proyectos terminados, los datos financieros todavía no reflejan los desembolsos finales a los beneficiarios, ni la devolución a la 85ª reunión. El Oficial superior de supervisión y evaluación trabaja con los organismos de ejecución pertinentes para asegurar que los datos financieros se incluyen en los respectivos informes de proyectos terminados.

[53] Apartados 6-105 de UNEP/OzL.Pro/ExCom/84/22/Add.1

250. Según lo acordado en la 84ª reunión, los planes sectoriales de halones y agente de procesos II terminarán el 31 de diciembre de 2020, y cualquier saldo restante en esa fecha se devolvería a la 87ª reunión, conforme a la decisión 84/39 b).

Recomendación

251. El Comité Ejecutivo podría:

a) Tomar nota de:

i) Los informes de auditoría financiera para los planes sectoriales de producción de CFC, halones, espuma de poliuretano, agente de procesos II, solvente y servicio de equipos de refrigeración en China, que figuran en el documento UNEP/OzL.Pro/ExCom/85/9;

ii) Que el Banco Mundial había devuelto a la 85ª reunión los saldos restantes en los sectores de la producción de CFC y espumas de poliuretano, de $EUA 314 015, y el interés acumulado de $EUA 22 119;

iii) Que la ONUDI había devuelto a la 85ª reunión los saldos restantes del plan sectorial de servicio de equipos de refrigeración de $EUA 752, más el interés acumulado de $EUA 99 178;

iv) Que el PNUD había devuelto a la 85ª reunión el interés acumulado de $EUA 356 151, del plan sectorial de solventes;

b) Pedir al Banco Mundial que presente a la 87ª reunión los informes de auditoría financiera para los planes sectoriales de halones y agente de procesos II que terminarían para el 31 de diciembre de 2020, conforme a la decisión 84/39 b), junto con los informes de proyectos terminados correspondientes y todo saldo restantes al 31 de diciembre de 2020; y

c) Pedir al Oficial superior de supervisión y evaluación que trabaje con el organismo de ejecución pertinente para asegurar que los informes de proyectos terminados presentados para los planes sectoriales de la producción de CFC, espuma de poliuretano, servicio de equipos de refrigeración, y solventes reflejan los desembolsos hechos a los beneficiarios finales, de forma coherente con la información proporcionada en los informes de auditoría financiera presentados a la 85ª reunión.

SECCIÓN IV: LISTA DE EMPRESAS FINANCIADAS BAJO LOS PLANES DE GESTIÓN DE ELIMINACIÓN DE LOS HCFC CON RETRASOS Y/O SUJETAS A CAMBIOS DEL PLAN DE EJECUCIÓN Y EMPRESAS PARA CONVERSIÓN A TECNOLOGÍAS CON BAJO POTENCIAL DE CALENTAMIENTO ATMOSFÉRICO CON LOS RETRASOS DEBIDO A CUESTIONES RELACIONADAS CON SU DISPONIBILIDAD EN EL MERCADO LOCAL Y/O COSTOS MÁS ELEVADOS (decisiones 84/27 y 84/42)

Antecedentes

252. En su 84ª reunión, el Comité Ejecutivo estudió los informes sobre proyectos con requisitos específicos de información.[54] Durante las deliberaciones, los miembros plantearon la importancia de

[54] UNEP/OzL.Pro/ExCom/84/22, Add.1, Add.2 y Add.3

considerar las razones de los retrasos en la introducción de alternativas aprobadas con potencial de calentamiento atmosférico. Posteriormente el Comité Ejecutivo pidió a la Secretaría que elaborase, para la 85ª reunión, una lista de empresas financiadas bajo los planes de gestión de eliminación de los HCFC para conversión a tecnologías con bajo potencial de calentamiento atmosférico, y que habían tenido retrasos de ejecución debido a cuestiones relacionadas con la disponibilidad en el mercado local y/o costos más elevados (decisión 84/27).

253. Para tener acceso a la información actualizada regularmente sobre las razones de cambios y cancelaciones de proyecto, en su 84ª reunión, el Comité también solicitó a la Secretaría que preparase, para la 85ª reunión, un cuadro simple, usando la información extraída de los informes sobre la marcha de las actividades conexos, sobre las situaciones de las empresas financiadas bajo los planes de gestión de eliminación de los HCFC que experimentaban retrasos y/o estaban sujetas a cambios en el plan de ejecución (decisión 84/42).

Medidas tomadas por la Secretaría y los organismos

254. Para tratar las peticiones de las decisiones 84/27 y 84/42, la Secretaría solicitó una actualización de los organismos de ejecución y bilaterales sobre proyectos que experimentaban retrasos, y examinó los informes sobre la marcha de las actividades relativo a la ejecución de los planes de gestión de eliminación de los HCFC presentados por los organismos de ejecución y bilaterales para complementar la información proporcionada por dichos organismos. El Anexo VIII del presente documento da una lista de todas las empresas con cuestiones relacionadas con la decisión 84/27 y/o la decisión 84/42.

255. El gobierno de Alemania informó que siete proyectos del sector de espumas se atrasaron en relación con las decisiones 84/27 y 84/42. Un proyecto se retrasó debido a la falta de disponibilidad de la tecnología seleccionada en el mercado local, y seis proyectos se retrasaron, entre otras cosas, debido a los cambios del plan de ejecución, para obtener financiamiento de contraparte o respetar las sanciones de la O.N.U.

256. El PNUD informó que 78 proyectos se retrasaron en relación con las decisiones 84/27 y 84/42; de éstos, 22 proyectos estaban en el sector de espumas, 52 proyectos estaban en refrigeración y climatización y cuatro proyectos estaban en el sector de solventes. Sesenta proyectos se retrasaron debido a las cuestiones relacionadas con la falta de la tecnología con bajo potencial de calentamiento atmosférico seleccionada y/o los costos más elevados de la misma en los mercados locales; en varios casos las empresas se retiraron de los proyectos debido a costos más altos y/o una falta de disponibilidad de componentes de la tecnología alternativa seleccionada. Dieciocho proyectos experimentaron retrasos debido a otros factores (por ej., el proceso administrativo de aprobación, la firma del documento pertinente por parte del gobierno, retrasos en firmar los acuerdos con empresas sobre ejecución del proyecto, y más tiempo para probar las alternativas y la acreditación de seguridad).

257. La ONUDI informó que 70 proyectos se retrasaron en relación con las decisiones 84/27 y 84/42; de éstos, 51 proyectos estaban en el sector de espumas y 19 proyectos estaban en el sector del refrigeración y climatización. Diez proyectos se atrasaron por cuestiones relacionadas con la disponibilidad en el mercado local y/o costos más elevados de la tecnología alternativa seleccionada; y 60 proyectos se retrasaron por otros factores (por ej., proceso administrativo de aprobación por parte del gobierno, firma del acuerdo con empresas, tiempo adicional requerido para aplicar las reglamentaciones relacionadas con los proyectos, la situación política/de seguridad y las sanciones de la O.N.U).

258. El Banco Mundial no identificó los proyectos que requerirían información en relación con las decisiones 84/27 y 84/42.

Observaciones de la Secretaría

259. La Secretaría toma nota con beneplácito de la información proporcionada por el gobierno de Alemania, el PNUD, la ONUDI y el Banco Mundial, para encarar los requisitos de las decisiones 84/27 y 84/42.

260. De los 155 proyectos empresariales con retrasos, 80 estaban en el sector de espumas, 71 en refrigeración y climatización, y cuatro estaban en el sector de solventes; 71 proyectos se retrasaron debido a la falta de disponibilidad y/o al costo más alto de la tecnología alternativa seleccionada, y 84 proyectos se retrasaron debido a otros factores. Además, podría haber otros proyectos con retrasos durante la ejecución del proyecto debido a las cuestiones específicas relacionadas con el proyecto; estas cuestiones de ejecución fueron abordadas por los organismos en consulta con las empresas y las partes interesadas nacionales.

261. La información proporcionada por los organismos mostró que las razones principales de retrasos en la ejecución del proyecto estaba relacionada con una menor aceptación en el mercado de la tecnología con refrigerantes con bajo potencial de calentamiento atmosférico comparado con tecnologías con refrigerantes con alto potencial de calentamiento atmosférico en usos de climatización disponible a costos más bajos y con una eficiencia energética más alta; y a la falta de formulaciones para soplado con HFO eficaces en función de los costos comparado con HCFC-141b/alternativas con alto potencial de calentamiento atmosférico[55] a pesar de la función importante que los proveedores de sistemas habían desempeñado en la prueba y adaptación de formulaciones alternativas.

262. Asimismo la Secretaría tomó nota de que en los informes sobre la marcha de las actividades relativos a la ejecución de los planes de gestión de eliminación de los HCFC para algunos proyectos, se informaron retrasos en la ejecución del proyecto, debido a los cambios del plan de ejecución pero se informaron con referencia a esta decisión (por ej., cambio de la tecnología durante la ejecución de la conversión del proyecto de aparatos de climatización residenciales y en cuatro proyectos del sector de espumas; o un costo más alto de instalación y mantenimiento de los aparatos de aire acondicionado autónomo que usan R-290). En sus respuestas los organismos mencionaron que según su evaluación, el retraso en la ejecución de esos proyectos no estaba relacionado con las cuestiones planteadas en las decisiones 84/27 y 84/42, y habían sido tratados como parte del proceso regular de gestión y de examen del proyecto.

263. Una evaluación exhaustiva de los retrasos de ejecución de proyectos a nivel de empresas, el impacto de esos retrasos en el logro de las metas del plan de gestión de eliminación de los HCFC y de las medidas propuestas por ejecutar para resolver las cuestiones de ejecución se aborda durante el proceso de examen de la petición del tramo del plan de gestión de eliminación de los HCFC y bajo los informes sobre proyectos con requisitos específicos de información. Los organismos mencionaron que este proceso no sólo los ayuda a encarar los retrasos manteniendo sin perder de vista las condiciones específicas al país y al proyecto, sino que también ayudan al Comité Ejecutivo a suministrar la orientación necesaria para apresurar la ejecución del proyecto. La prioridad de los organismos de ejecución y bilaterales es asegurar que la ejecución total de los planes de gestión de eliminación de los HCFC se lleva a cabo en fecha y alcanza los objetivos nacionales del consumo, asegurando la sustentabilidad de la eliminación lograda.

Recomendación

264. El Comité Ejecutivo podría tomar nota de los informes presentados por el gobierno de Alemania, el PNUD, la ONUDI y el Banco Mundial, conforme a las decisiones 84/27 y 84/42, como figura en el documento UNEP/OzL.Pro/ExCom/85/9.

[55] En proyectos donde se adoptaron agentes espumantes con pentano, no se experimentaron retrasos dado que la tecnología fue probada y adoptada en diferentes países desde la época de eliminación de CFC.

SECCIÓN V: PROYECTOS DE INVERSIÓN Y ACTIVIDADES DE FACILITACIÓN RELACIONADOS CON HFC FINANCIADAS USANDO LAS CONTRIBUCIONES ADICIONALES PROVENIENTES DE UN GRUPO 17 PARTES QUE NO ESTÁN AL AMPARO DEL ARTÍCULO 5 (DECISIÓN 84/12 b))

Antecedentes

265. En su 84ª reunión al estudiar el informe refundido sobre la marcha de las actividades del Fondo Multilateral al 31 de diciembre de 2018, el Comité Ejecutivo solicitó a la Secretaría que en la 85ª reunión presentase un informe adicional sobre los proyectos de inversión relacionados con HFC y las actividades de facilitación financiadas usando las contribuciones adicionales provenientes de un grupo de 17 Partes que no están al amparo del Artículo 5, identificando los países para los cuales se habían aprobado los proyectos y suministrando una reseña de los objetivos, el estado de ejecución, los resultados clave y las lecciones aprendidas, las cantidades de HFC eliminadas, cuando proceda, el nivel de fondos aprobados y desembolsados y las dificultades potenciales en la terminación de los proyectos y las actividades, a condición de que esa información fuese proporcionada individualmente para proyectos de inversión relacionados con HFC y sobre una base agregada para las actividades de facilitación con HFC (decisión 84/12 b)).

266. La Secretaría desarrolló un formato para facilitar la recopilación de información[56] y lo presentó a los organismos de ejecución y bilaterales en la reunión interinstitucional de coordinación.[57]

267. En respuesta a la decisión 84/12 b), la Secretaría presentó a la 85ª reunión el informe adicional sobre los proyectos de inversión y las actividades de facilitación relacionados con HFC usando el formato actualizado después de incorporar las sugerencias pertinentes hechas por los organismos.

Informe sobre los proyectos de inversión relacionados con HFC

268. Los organismos de ejecución proporcionaron informes de situación detallados sobre la ejecución de los proyectos de inversión relacionados con HFC para Argentina, Bangladesh, China, Líbano, México, y Tailandia. El Cuadro 13 da un resumen de los proyectos y el anexo IX del presente documento brinda una información más detallada.

Cuadro 13. Resumen de proyectos de inversión relacionados con HFC

País	Organismo	Productos	HFC utilizado (tm)	Alternativa usada	CO2-eq en tm	Aprobado ($EUA)	Desembolsado ($EUA)
Argentina	ONUDI	Refrigeradores domésticos y comerciales	HFC-134a (96,60 tm)	R-600a/R-290	137 993	1 840 755	1 065 380
Bangladesh	PNUD	Refrigeradores domésticos y compresores	HFC-134a (230,63 tm)	R-600a	329 372	3 131 610	3 126 415
China	PNUD	Espuma aislante para refrigeradores domésticos	Ciclopentano + HFC-245fa (250,00 tm)	Ciclopentano + HFO-1233zd (E)	256 750	1 275 000	380 000
Líbano	ONUDI	Refrigeradores domésticos y comerciales	HFC-134a/R-404A (112,58 tm)	R-600a/R-290	137 993	1 053 858	842 975
México	ONUDI	Refrigeradores	HFC-134a/R-404A	R-600a/R-290	90 793	1 018 123	41

[56] Anexo IV del documento MLF/IACM.2020/1/7

[57] Montreal, 25-27 de febrero de 2020.

País	Organismo	Productos	HFC utilizado (tm)	Alternativa usada	CO2-eq en tm	Aprobado ($EUA)	Desembolsado ($EUA)
		comerciales	(56,04 tm)				
Tailandia	Banco Mundial	Refrigeradores comerciales	HFC-134a (8,78 tm)	R-600a	12 543	183 514	0
Total			**754,64**		**965 444**	**8 502 860**	**5 414 811**

269. Se terminó un proyecto (Bangladesh) y el PNUD proporcionó un informe detallado del mismo. Si bien los cinco proyectos restantes avanzan satisfactoriamente, la situación creada por el COVID-19 puede causar algunos retrasos en su terminación.

Informe sobre las actividades de facilitación para la reducción de HFC

270. La lista de países que recibieron financiación para las actividades de facilitación para la reducción de HFC aparece en el Anexo X del presente documento. Los objetivos principales de los pedidos de financiamiento para actividades de facilitación, *entre otras cosas,* incluyeron la ayuda para la pronta ratificación de la Enmienda de Kigali; la ejecución de las actividades identificadas en el apartado 20 de la decisión XXVIII/2 dirigida a iniciar arreglos para apoyar instituciones, el examen de sistemas de otorgamiento de licencias, presentación de datos sobre el consumo y la producción de HFC, y la demostración de las actividades sin inversión, como la capacitación y divulgación de la información. El Cuadro 14 hace una reseña del estado de ejecución de los componentes clave de las actividades de facilitación que están ejecutándose actualmente.

Cuadro 14. Panorama de las actividades clave ejecutadas bajo las actividades de facilitación para la reducción de HFC

Organismo	Número de países	Ratificación de la Enmienda de Kigali (*)		Sistema de otorgamiento de licencias y cuotas		Recopilación de datos y sistema de vigilancia		Actividades de demostración sin inversión	
Organismo		**Sí**	**No**	**Sí**	**No**	**Sí**	**No**	**Sí**	**No**
PNUD	11	5	6	2	9	5	6	2	9
PNUMA	79	30	49	21	58	18	61	15	64
ONUDI	28	13	15	12	16	11	17	7	21
Banco Mundial	3	0	3	0	3	1	2	1	2
Alemania	3	1	2	1	2	3	0	0	3
Italia	4	3	1	3	1	3	1	3	1
Total	**128**	**52**	**76**	**39**	**89**	**41**	**87**	**28**	**100**

(*) La información cambiaría con el tiempo.

Panorama del progreso de la ejecución de proyecto

271. Las actividades de facilitación avanzan bien en casi todos los países. Hasta el momento, el PNUMA[58] y la ONUDI[59] han terminado las actividades de facilitación en tres países cada uno.

272. A continuación se da un resumen de las actividades informadas:

a) Ratificación de la Enmienda de Kigali: Las actividades en ejecución incluyen consultas con interesados directos; redacción de documentos jurídicos con la ayuda de un consultor

[58] Camboya, Kirguistán y Tonga.
[59] Albania, Montenegro y Viet Nam.

en algunos casos; la coordinación y la divulgación de la información a diversos interesados directos; informe de evaluación del país sobre tendencias del consumo de HFC e impacto de la Enmienda de Kigali en diversos interesados directos; evaluación de necesidades de capacitación para el sector de servicios sobre la introducción de tecnologías sin HFC; y participación en un taller regional sobre la ratificación de la Enmienda de Kigali;

b) Desarrollo y aplicación del sistema de otorgamiento de licencias y cuotas: Las actividades en ejecución incluyen el examen y/o la revisión de legislaciones y reglamentaciones para incluir disposiciones de la Enmienda de Kigali en el sistema de otorgamiento de licencias y cuotas; talleres de consulta sobre el desarrollo de dicho sistema; y consultas sobre los mecanismos para supervisar el suministro y el uso de HFC en cooperación con aduanas y otros interesados directos;

c) Ayuda para la aplicación del sistema de recopilación y supervisión de datos: Las actividades en ejecución incluyen el desarrollo del sistema de recopilación de datos para HFC; consultas de interesados directos con los importadores, comerciantes y otros interesados directos en HFC y la recopilación de datos de las mezclas con HFC; los requisitos de información y supervisión; la actualización del sistema de códigos armonizados para supervisar los HFC y las mezclas que lo contienen; adquisición de equipos para la identificación de refrigerantes con HFC;

d) Actualización de otras actividades como demostración y capacitación: Las actividades en ejecución incluyen el programa de capacitación para las alternativas con bajo potencial de calentamiento atmosférico, incluyendo los refrigerantes inflamables, con ayuda de expertos técnicos; programas de divulgación para sensibilización del público sobre la Enmienda de Kigali, los HFC y las alternativas sin HFC utilizadas en diversos usos, la adopción de alternativas con bajo potencial de calentamiento atmosférico; controles reglamentarios supervisión para el sector de fabricación y/o servicios de equipos de refrigeración, el gobierno y las instituciones técnicas y el público; e impuestos diferenciados basados en el potencial de calentamiento atmosférico de refrigerantes; y

e) Actividades relacionadas con la eficiencia energética: Las actividades en ejecución incluyen la coordinación con las instituciones de eficiencia energética para incluir las disposiciones de la Enmienda de Kigali mientras se aplican las medidas de eficiencia energética (por ej., normas de eficiencia energética mínima, programas de etiquetado, mejora de eficiencia energética para equipos de refrigeración y climatización, participación en el desarrollo de planes de refrigeración para promover tecnologías ecoenergéticas con bajo potencial de calentamiento atmosférico, aportes durante el desarrollo de las normas regionales sobre adopción de tecnologías de eficiencia energética);[60] fomento de participación de las partes interesadas en ecoenergía en reuniones relacionadas con la Enmienda de Kigali; promover la eficiencia energética referente al enfriamiento en medidas sectoriales de promoción de eficiencia energética; capacitación en tecnologías ecoenergéticas de equipos de refrigeración y climatización; demostración de ahorros a los usuarios con la adopción de equipos ecoenergéticos y diseño de equipos de refrigeración y climatización ecoenergéticos y medidas para aumentar la adopción de las tecnologías ecoenergéticas.

[60] Hay numerosas actividades nuevas sobre la mejora de la eficiencia energética que se ejecutan en los países; por lo tanto, la información sobre los tipos de proyecto es ilustrativa y no exhaustiva.

Resultados clave y las lecciones aprendidas

273. Durante la ejecución de actividades de facilitación, los países adquirieron experiencia en el proceso de ratificación de la Enmienda de Kigali y la ejecución de actividades de facilitación para la reducción de HFC, según lo que se resume a continuación:

a) El informe de evaluación del país para comprender las tendencias del consumo de HFC ayuda a los interesados directos a identificar las medidas que se tomarán y sus responsabilidades en la aplicación de las mismas; se prepararon y difundieron a todas las partes interesadas implicadas directrices sobre metodologías de recopilación de datos y cuestionarios de encuesta estructurados/plantillas de informes; y se asimilaron las interfaces con actividades de planes existentes y planeados de gestión de eliminación de HCFC mediante el análisis de los niveles de consumo de los HCFC y los HFC, y consultas con las partes interesadas de la industria;

b) El fortalecimiento del sistema de otorgamiento de licencias y cuotas para incluir los HFC y mezclas con HFC es medida prioritaria para supervisar e informar, que requiere consultas detalladas con las instituciones pertinentes; la ejecución de sistemas en línea es apreciado por los oficiales de aduanas y los importadores, pues ahorra tiempo, costos y esfuerzos; la creación de capacidad y la capacitación adicionales de los funcionarios que manejan la recopilación de datos y que los supervisan es también una medida prioritaria; y la capacitación de oficiales de aduana y responsables de la aplicación de las reglamentaciones y el fortalecimiento de puntos fronterizos de control con equipos de identificación es esencial para impedir el comercio ilícito de los HFC;

c) Seguimiento continuo por parte de la Dependencia Nacional del Ozono con las autoridades responsables de la formulación, finalización y aprobación de las políticas y las reglamentaciones sobre HFC;

d) Esfuerzos significativos necesarios para la aprobación de las reglamentaciones para adoptar los refrigerantes con bajo potencial de calentamiento atmosférico, especialmente referentes a los aspectos de seguridad; creación de capacidad, inclusive la capacitación y la divulgación de la información técnica, es esencial para la adopción sostenible de los refrigerantes con bajo potencial de calentamiento atmosférico que son inflamables, tóxicos y funcionan bajo alta presión; y la creación de capacidad en la capacitación y las instituciones técnicas, la acreditación de los técnicos de servicio para manejar los refrigerantes con bajo potencial de calentamiento atmosférico y la formación para programas de técnicos son esenciales;

e) La introducción de normas de eficiencia energética mínima y un sistema progresivo de impuesto/aranceles basado en eficiencia energética de equipos de refrigeración y climatización que no utilizan HFC crean incentivos para que la industria se dirija hacia equipos con bajo potencial de calentamiento atmosférico y eficiencia energética; y la importación de equipos de refrigeración y climatización de segunda mano que tienen niveles más bajos de eficiencia energética afecta la aplicación de las medidas destinadas a mejorar la eficiencia energética;

f) Identificación de la pericia local para emprender actividades que requieren la ayuda continua por parte de la Dependencia Nacional del Ozono y para la creación de capacidad; y

g) Actividades de sensibilización y divulgación a través de consultas y de comunicación frecuentes son esenciales para asegurar que las partes interesadas comprenden las implicaciones de la Enmienda de Kigali.

Posibles dificultades

274. Hay algunos desafíos específicos a los proyectos (por ej., los cambios en la estructura institucional del gobierno resultan en retrasos de la aprobación y la ejecución de ciertos componentes del proyecto, la situación política que afecta a la ejecución) que pueden retrasar ciertos proyectos; éstos se tratan por separado en los informes sobre la marcha de las actividades que se presentarían a la 86ª reunión y se incluyen en los informes finales sobre las actividades de facilitación.

Fondos aprobados y desembolsados

275. En marzo de 2020, los fondos totales aprobados para los proyectos de inversión con HFC y las actividades de facilitación bajo contribuciones adicionales provenientes de un grupo de 17 países donantes ascendieron a $EUA 23 687 811, con un desembolso total de $EUA 13 114 664.

Observaciones de la Secretaría

276. La Secretaría tomó nota de que están progresando los proyectos de inversión y las actividades de facilitación relacionados con HFC para la reducción de esas sustancias; se ha terminado un proyecto de inversión relacionado con HFC y las actividades de facilitación para seis países. Es probable que la situación creada por el COVID-19 afecte la terminación en fecha de algunos de estos proyectos.

Recomendación

277. El Comité Ejecutivo podría tomar nota de la información sobre los proyectos de inversión relacionados con HFC y las actividades de facilitación, presentados por los organismos de ejecución y bilaterales, conforme a la decisión 84/12 b), que figuran en el documento UNEP/OzL.Pro/ExCom/85/9.

Anexo I

PROYECTOS CLASIFICADOS COMO CON "CIERTO PROGRESO" Y QUE SE RECOMIENDAN PARA SUPERVISIÓN CONTINUA

País	**Código**	**Título del proyecto**	**Organismo**
China	CPR/ARS/56/INV/473	Plan sectorial para eliminar el consumo de los CFC en el sector de inhaladores de dosis medida	ONUDI
Egipto	EGY/ARS/50/INV/92	Eliminación del consumo de CFC en la fabricación de aerosoles con inhaladores de dosis medida	ONUDI
Iraq	IRQ/REF/57/INV/07	Reemplazo del refrigerante CFC-12 por el isobutano y el agente de espumación CFC-11 por ciclopentano en la fabricación de refrigeradores domésticos y de congeladores horizontales en Light Industries Company	ONUDI
San Vicente y las Granadinas	STV/PHA/77/TAS/24	Informe de verificación sobre la ejecución del plan de gestión de eliminación de los HCFC	PNUMA
República Árabe Siria	SYR/REF/62/INV/103	Eliminación de HCFC-22 y HCFC-141b en la fabricación de equipos de sistemas unitarios de aire acondicionado y paneles de aislamiento de poliuretano rígido en Al Hafez Group	ONUDI

Anexo II

PROYECTOS PARA LOS SE PIDEN INFORMES DE SITUACIÓN ADICIONALES

País	Código	Título del proyecto	Organismo	Recomendaciones
Argelia	ALG/SEV/73/INS/81	Prórroga del proyecto de fortalecimiento institucional (fase VI: 12/2014-11/2016)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos
Botswana	BOT/SEV/76/INS/19	Prórroga del proyecto de fortalecimiento institucional (fase V: 6/2016-7/2018)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y firma del Acuerdo de financiamiento a escala reducida (acuerdo de financiación a pequeña escala)
República Centroafricana	CAF/SEV/68/INS/23	Prórroga del proyecto de fortalecimiento institucional (fase VI: 1/2013-12/2014)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos, firma del Acuerdo de financiación a pequeña escala, y progreso en la ejecución
República Democrática del Congo	DRC/PHA/79/PRP/42	Preparación del plan de gestión de eliminación de los HCFC (etapa II)	PNUD	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y la situación de la presentación de la etapa II del plan de gestión de eliminación de los HCFC
República Democrática del Congo	DRC/PHA/79/PRP/43	Preparación del plan de gestión de eliminación de los HCFC (etapa II)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y sobre la presentación de la etapa II del plan de gestión de eliminación de los HCFC
Dominica	DMI/SEV/80/INS/23	Ayuda de emergencia adicional para fortalecimiento institucional	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y firma del Acuerdo de financiación a pequeña escala
Dominica	DMI/SEV/80/TAS/01+	Actividades de facilitación para la reducción de HFC	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y el progreso en la ejecución

País	Código	Título del proyecto	Organismo	Recomendaciones
Dominica	DMI/SEV/81/INS/24	Prórroga del proyecto de fortalecimiento institucional (fase VII: 6/2018-5/2020)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y la firma del Acuerdo de financiación a pequeña escala
Haití	HAI/PHA/76/TAS/21	Plan de gestión de eliminación de los HCFC (etapa I, segundo tramo)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre el progreso de la ejecución
Haití	HAI/SEV/75/INS/20	Prórroga del proyecto de fortalecimiento institucional (fase IV: 11/2015-10/2017)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre el progreso de la ejecución
Líbano	LEB/DES/73/DEM/83	Proyecto experimental de demostración sobre gestión de desechos y destrucción de SAO	ONUDI	Instar a la ONUDI que presente el informe de terminación de proyecto conforme a la decisión 82/15 c)
Libia	LIB/FOA/82/PRP/41	Preparación para actividades de inversión para eliminar los HCFC (etapa II) (sector de espumas)	ONUDI	Pedir un informe de situación para la 86ª reunión sobre el progreso de la preparación de la etapa II del plan de gestión de eliminación de los HCFC
Libia	LIB/PHA/82/PRP/43	Preparación del plan de gestión de eliminación de los HCFC (etapa II)	ONUDI	Pedir un informe de situación para la 86ª reunión sobre el progreso de la preparación de la etapa II del plan de gestión de eliminación de los HCFC
Perú	PER/SEV/80/INS/56	Renovación del proyecto de fortalecimiento institucional (fase V: 1/2018-12/2019)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y el progreso de la ejecución
Qatar	QAT/PHA/65/TAS/17	Plan de gestión de eliminación de los HCFC (etapa I, primer tramo) (sector de servicios de refrigeración)	PNUMA	Pedir una actualización para la 86ª reunión sobre la situación de la devolución de saldos
Qatar	QAT/PHA/73/PRP/20	Preparación del plan de gestión de eliminación de los HCFC (etapa II)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y sobre la preparación de la etapa II
Qatar	QAT/PHA/73/PRP/21	Preparación del plan de gestión de eliminación de los HCFC (etapa II)	ONUDI	Pedir un informe de situación para la 86ª reunión sobre el progreso de la preparación y la

País	Código	Título del proyecto	Organismo	Recomendaciones
				presentación de la etapa II
Arabia Saudita	SAU/FOA/62/INV/13	Eliminación del HCFC-22 y del HCFC-142b provenientes de la fabricación de paneles de poliestireno extruido en Al-Watania Plastics	ONUDI	Pedir un informe de situación para la 86ª reunión sobre la conclusión de la subasta
Arabia Saudita	SAU/SEV/67/INS/15	Prórroga del proyecto de fortalecimiento institucional (fase II: 7/2012-6/2014)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y la firma del Acuerdo de financiación a pequeña escala
Sudán del Sur	SSD/PHA/77/TAS/04	Plan de gestión de eliminación de los HCFC (etapa I, primer tramo)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y firma del Acuerdo de financiación a pequeña escala
Sudán del Sur	SSD/SEV/76/INS/03	Proyecto del fortalecimiento institucional (fase I: 5/2016-4/2018)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y firma del Acuerdo de financiación a pequeña escala
Suriname	SUR/PHA/81/TAS/26	Plan de gestión de eliminación de los HCFC (etapa I, tercer tramo)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre los desembolsos de los fondos y firma del Acuerdo de financiación a pequeña escala
República Árabe Siria	SYR/FOA/61/PRP/102	Preparación para actividades de inversión para eliminar los HCFC (sector de espumas)	ONUDI	Pedir un informe de situación para la 86ª reunión sobre la preparación del proyecto y la fecha propuesta para la presentación del plan de gestión de eliminación de los HCFC
República Árabe Siria	SYR/PHA/55/PRP/97	Preparación del plan de gestión de eliminación de los HCFC	ONUDI	Pedir un informe de situación para la 86ª reunión sobre la preparación del proyecto y la fecha propuesta para la presentación del plan de gestión de eliminación de los HCFC
República Árabe Siria	SYR/SEV/73/INS/104	Prórroga del fortalecimiento institucional (fase V: 1/2015-12/2016)	ONUDI	Pedir un informe de situación para la 86ª reunión sobre el progreso de la ejecución y el nivel

País	Código	Título del proyecto	Organismo	Recomendaciones
				de desembolso de los fondos
Yemen	YEM/SEV/73/INS/43	Prórroga del proyecto de fortalecimiento institucional (fase VIII: 1/2015-12/2016)	PNUMA	Pedir un informe de situación para la 86ª reunión sobre el progreso de la ejecución

FINAL REPORT

PROJECT TITLE: Demonstration project for the introduction of trans-critical CO_2 refrigeration technology for supermarkets (Argentina and Tunisia)

PROJECT NUMBER: GLO/REF/76/DEM/335

Table of Contents

BACKGROUND

On its 76th Meeting, the Executive Committee decided:

(a) To approve the demonstration project in Argentina and Tunisia for the introduction of trans-critical CO_2 refrigeration technology for supermarkets, in the amount of US $846,300, plus agency support costs of US $59,241 for UNIDO, in line with decision 72/40; and

(b) To request the Governments of Argentina and Tunisia, and UNIDO, to complete the projects within 30 months of its approval, and to submit a comprehensive final report soon after project completion. **(Decision 76/27)**

The subproject designed for Tunisia was not implemented due to lack of interest. The project funds approved for Tunisia amounts to **USD 319,131**. The remaining funds available will be returned as per decision.

The project funds approved for Argentina amounts to **USD 527,169** plus agency support cost.

This document is prepared for the information of the members of the Executive Committee and takes account of the background, the implementation process and the results achieved as well as the experience gathered through the subject demonstration project.

The supermarket sector in Argentina

Between 2010 to 2016, the five largest Argentine supermarket chains had grown by 63%. The total estimated points of sale were of 8,672 in 2010[1], reaching around 13,000 in 2016[2] and a future growth[3] had been expected.

The growth was boosted by the opening of proximity small self-service markets by the big players of the sector.

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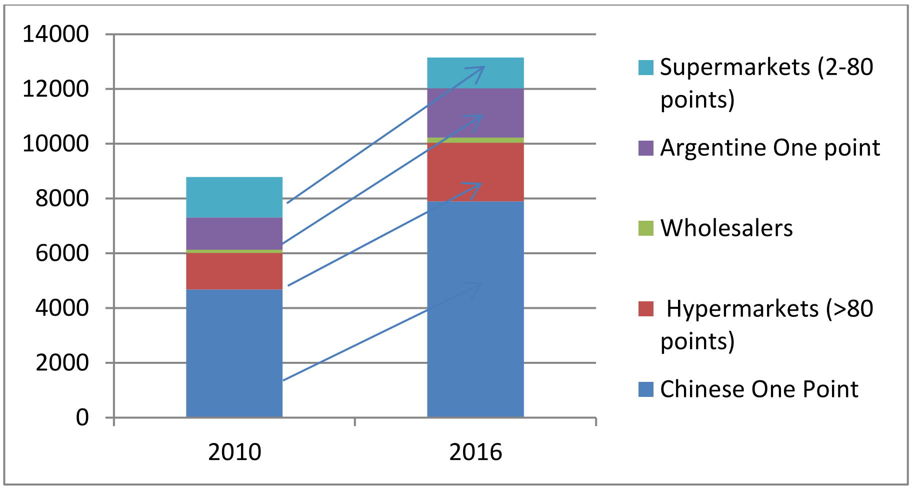
[1] Informe Relevamiento sobre Supermercados en Argentina. 2011. Federación Argentina de Empleados de Comercio y Servicios.
[2] Informe de Actualización: Evolución del Sector Supermercadista. 2016 Federación Argentina de Empleados de Comercio y Servicios.
[3] Encuesta de Supermercados. Informes Técnicos vol. 1 nº 65, Comercio vol. 1 nº 9. INDEC, Febrero de 2017.



Refrigerants used in the food chain

Synthetic refrigerants have been typically used in retail food refrigeration. At the beginning CFCs were used; later they were replaced by HCFCs.

HCFC-22 has been the most popular refrigerant over the past decades for retail food refrigeration systems and it is still widely used in the supermarket sector. Therefore, consumption of HCFC-22 in this sector is still very relevant in Argentina; it is estimated at around 750-800 MT. Leakage rates are very high ranging from 35% for big and medium size installations to above 70% for small installations. This is caused by inadequate maintenance and sometimes bad quality installations.

When HCFCs phase-out gathered momentum, it became a priority to replace HCFC refrigerants used in the supermarkets. As a result, HFCs have started replacing HCFCs. Natural refrigerant technologies had not been commonly used in this sector in Argentina.

The Kigali amendment is imposing limitations on the use of HFCs refrigerants with high GWP. As a result, the refrigerant manufacturing chemical industry as well as the end users of their products have been compelled to find new low GWP alternatives**.** In view of the growing concern about climate change, new technologies with very low GWP alternatives have been developed, matured and put into the market. These are spreading fast in many A2[4] countries. Among these low GWP refrigerants CO_2 is gaining popularity.

Environmental impact of supermarket systems

The environmental impact of the supermarket sector is caused by its

i. High energy consumption, and
ii. Significant consumption of ozone depleting refrigerants, and

[4] Article 2 countries under Montreal Protocol

iii. Increased use of high GWP refrigerants.

Among the commercial outlets, supermarkets have the highest specific energy consumption, typically in the range of 400-600 kWh/m^2 annually. The largest energy consumers in a supermarket are the refrigeration equipment (30%-50%), which is followed by ventilation, heating and cooling of the store and its lighting.

The generation of electricity used by the supermarkets is associated with CO_2 emission in various degree depending on the energy mix. The effect of this type of CO_2 emission is called indirect impact.

THE DEMONSTRATION PROJECT

Objective

The primary objective of the project was to evaluate the performance and energy efficiency of trans-critical CO_2 technology in a real case scenario: a carefully selected representative supermarket located in moderately warm climatic conditions

The other objective was to identify incentives and barriers related to an upgraded to trans-critical CO_2 technology, by phasing out HCFCs and leapfrogging the HFC conversion step.

When successful, the project is expected to be replicated in countries of the region thereby promoting the use of low-GWP refrigerants in the sector.

Project Budget

The project was approved by the Executive Committee of the MLF in May 2016 with a budget of U$527,169, with UNIDO as implementing agency and an implementing period of 30 months.

The details of the budget are shown in the table below:

TABLE 1. PROJECT COST

Item	USD
Refrigeration plant	
Transcritical plant	117,497
Condenser / gas cooler	19,299
Subcooler (Option 2 R-290 refrigerant)	41,060
8 x evaporators	12,675
Refrigeration installation and materials	115,632
Electrical installation	54,828
Electrical panels and electronics	28,875

Total refrigeration system	**389,866**
Food display cabinets	
8 fresh food cabinets with doors and led model	66,754
5 frozen food islands	35,722
2 semi-cabinets for frozen food	25,630
6 Fresh food cabinets	34,197
Less cost sharing	-60,000
Total cabinets	**102,303**
Subtotal equipment cost (incl. installation)	**492,169**
Engineering and transport	
Engineering	10,000
Transportation, 3%	11,451
Cost sharing	-6,451
Total services	**15,000**
Total cost of equipment and services	**507,169**
Demonstration project for 20 participants	20,000
TOTAL COST OF SUB-PROJECT 1: ARGENTINA	**527,169**

Methodology used in the project

The main barrier for introducing low GWP alternatives, especially CO_2 in the supermarket sector in Article 5 countries is the lack of knowledge and experience as well as the limited availability of equipment components and know-how related to the new technology as well as the still high initial cost implication.

For these reasons, even when the end users decide to phase out HCFCs in their installations, the likelihood that they would opt for an HFC well-known technology is rather high. Furthermore, such conversions require less modifications and thus it will be the less costly solution.

At the time the project was formulated, there was only one supermarket in Argentina using a transcritical CO_2 centralized refrigeration system. This is operated in the south of Argentina (Patagonia region) - a location with a very cold climate condition.

Therefore, Argentina decided to implement a project to address the issues and barriers related to as well as the feasibility of CO_2 technology in warmer climatic conditions where the CO_2 transcritical technology had not yet been used.

Determination of baseline data

In the past, the electricity consumption of the refrigeration equipment was neither measured, nor monitored. Thus, in order to quantify the impact of the project on the energy consumption of the technological equipment La Anonima separated the electrical supply of the refrigeration systems from the air conditioning and lighting. They also installed separate power meters with data loggers.

The electricity consumption of refrigeration equipment had been meticulously measured during the first year of the project, when only the bidding, manufacturing and delivery of equipment took place. The data collected in the pre-startup year was used to determine the baseline electrical consumption level.

Temperatures, as well as, general climate condition information were taken for all the measuring period from the nearest meteorological station.

The consumption of refrigerants was not strictly monitored by the supermarket. After approval of the project the supermarket started strict monitoring of the actual use of refrigerants and the causes of leaks.

Post project data

During the one-year post conversion period the measurements of electricity consumption of the refrigeration equipment as well as refrigerant continued, and the data were compiled.

Thus, we were able to compare the pre- and post-conversion energy consumption based on real data.

Sustainability and barriers

To identify potential barriers, the long-term sustainability, as well as the impact of this demonstration project, we assessed various aspects, such as:

- Technical viability,
- Investment and relevant operating costs,
- Environmental benefits,
- Impact of energy consumption
- Availability of components,
- Installation and servicing skill requirements,
- Other possible advantages and disadvantages.

These factors are also important to assess the opportunities for replication at country level, regionally and/or globally.

During the project we organized several meetings with the supermarket's maintenance management and staff, as well as with the vendor of the equipment and technology, in order to investigate and collect cost data, maintenance requirements and other financial and technical matters.

Location and Baseline Situation

OPROZ contacted several nationally owned supermarket chains to select the supermarket ready and capable to implement the demonstration project in a timely manner. In order to enhance the demonstration value of the project it was important to find a supermarket located in one of the warmest locations of the country, which could serve as a model for other supermarkets in moderately hot A5 countries. It was also important to find a company with appropriate financial means and technical expertise required to complement the resources and technical inputs granted through the project.

The selection was narrowed down to a supermarket in the town of Lincoln, Buenos Aires Province. It is part of a large Argentine supermarket chain, which belongs to Sociedad Anónima Importadora y Exportadora de la Patagonia, in short La Anónima. This supermarket is located in a moderately warm climatic zone (GPS coordinates: Latitude: -34.8637778 (34º 51' 49.6" S), Longitude: -61.528350 (61º 31' 42.062" W). The chain had been in healthy financial situation, possess highly trained technical and maintenance staff and has been eager to participate in the demonstration project. So, it had complied with all criteria of the demonstration project.

Figure 1 La Anonima, Lincoln Branch

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TABLE 2. AREA OF THE SUPERMARKET

Area	m²
Total sales area	1,258
a. Cold food cabinets	49
b. Frozen food cabinets	6
c. Frozen food aisles	16
Total storage area	449
a. Cold storage	108
b. Walk-in freezers	14

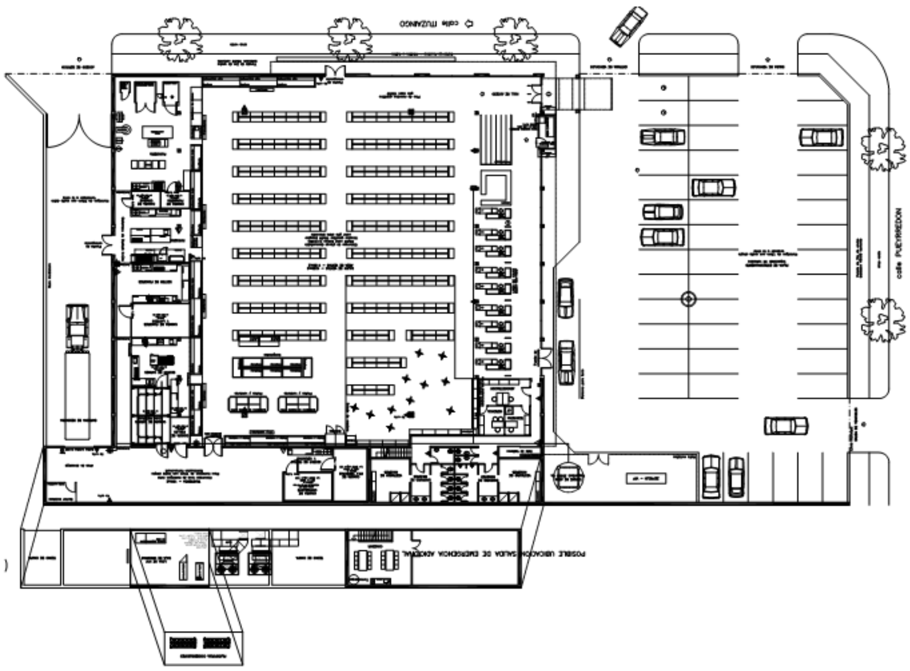

Figure 2 Layout of the LaAnonima Supermarket in Lincoln

Figure 2 depicts the layout of the supermarket with the location of the refrigerated and frozen food sections and the roof with the machine room.

In the baseline, the supermarket had two central refrigeration systems, one for low and another for medium temperature.

Figure 3 Baseline machine room

The refrigerant used in the central systems was **HCFC-22**.

Furthermore, there were a number of self-contained freezer units (islands and upright reach-in cabinets) working with **HFC-404A**.

Figure 4 Baseline Cabinets and Freezer Aisles

Figure 5 Baseline Dairy Cold room

Selection of CO_2 commercial refrigeration technology

In the last 15 years, as environmental considerations gradually came to the forefront, CO_2 technology was "reinvented" as an environmentally friendly solution in commercial refrigeration, based on the low Global Warming Potential (GWP) of CO_2 resulting in lower Total Equivalent Warming Impact (TEWI) compared with HFC refrigerants. Today, in A2 countries there is no difficulty in sourcing all the necessary equipment for CO_2 technology. However, in A5 countries this technology is still new and rarely used in areas of warm climate.

Booster systems have been the preferred option due to their relative simplicity and lower initial cost compared to cascade systems. At the time of the preparation of the project there were already some

4,000 systems, mainly in supermarkets, which use the traditional booster system shown below. According to Danfoss there is a 100% market growth on year on year basis for these systems and it seems that in moderate climate countries booster system is now the market standard. The trend is now to move the market towards warmer regions.

However, at higher ambient temperatures the inherent properties of R-744 lead to loss of efficiency and elevated equipment costs. The efficiency of systems with CO_2 depends more on the application and the climate conditions prevailing on the site of installation than in the case of other refrigerants. For all refrigerants there is a decline in system efficiency with increasing condensing temperatures, and CO_2 is among the refrigerants with the steepest drop. The good thermo-physical properties of CO_2 can compensate to some extent, but there is a limit.

The problem with transcritical CO_2 systems in warm climate is not that they will not work, but more that there is a significant loss of capacity and efficiency.

In cold climates like the Nordic climate we see 10% lower energy consumption, but going to warm climates like Asia, South Europe, Southern part of North America, Latin America and Africa is a challenge for CO_2 systems. The extra cost of compressors and loss of efficiency could make the technology less attractive.

The traditional booster system is illustrated on Figure 6.

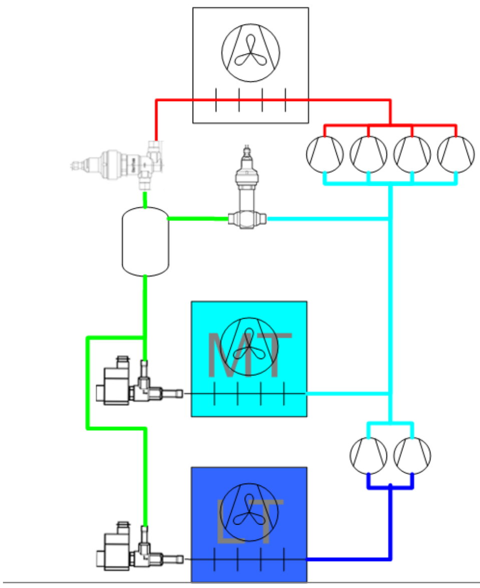

Figure 6 Traditional Booster System

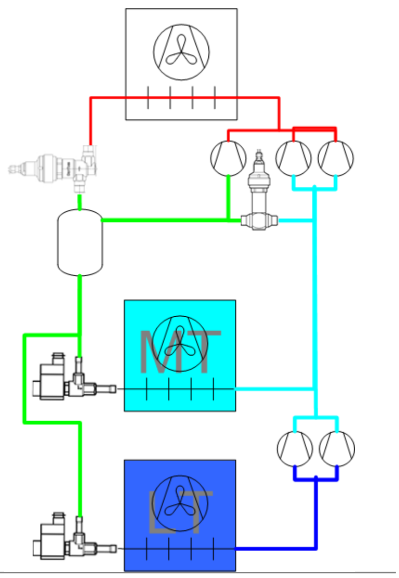

Figure 7 Booster System with Parallel Compression

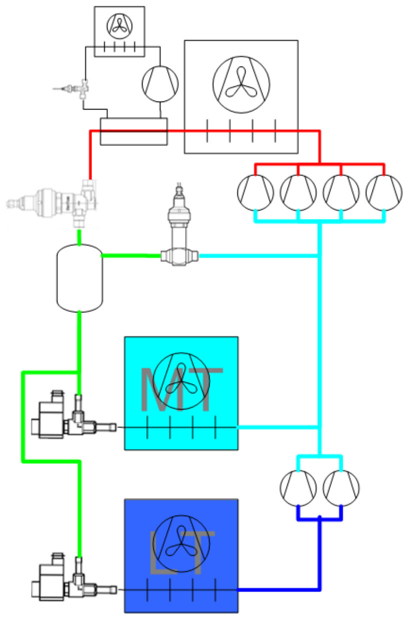

Figure 8 Booster System with Parallel Compression and Subcooling

Figure 7. shows that the traditional booster system is complemented with a compressor, which compresses the flash gas from the refrigerant valve that regulates the pressure in the liquid receiver (flash tank) and associated pipe work. The advantages of this solution are:

a. Solution is mature and well proven,
b. 5-10% energy improvement in warm climates,
c. Approximately 25% saving on installed capacity,
d. Can be combined with other features to enhance the system.

The system shown on Figure 8 includes an additional heat exchanger – so called subcooler. The advantages of this solution are:

a. Solution is ready
b. 5-10% energy improvement in warm climates
c. Up to 50% saving on compressor capacity, but the capacity is needed on the auxiliary cooling unit.

In warm climates, when the system works in transcritical cycle the amount of flash gas inside the liquid receiver increases.

In a transcritical system the receiver pressure is controlled by expanding the vapor released through connection of a by-pass Flash Valve to the medium temperature suction header.

The parallel compressor in the system the result is a better performance due to a reduction in the compression work between the intermediate pressure in the receiver and the common discharge pressure.

For example, under external temperature of 40 ºC, the system develops increased amount of flash gas. Medium temperature compressors will work with a COP of 1.34 and the parallel compressor will have a COP=2. Without parallel compressor all the flash gas will pass through the medium temperature compressors.

Other component added to the system to save energy is an external subcooler installed before the transcritical valve. It is a plate heat exchanger, which works with a dedicated chiller. This subcooler reduces the gas's enthalpy and reduces the amount of flash gas.

Figure 9 shows the actually installed system and provides additional explanations.

With the aim of increasing energy efficiency during the warm periods of the year when there are excessive room temperatures in the supermarket, a Subcooler was installed.

UNIDO and the counterpart decided to reduce the climate impact of the new system by using only natural low GWP refrigerants. We succeeded to convince the supplier to design a subcooler with a refrigeration system using R-290 refrigerant. R-290 is refrigerant grade propane, a natural refrigerant widely used in a wide range of refrigeration and air conditioning applications with smaller charge size. The use of R-290 in various applications is increasing due to its low environmental impact and excellent thermodynamic performance. It is non-toxic with zero ODP (Ozone Depletion Potential) and very low GWP (Global Warming Potential).

However, R-290 is a flammable refrigerant so it is vital to take appropriate safety measures at the installation site. R-290 may react violently with oxidants, air, oxidizers. It was necessary to study carefully the national safety rules and designate a suitable outside location for the machine. In view of the charge size. It is important to demarcate the area around the subcooler, where heat, sparks, open flames, hot surfaces, and no smoking is allowed. In our case the sub-cooler was installed on the roof where good natural ventilation is prevailing, so there was no need to install special sensors

The subcooler includes an inertia module with CO_2 - Glycol plate heat exchanger.

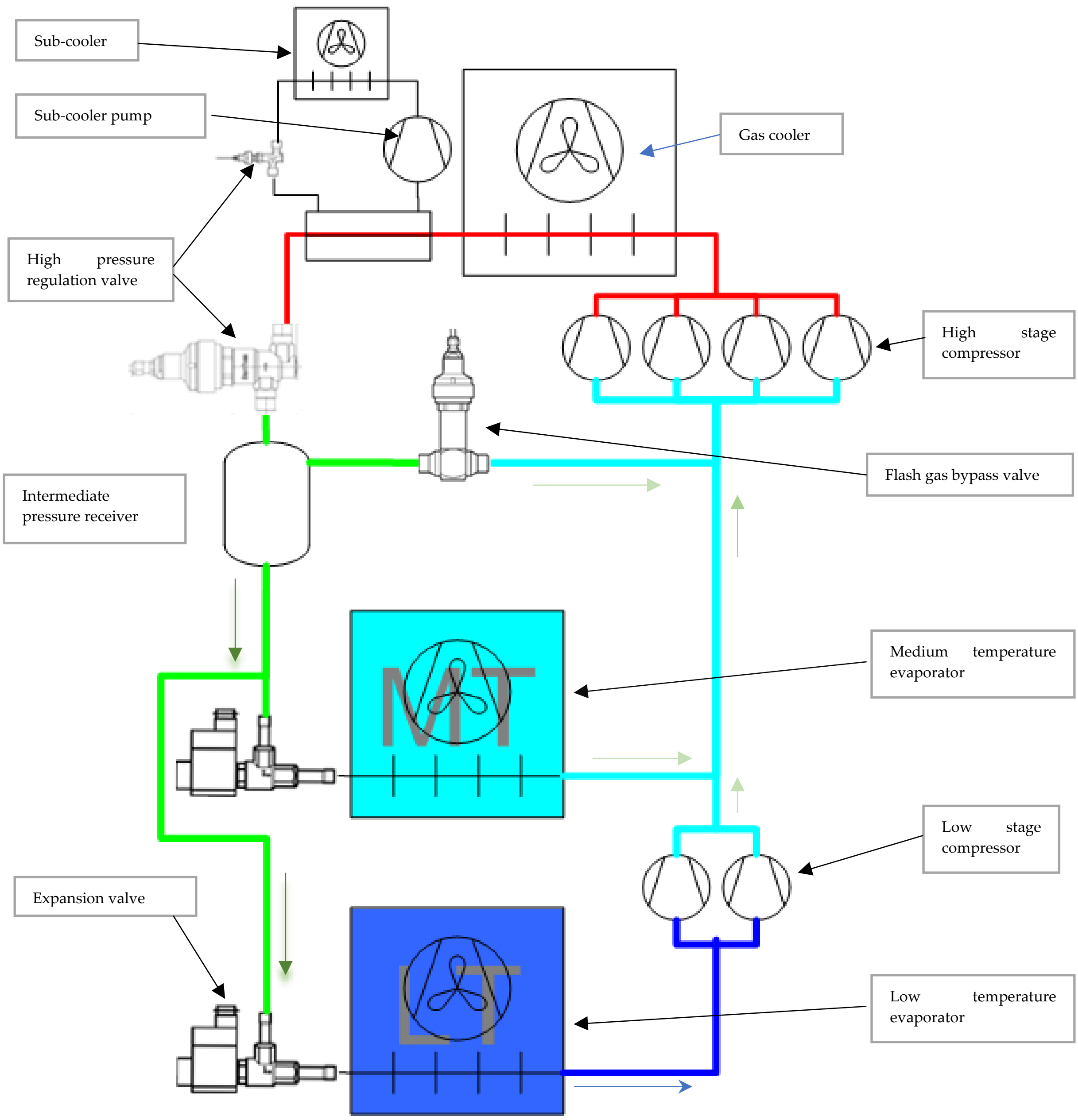

Figure 9 Booster System with Parallel Compression and Subcooling

The latest development is the so-called Ejector Compression System. At the time of the development of the project, this technology had been still under development and had not yet come out on the market.

Further energy savings could have been be achieved by utilization of waste heat developed in the refrigeration system. Such integrated systems combining the energy requirements of cooling, heating and air-conditioning are extremely attractive under cool or moderate climate condition but could bring benefits also in warmer countries e.g. to produce hot water. The applicability is to be evaluated based on the cost-benefit ratio. This combination was not considered in the subject demonstration project.

Thus, after thorough review of the available technological options in 2015 suitable for supermarkets located in warm climate conditions, it was decided to introduce a transcritical CO_2 booster system with parallel compression and subcooling. In order to use natural refrigerants for all the system it was decided to incorporate a R290 subcooler.

PROJECT IMPLEMENTATION

Timeframe

After the approval of the project in May 2016 the implementation was organized by OPROZ and UNIDO in close cooperation with the beneficiary company.

The Terms of Reference was prepared, and the bidding was initiated by the end of 2016. After the contract award, the equipment was manufactured in Argentina by EPTA and in Italy by EPTA's mother company and delivered to the site in 2017. The installation was completed in December 2017. The supermarket has been operated with the new technology as of January 2018 and the monitoring of energy consumption was undertaken throughout all the year of 2018.

Thus, the actual implementation took about 1.5 years, the remaining time of the project duration was spent to study and monitor the post-conversion situation and to assess the project performance.

According to the Project Document the duration of the physical implementation (bidding, purchase, delivery of equipment, its installation and start up) of the project was projected for 2 years.

To gain a true picture of the long-term reliability of operation, maintenance requirement, leakage rate and also of the energy efficiency the originally planned 6-month project evaluation was extended to 12 months. It was necessary, because the energy consumption is fluctuating during the year depending, inter alia, on the climate/temperature fconditions. Thus, it was decided to measure the energy consumption for an entire year prior conversion and also an entire year after conversion and compare the results. Thus, the project was not delayed, but more information has been obtained than expected.

Installation and start-up of the new equipment

The CO_2 transcritical system design was developed in Argentina by EPTA with the assistance from their design headquarters in Italy and UK following UNIDO and OPROZ national and international consultants' technical requirements.

A critical point was the design, calculation and manufacturing of the R290 subcooler. This work was undertaken by the equipment manufacturer. The refrigeration system was built by EPTA using a subcooler of an Italian manufacturer. All piping calculations were adjusted locally

The conversion did not affect the layout of the supermarket.

The arrangement, number, configuration and temperature set points of the new display cases, cold rooms and walk-in coolers are nearly identical to the baseline too.

The stand-alone R404A units of the baseline installation were replaced and the new ones were integrated into the CO_2 centralized system.

The refrigeration capacity of the medium temperature circuit is 68,79 kW and the same of the low-temperature side 9,53 kW. This is smaller than in the baseline: 72,09 kW for the HCFC-22 positive temperature cabinets and cold room, and 10,05 kW for the HFC-404A low-temperature cabinets and cold rooms.

In order to supply the refrigeration needs of all supermarket's refrigeration equipment a multi compressor refrigeration central has been installed. A parallel compressor was incorporated into the refrigeration plant and mounted on the refrigeration plant's frame.

Figure 10 The CO_2 Transcritical Refrigeration Machinery

Figure 11 Walk-in Vegetable Cooler and its CO_2 Evaporator

The installation`s condensation is achieved by using a Condenser/Gas Cooler designed to withstand a pressure of 120 bar pressure. To avoid accidents the installation is protected by safety pressure valves, which release the refrigerant pressure in the event of exceeding the said 120 bar.

In a CO_2 transcritical installation, it is necessary to use a correctly dimensioned Condenser/Gas Cooler to ensure that the heat dissipation requirements of the discharge of the compressors are met even in extreme heat conditions.

The cold rooms remained unchanged; however, their evaporators had to be replaced. All evaporators for the positive temperature cold rooms, the working rooms and the negative temperature cold rooms are compact and equipped with integrated ventilators and electronic expansion valves.

Figure 12 New CO_2 Freezer Cabinets and Aisles

With the aim of increasing the energy efficiency during the warm periods of the year, a R290 subcooler was installed. The subcooler is a R290 (Propane) chiller and propilenglycol is the recirculated fluid. The R290 charge size (1,7 kilograms) is small and the device is located in the open air. Anyway, it is important to demarcate the area around the subcooler where heat, sparks, open flames, hot surfaces, and smoking are not allowed.

The application of CO_2 in the loop required the change of the pipes to harmonize the system to the lower charge and also to withstand the very high operating pressures.

A system for continuous display of the refrigeration parameters in both the cold rooms and display cabinets was installed. This display system allows easy observation of the working parameters on a screen incorporated into the electronics module.

Other important safety devices are the leak detectors and alarms installed in the cold rooms. In the case of excessive refrigerant gas (R-744) leak this detector closes the electronic valves of the CO_2 supply side of the circuit to avoid suffocation hazard through build-up of CO_2 concentration.

During the implementation of the conversion process the smooth operation of the supermarket was maintained, thus the operation of the baseline machinery had been in operation until the new took over their role. The old machinery was dismantled only after successful start-up and trial runs of the new system.

Figure 13 CO2 Leak Detector

Figure 14 Display of the Electronic Control System

LESSONS LEARNT

The project was approved for the introduction of transcritical CO_2 system to replace the medium and low temperature refrigeration system of a supermarket working with HCFC-22 and HFC-404A refrigerant, respectively. No funds were approved to convert a similar supermarket to HFC (R-404A or R-134a) refrigerants. Thus, we could only compare the performance of base-line pre-project and the post-project scenarios (transcritical CO_2 equipment).

Equipment related issues

1. Since HCFC-22 is being phased out, the most important competitor of transcritical CO_2 equipment in Latin America is HFC-404A. In view of lack of direct information on the cost of conversion to HFC of a similar supermarket, we estimated the difference between the investment cost of the traditional HFC 404A and the transcritical system using indirect investment cost information collected from the industry and the technical literature.

   The initial cost of a CO_2 transcritical system used to be substantially higher than a conventional HFC 404A system. A study prepared for the US Department of Energy[5] in 2015 stated: "Given the nascence of transcritical CO_2 technology in the US market, these systems currently have an upfront cost that is 40-50% higher than that of conventional systems at the time of this study". Lately the price difference has been decreasing due to the standardization of several components. Today, according the information received from a large equipment manufacturer the price of an HFC-404A

5

installation is about 20% lower the equivalent CO_2 one in case of a direct cooling system and around 10-13% lower in case of an HFC/glycol system in the Latin American Region depending on the size and characteristics of the systems. The reason of this price difference is related to the substantially higher pressure used in the CO_2 installations. Thus, they require the use of stronger piping, better welding of the circuit and also several controls and monitoring devices that are normally not part of an HFC systems.

2. Cost of installation of CO_2 system due to the high-pressure requirements is still very high in Argentina. TIG brazing is made by specialized companies so the price is much higher than standard brazing. Availability of specialized brazing companies is lacking in some locations of the country. Two of such specialized brazing companies have been employed during Lincoln installation.

3. The installed CO_2 transcritical system did not leak from the start up until now and, if leaks would occur in the future, the recharge would be done at a low price due to the much lower price of CO_2 compared to the current prices of synthetic refrigerants.

4. The refrigeration systems are optimized for the designed refrigerant charge. Leaks would lead to suboptimal conditions loss of refrigeration capacity, increased energy consumption. Such systems will cause damages to the perishable goods, so losses could be quite significant. Thus, low leakage rates of the new system is advantageous from several points of view.

5. The first charge of CO_2 was supplied by EPTA. Industrial gas vendors like Praxair and Air Liquide are located in Argentina and offer CO_2 with 20 ppm humidity and since it is used for sparkling beverages, it is easily available. This CO_2 is also used for some other refrigeration systems in Argentina.

6. R290 has been supplied to EPTA by a local refrigerant importer and EPTA maintains a stock for emergencies.

7. Frequency of preventive maintenance is similar to HCFC/HFC systems and the only is the adequate training of the service staff. The equipment of La Anonima Lincoln is maintained by its own staff, they have been properly trained by EPTA, as part of the project.

8. The selected vendor had the necessary expertise to provide assistance during installation and start up as well as after sales maintenance. During the procurement process this was a condition required from the bidders. Vendor was also required to train the maintenance staff of the Lincoln supermarket on the following:

   - Procedures to intervene on a CO_2 system under pressure
   - Maintenance procedures like filters and oil replacement, sight glass control.

- Management of electronic controls of the refrigeration rack and system
- Operation of monitoring system

9. OPROZ also offered during 2017 and 2018 all over the country trainings for more than 700 technicians on Good Practices in Handling Low GWP refrigerants which included CO_2.

10. Parts to be replaced most frequently are manometers and valves. These devices are now available in Argentina. As previously stated, several components, like valves, are standardized today for several refrigerants and their working pressures are adequate even for CO_2.

11. Availability of CO_2 transcritical system vendors in the local market is low. CO2 central refrigeration systems as well as the evaporators and subcooler were manufactured in Italy by EPTA Italy. The size of the market is still not sufficient for manufacturing it locally.

12. Compressors in this case were manufactured by Bitzer and the service center for these compressors is located in Brazil, so the project vendor has a reduced stock for emergency. Because of this, the capacity of the CO_2 central was calculated with a slight reserve so it could work even if one of the compressors fails.

13. Display cabinets are manufactured by EPTA Argentina locally at their Rosario manufacturing plant but some of the components are imported.

14. Most electrical components are available locally but some cables as well as special connectors are imported.

15. The Control system is manufactured by Carel, which is based in Brazil and has distributors in Argentina. Carel control systems for CO_2 transcritical installations are manufactured in Italy so the project vendor maintains a complete control system in stock as well as pressure transducers to be able to assist in case of emergency.

Electricity consumption

As expected with any refrigeration system, the electricity consumption of the CO_2 transcritical booster refrigeration system showed correlation with the ambient temperatures. In the summer period from December to March the average maximum temperature was 32 °C, and most of the time over 30°C, as shown in the following figure.

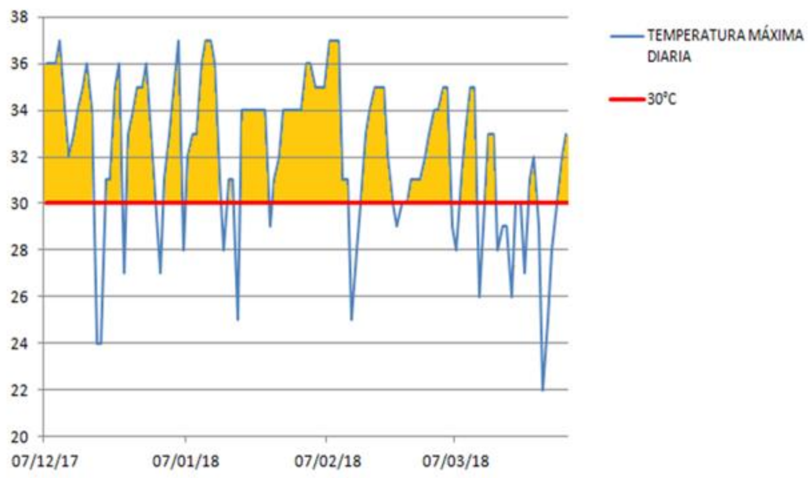

Figure 15 Average maximum temperature between December 2017 and March 2018

Year 2018[6] showed more extreme temperatures than the baseline year 2017[7], with an increase of almost 2 Celsius degrees in the maximum temperatures during several days.

Prior to the project the supermarket had only one meter to measure all electrical consumption of the shop. Thus, the supermarket did not have any information on the consumption of the refrigeration equipment. In order to be able to assess the impact of the project, the first thing was to install of a separate meter to delineate the measurement of the electrical power consumption of the cooling equipment only. In the following figure and table, the monthly electricity consumption of the new CO_2 transcritical system is presented versus the baseline registered during the test period from January to November.

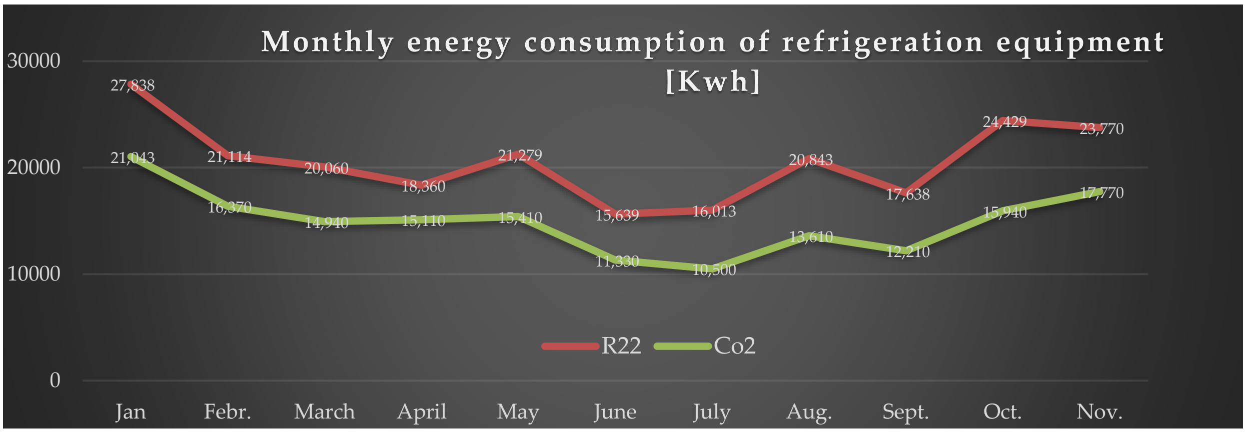

Figure 16 Energy consumption of refrigeration equipment

[6] Monitoreo Regional de la Temperatura 2018. Servicio Meteorológico Nacional
[7] Monitoreo Regional de la Temperatura 2017. Servicio Meteorológico Nacional

During the first 11 month of the trial period, the cumulative electric consumption of the CO_2 transcritical system in the first year of its operation was 27.64% lower compared to the pre-project annual electric consumption of the baseline equipment. The annual energy consumption was extrapolated based on the power-meter measurements of the first 11 months and the results are shown on the following graph.

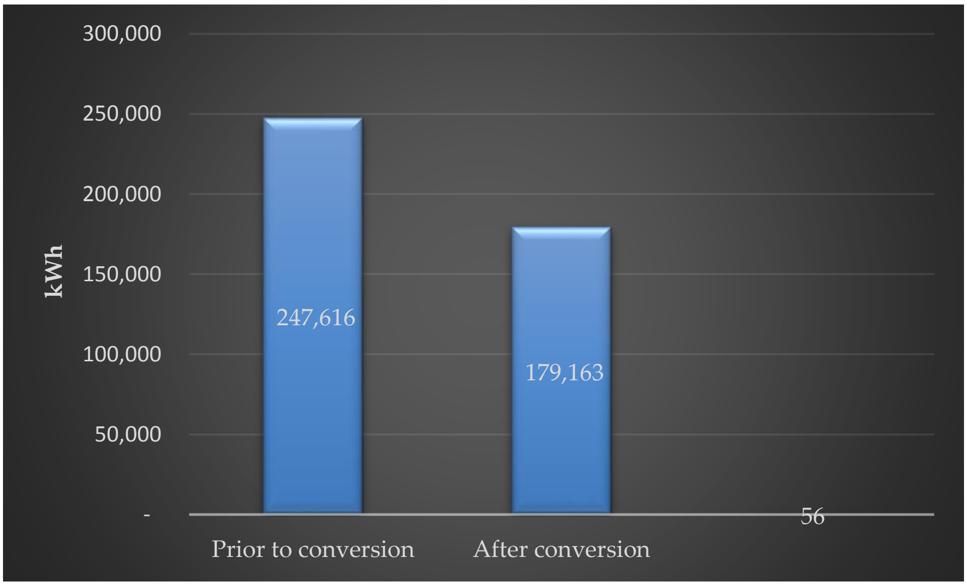

Figure 17 Annual electrical energy consumption of refrigeration equipment

The annual electricity bills (including non-technological energy use) showed a 27% year saving of pesos $343,673 (U$S 9,200).

The following graph shows energy cost comparison based on electricity bills of 2017 and 2018.

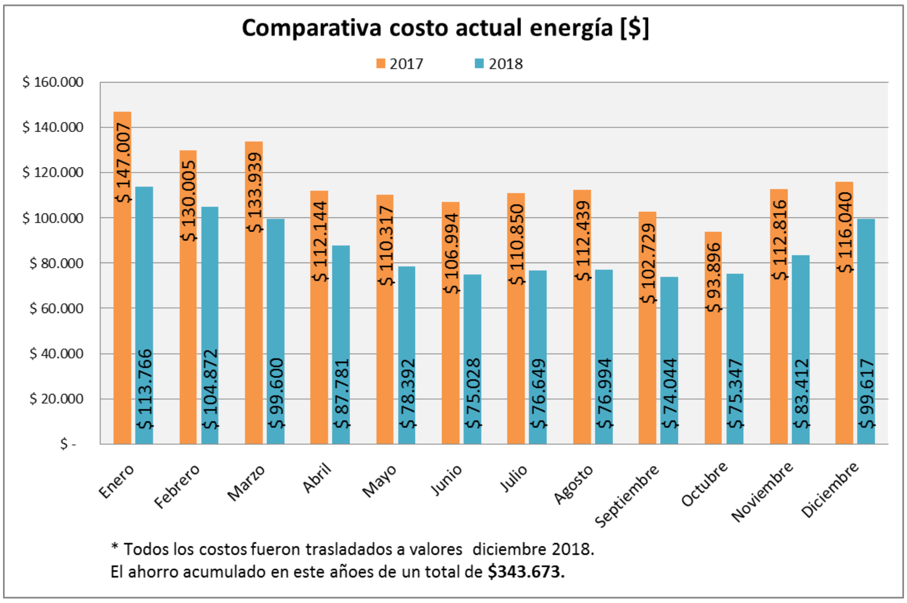

Figure 18 Electricity cost of the supermarket

Refrigerant leaks

The refrigerant charge amounts and leakage data are shown in Table 3.

TABLE 3. REFRIGERANT CHARGES AND LEAKS, SUPERMARKET IN LINCOLN

Year	HCFC-22 (kg)			HFC-404A		
	Charge [kg]	**Leak**	**%**	**Charge [kg]**	**Leak**	**%**
2011	400	244	61%		N/A	-
2012	400	593	148%		N/A	-
2013	400	312	78%		N/A	-
2014	400	517	129%	10.6	27.2	**257%**
2015	400	272	68%	10.6	40.8	**385%**
Average	**400**	**387.6**	**97%**	**10.6**	**34.0**	**321%**

The baseline annual consumption of refrigerants at the Lincoln La Anónima supermarket amounted to 398.2 kg. The associated refrigerant cost amounted to 5,700 USD.

The new system is filled with 300 kg CO_2.

In view of the high pressure of the CO_2, high quality pipes are used. Special attention and qualified/certified technicians and welders were employed for the connections and installation of the circuits and equipment. Rigorous testing of all joints and of the entire circuit was carried out prior commissioning and start-up. In view of the high quality of the equipment and installation work, almost no leaks occurred during the first year of operation. Thus, the cost of the refrigerants is now saved and also the labour cost of replacements and repairs associated with it. The loss of perishable goods was not quantified.

Environmental impact

The following table shows the impact of direct and indirect green-house gas emissions during the monitoring period. As shown in Table 4 the direct green-house gas emission reduction is 834.9 T_{CO2eq} due to the high GWP of R-22 refrigerant as well as the extensive baseline annual leakage average amounting to 97% of the total charge compared to the GWP and leakage of R744 and R290 of the new system.

In 2019, during the generation of 1 kWh electrical energy in Argentina 310 g of $CO_{2\ eq}$ greenhouse gas was emitted[8]. Even if this figure is not too excessive compared to other countries (e.g. EU- 269 g_{CO2eq}/kWh[9], USA – 401 g_{CO2eq}/kWh[10], China 555g_{CO2eq}/kWh[11]) the energy saving results in substantial greenhouse gas savings amounting to 21.43 t_{CO2eq}. Even though this is quite low compared to the direct emission saving, but it is recurring annually during the entire lifetime of the machinery.

TABLE 4 CALCULATION OF CLIMATE IMPACT OF THE PROJECT

DIRECT EMISSION			
Chemicals	Average leakage (kg)	GWP	Direct emission (tCO2eq)
Prior to conversion			
R-404A	34	3,922	133.35
HCFC-22	387.6	1,810	701.56
Total			834.90
After conversion			
R-290	0	5	0
CO_2	0	1	0
Saving			**834.90**
INDIRECT EMISSION			
	Electricity consumption	Intensity of power generation (g_{CO2eq}/kWh)	Indirect emission (t_{CO2eq})
Prior to conversion	247,616	313	77.50
After conversion	179,163	313	56.08
Saving			**21.43**
CLIMATE IMPACT			
Total emission saving			**856.33**

The climate impact is illustrated on the following graphs.

[8] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_Argentina.pdf
[9] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_EU.pdf
[10] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_USA.pdf
[11] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_China.pdf

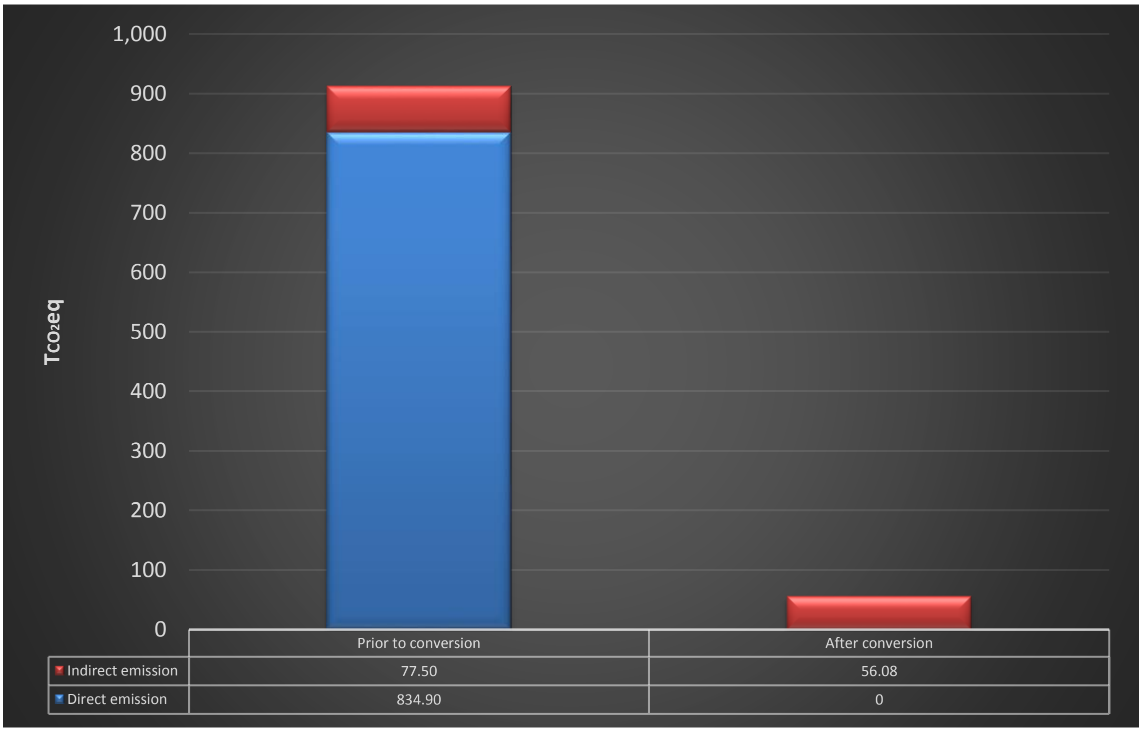

Figure 19 Overall climate impact of the project

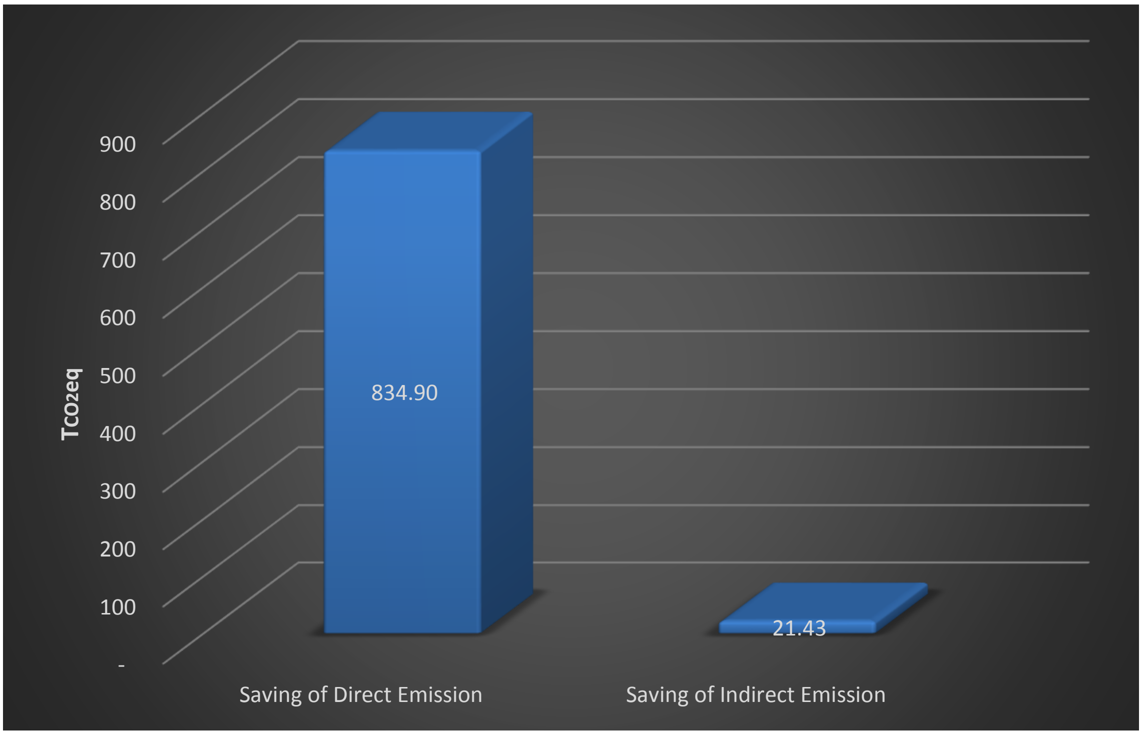

Figure 20 Climate impact of the project by emission types

The total annual reduction of climate impact in the year after the conversion amounted to approximately 856 metric tons CO_2 equivalent. For illustration, this number is equivalent to the annual CO_2 release of approx. 420 passenger cars running 15,000 km in a year! (A currently used mid-size car releases 110 - 160 g CO2 per km.)

The strong commitment of the recipient company as well as of OPROZ, the vendor and of the skills and hard work of the national and international consultants' of UNIDO contributed to the successful completion of the project and laid the foundation for its long-term sustainability and replicability in the country.

Based on the good results obtained in the project, the recipient company La Anónima, has adopted transcritical CO_2 as the default technology for its new branches as well as for updating or refurbishing of current ones, whenever it is feasible.

The project helped to create confidence in the technology. It demonstrated its feasibility, removed many barriers and accelerated the adoption of this technology even for warmer climate zones of this country (e.g. Córdoba, Santa Fe, Salta and Tucuman). As of the date of this report, the number of supermarkets using CO_2 transcritical systems in Argentina increased to a total of 20, belonging to eight different supermarket chains.

At regional level, the same vendor has installed 3 more systems in Chile, 1 in Colombia and 12 in Ecuador from 2017 up to now.

SUSTAINABILITY

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At regional level, the same vendor has installed 3 more systems in Chile and 9 in Ecuador from 2017 up to now.

The following e-mail represents a true testimony of the success of the project:

> ***De:*** *Gil Nestor - Epta Argentina <Nestor.Gil@epta-argentina.com>*
> ***Enviado el:*** *miércoles, 26 de febrero de 2020 04:03 p.m.*
> ***Para:*** *Laura Estela Berón <lberon@ambiente.gob.ar>*
> ***Asunto:*** *Buenas nuevas*

Hola Laura, tenemos buenas noticias !

A partir de los resultados de Lincoln, La Anonima y Epta firmamos un acuerdo estratégico para comenzar a reemplazar gases sintéticos por CO2 en sus tiendas existentes. Es una excelente noticia ya que fue anunciada en el marco de EuroShop en Alemania.

Pensábamos que estaría bueno distinguir a La Anonima como primera cadena en instalar Trancritico y también en tomar una decisión de esta característica.

Que opinas ?

Translation:

Hi Laura, we have good news!

Based on the results of Lincoln, La Anonima and Epta, we signed a strategic agreement to begin replacing synthetic gases with CO2 in their existing stores. This is excellent news as it was announced within the framework of EuroShop in Germany.

We thought it would be good to distinguish La Anonima as the first chain to install transcritical equipment and also of having taken a decision accordingly. What do you think ?

Thank you and regards,

Nestor

SUB-PROJECT: TUNISIA

The project funds approved for the Tunisia component amounts to **USD 319,131**.

UNIDO has been working closely with the NOU on the introduction of trans-critical CO_2 refrigeration technology at Monoprix supermarket within the framework of the contract “Demonstration project for the introduction of trans-critical CO_2 refrigeration technology for supermarkets in Tunisia”. Technical experts were mobilized and the needed ToRs have been prepared and approved by all partners. Unfortunately, the beneficiary decided to withdraw and the project was on hold.

In June 2019, a meeting was held with the NOU and it was decided to look for an alternative beneficiary that can participate in the project. Carrefour was identified as a potential partner. UNIDO mobilized an international expert and a meeting was held with the representative of Carrefour and the Manager of the Technical Department. Carrefour confirmed the plan to build a new supermarket by February 2020 that will be opened by March 2020. No delay on these dates will be allowed given to profitability reasons. The company is present in Tunisia as a franchise of the French firm. This means that the ownership is from Tunisia; there are no French capitals.

The planned cooling capacity is 53,188 W for the positive temperature and 4,700 W for negative temperature. The original plan was to install a system based on R404A. Carrefour representatives committed their agreement to installing a CO_2 trans-critical system in the new supermarket.

After further consultations with the MLF Secretariat, it was decided not to proceed with the installation as the initial intention was to replace an existing technology with the CO_2 trans-critical system rather than performing a new installation. The NOU and the beneficiary have been notified accordingly.

The remaining funds after financial completion will be returned as per decision.

BUDGET AND EXPENDITURES

The financial status of the Project is summarized in Table 3 overleaf.

Item as per Approved Proposal	Budget as per Approved Proposal (US$)	Disbursements So Far (US$)	Remaining Obligations (US$)	Balance (US$)	Comments
Argentina					
New refrigerating equipment	389,866	484,372 (*)			
Food display cabinets	102,303	Included in (*)			
Engineering and transport	15,000	Included in (*)			
Workshops to disseminate results of the project	20,000	23,763			
Subtotal Argentina	**527,169**	**508,135**			
Tunisia					
New refrigerating equipment	245,347	0			
Food display cabinets	43,784	0			
Engineering and transport	10,000	0			
Workshops to disseminate results of the project (intern. consultant, meetings, traveling**)	20,000	20,000 **			
Subtotal Tunisia	**319,131**	**20,000**			
Totals (Argentina + Tunisia)	**846,300**	**528,135**		**318,165**	The remaining funds from the project will be returned to the MLF upon financial closure.

Annex IV

DEMONSTRATION PROJECT ON REFRIGERANT QUALITY, CONTAINMENT AND INTRODUCTION OF LOW-GLOBAL-WARMING POTENTIAL (GWP) ALTERNATIVES

Final Report

85th meeting of the Executive Committee for the Implementation of the Montreal Protocol

March 2020

CARIBBEAN SUB-COMPONENT

Countries:	the Bahamas, Grenada, Saint Lucia, Saint Vincent and the Grenadines, Suriname
Title:	Safe handling of low-GWP flammable refrigerants
Project Budget:	USD 234,584
Implementing Agency:	UNIDO
National Counterparts:	National Ozone Units, National Refrigerant Associations, Vocational Schools

Table of content

I. Background

The phase-out of hydrochlorofluorocarbons (HCFCs), specifically in the refrigeration and air-conditioning sector, brought about a broader discussion on suitable long-term alternatives. Readily available refrigerant alternatives, which are hydrofluorocarbons (HFCs), have however high global warming potentials (GWPs) and contribute to global warming. The refrigeration and air-conditioning manufacturing sectors worldwide, are thus gearing towards the use of low-GWP alternatives, such as hydrocarbons (HCs) and novel refrigerant formulations of HFO and HFC blends, which are designed to have short atmospheric lifetimes.

It has been established that refrigeration service technicians in countries with large service sectors need to be well trained and equipped to cope with the installation and maintenance demands of next-generation appliances. HCs and HFOs have zero-ODP and low-GWP properties, but are flammable. HCs, such as propane, are classed as “A3 - highly flammable”. HFOs and HFC blends are classified with “A2L – mild flammability” with slow propagation. Countries are steadily beginning to take up hydrocarbons as an alternative to HCFCs in air-conditioning although few technicians are trained to handle the alternatives effectively. It is anticipated that as old installations near decommissioning, more end-users will opt for hydrocarbon-based appliances.

However, specialised training for technicians on flammability needs to be done to ensure that only well-trained technicians service hydrocarbon-based equipment. Hydrocarbons such as propane, LPG and hydrocarbon mixtures have been used during service operations, where the risks associated with the flammability and the thermodynamically properties of the refrigerants has not always been taken into account. Hence it is important to increase the know-how and confidence of technicians with regard to using flammable low-GWP refrigerants when installing new units or servicing old units.

To address these barriers, the Executive Committee for the Implementation of the Montreal Protocol approved at its 76^{th} in May 2016 a demonstration project on refrigerant quality, containment and introduction of low-global-warming potential (GWP) alternatives. The project was implemented through two components, one in the Caribbean, and one in Eastern African, by UNIDO (lead implementing agency) and UNEP (co-operating implementing agency).

The Caribbean component was implemented by UNIDO in the Bahamas, Grenada, Saint Lucia, Saint Vincent and the Grenadines, and Suriname for a total funding of USD 234,584.

II. Project objectives

In order to facilitate the introduction of low-GWP refrigerants in the servicing sector, the demonstration project aimed to:

- Enhance the expertise of technicians and train specialized trainers;
- Upgrade the training curricula at vocational centers;
- Augment the equipment at the regional training center;
- Expose stakeholders to the latest HC-based equipment and components on the market.

The activities planned under the project were linked to the countries' respective HPMPs. The use of flammable refrigerant alternatives is covered to varying extents in the HPMPs. However, the funding levels of the HPMPs could not adequately cover the issue of flammability. Therefore, regional, as well as country-specific activities were required to bring about a more comprehensive approach that would enable the countries to transition to flammable low-GWP refrigerants in a safe manner, as proposed in the project and described in more details below. Moreover, it was vital that these activities were carried out as soon as possible, so that current HC service practices are conducted safely, in light of the concerns pointed out under decision 72/17 of the Executive Committee.

III. Implementation plan

Activities	**Budget (USD)**	**Countries**
1. Design of training curriculum preparation and monitoring of training	30,000	All
2. Upgrading training centre	72,417	Grenada
3. Train the trainers regional workshop	42,792	All
4. Training sessions for technicians	49,375	All
5. Workshop and exhibition	5,000	Grenada
6. Regional expert group meeting and dissemination of results	35,000	All
Total	**234,584**	

IV. Implementation report

Activity 1: Design of training curriculum preparation and monitoring of training

A regional workshop for policy makers and curriculum developers was held in May 2017, where representatives from national ozone units and training providers were trained on preparing a training course and operational and organisational activities featuring the essential aspects of the training organisation. In addition, various types of certification schemes from different regions were introduced and discussed to serve as a platform to selecting the right components for a scheme for the Caribbean region.

The National Ozone Officers, their alternates, national consultants and training provider during the regional workshop

A regional training curriculum was designed to ensure that only qualified technicians are handling and servicing equipment and flammable fluids. This curriculum encompasses theoretical knowledge as well as specifies practical expertise that must be achieved to get the necessary skills to safely handle low-GWP alternatives and flammable refrigerants. It includes a list of the appropriate equipment and materials for training of technicians. In addition, the competence and requirements for an adequate assessor and venue requirements are also provided. This curriculum should be adapted by each country for their respective schemes, but it is already in use at the regional training center in Grenada, together with a training programme developed by the GIZ. The complete curriculum is provided in annex 1.

Activity 2: Upgrading Training Centre

In order to facilitate the introduction and the safe use of low-GWP refrigerants, the regional training centre in Grenada at the T.A. Marryshow Community College (TAMCC), St. George's was upgraded in 2017 with equipment, tools and materials suitable for low-GWP flammable refrigerants.

The list of items was established in consultation with the National Ozone Officer of Grenada, and other National Ozone Officers of the region, based on needs identified at the regional level and following the recommendations contained in the training and certification curriculum on flammable refrigerants developed as part of the project and the "Guidelines for the safe use of hydrocarbon refrigerants" developed by the GTZ Proklima in 2010.

Items delivered included manifolds with gauge for hydrocarbons, electronic leak detectors for flammable refrigerants, portable charging stations for hydrocarbons, propane and butane gas cylinders, and other tools and material for use of low-GWP refrigerants in air-conditioning. The complete list of equipment, tools and materials delivered is provided in annex 2.

In 2019, the regional training center was operating fully for the RAC technicians of Grenada, and will open to technicians of other countries of the region in 2020. The training center has the capacity to train up to 20 technicians per session, and it is envisaged that once open to other neighbouring and participating countries, up to 10 technicians could come from outside Grenada at each session. Participation of technicians from all countries in the training remains subject to availability of financing. Countries are therefore invited to consider possible source of funding such as the national HPMPs or other ozone or climate related projects.

Activity 3: Train the trainers Regional Workshop

A regional train-the-trainers workshop was organised in Grenada on 22-25 August 2017. 20 RAC technicians, four from each of the participating countries, were trained as trainers on theoretical and practical aspects of refrigeration servicing, in particular on the safe handling of refrigerants and alternatives. Technicians who participated in the workshop already possessed consistent knowledge and practical skills on HFCs and other traditional refrigerants. The full list of technicians who attended the workshop is provided in annex 3.

The objectives of the workshop were more specifically to:

- Disseminate technical knowledge on the flammable refrigerants necessary to operate with these types of refrigerants;
- Showcase the reduction of direct and indirect global warming emissions that it is possible to obtain with systems using flammable refrigerants thanks to their better energy efficiency;
- Present the safety aspects, as mandatory knowledge required when dealing with the flammable refrigerants;
- Provide practical and technical skills, which would allow technicians to maintain andrepair flammable refrigerant-systems in safe conditions;
- Provide a consistent theoretical and practical knowledge (train-the-trainers) for future training of other technicians in their area;
- Activate a l knowledge process, which students could further develop for a life project of continuous learning.

The workshop consisted of both theory and practice sessions, preparing for the final assessment. The training took place at the TAMCC, recently upgraded with equipment, tools and materials suitable for low-GWP flammable refrigerants. Part of the theoretical lessons were prepared based on the REAL alternatives learning material, and on guidelines on F-gas refrigerants. Furthermore, additional material was prepared specifically by the trainer, based on European laws.

The theoretical topics presented during the workshop included:

- Information on HCFC-free technologies available or HCFC alternative substances in servicing including training on the safe handling of refrigerants and alternatives, mainly those with high toxicity, flammability or pressure;
- Refrigeration principles and fundamentals, refrigerants, temperature-pressure relation and diagrams, refrigerant properties;
- Thermodynamic principles, basic components of the refrigeration cycle;
- Applications with a choice of components, compressors, evaporators, condensers, calculations and sizing;
- Refrigerating plant: efficiency and refrigerating capacity, maintenance, disadvantages, correct installation, component functionality control (compressor, condenser, evaporator, valves), main electrical problems, different types of refrigerants, lubricants and problems connected with their utilisation, faulty functioning of refrigerating plants;
- Presentations of hydrocarbon applications in window and split type air-conditioners, chiller, etc.;
- Methodology for conducting risk assessments for systems and equipment using

hydrocarbon/flammable refrigerants, e.g. electrical components.

Participants during the theoretical session

The practical session covered the following aspects:

- Introduce good practices to avoid the refrigerant emissions during servicing, troubleshooting and maintenance, including refrigerant containment;
- Vacuum, charge. regulation, tools, recovery, retrofit, drop-in, manometer reading, pressure gauge;
- Research and damage detection, leak detection, valves, filters, oil and liquid separators;
- Practical applications of hydrocarbons in the refrigeration-servicing sector;
- Safe handling of flammable refrigerants.

At the end of the training course, an assessment was carried out and successful participants received the F-gas and the REAL alternatives certifications. These certifications are recognised worldwide and certify the competence level of technicians for handling refrigerant gases- in this case, F-gases and flammable refrigerants. An example of the REAL alternatives certificate is provided as annex 4.

Activity 4: Training sessions for technicians

Two hydrocarbon-based air-conditioning units were delivered to each country (apart from Grenada, which received units earlier for the regional training centre) to organise their in-country training sessions. This activity met with difficulties as manufacturers of hydrocarbon-based air-conditioners are still reluctant to sell small quantities commercially. Based on consultations with National Ozone Officers, additional purchases of materials were made in all countries but Grenada to ensure that each country is well equipped for their in-country training. The complete lists are provided as annex 5.

As of March 2020, 85 air-conditioning technicians have already been trained during the country training sessions organised since the train-the-trainers regional workshop which took place in August 2017 in Grenada. An additional 40 to 70 technicians will be trained before August 2020. When possible, the trainers trained during the workshop have been carrying out the country training sessions. The detail of the training sessions by country is provided hereafter.

The Bahamas:

A three-evening training course was organised on 20-22 August 2019 for 9 technicians. One local RAC trainer and the National Ozone Officer conducted the training. The full list of participants to the training is provided in annex 6.

The topics covered included: properties of hydrocarbons, toxicity, flammability restrictions on use of hydrocarbons, availability of hydrocarbons, design characteristics of appliances using hydrocarbons, leakage issues and leak detection, maintenance and repairs of appliances using hydrocarbons.

Grenada:

A two-day training course was organised on 8-9 May 2019 for 32 technicians. Two local RAC trainers and the National Ozone Officer (NOO) conducted the training. The technicians were required to have at least three years working experience in the field of RAC to participate in the training. The full list of participants to the training is provided in annex 6.

Major topics covered in the training included but were not limited to: properties of hydrocarbons, risk assessment, legislation, policy and standards, fire and electrical safety, charge limitation and room size calculations, personal protective equipment and specialise tools and equipment required for installation and servicing, leak detection, installation, servicing and maintenance practices, and brazing and pipe connections. The methodology used included a combination of power point presentations, lectures, handouts and multi-media.

Participants during the theoretical session

During the practical training, the participants were required to demonstrate their competence in brazing, flare joint connections, leak and pressure testing, evacuation, venting and charging of refrigerants.

Participants during the practical work

During the evaluation participants were asked to give their overall rating of the training. Out of 27 respondents, 18 rated the training as been excellent, eight as very good and one as good. At the end of the training, certificates of participation were awarded to all the participants.

Participants receiving their certificate

<u>*Saint Lucia:*</u>

A two-day training session was organised on 4-5 February 2020 for 11 air-conditioning technicians. The facilitators of the training were two refrigeration technicians who underwent training in flammable refrigerants and their technology under the "train the trainer" component of the project. The full list of participants to the training is provided in annex 6.

Participants during the theoretical session

The first day was dedicated to theoretical aspects, including a presentation of the Montreal Protocol and of the HPMP for Saint Lucia, descriptions of the most common types of refrigerants, measures for the safe handling of flammable refrigerants and good servicing practices for flammable refrigerants, and a reminder of thermodynamic notions relevant to refrigeration and air-conditioning, At the end of the first day, participants were given an examination to assess their knowledge and understanding on the subjects covered during the theoretical component. The second one consisted of practical sessions and hands-on exercise.

Overall, the technicians found the training to be very useful and informative. The recommendations which were made by participants included the organisation of longer training sessions and the possibility for RAC technicians to purchase HC-based servicing tools to familiarise themselves with the technology.

Saint Vincent and the Grenadines:

A four-day training course was organised on 10-13 February 2020 for 11 technicians on the safe handling of low-global warming potential flammable refrigerants. Two local RAC trainers and the National Ozone Officer conducted the training. The full list of participants to the training is provided in annex 6.

The range of topics selected for the training session were geared towards ensuring that technicians are adequately prepared for the introduction and use of flammable refrigerants. These topics included: refrigeration cooling system, hydrocarbon refrigerants, flammable refrigerant safety, GIZ cool training programme and overview of training, safe design and general criteria for hydrocarbon refrigerants, hydrocarbons vs hydrochloroflourocarbons.

Participants during the theoretical session

The training also included practical work and hands-on exercise on the following topics: brazing project, testing and evaluation, demonstration of brazing with and without nitrogen, fabrication according to best practice, installations of hydrocarbon air conditioner, collection of data and system's analysis, requirements for data recording and labelling of systems, leak testing.

Participants during the practical work

Full day sessions were well attended by all registered participants. Theoretical sessions not only created an opportunity for technicians to have a better understanding of the use of hydrocarbon refrigerants, but also created a forum where participants were able to interact and network with other personnel within the industry to share their experiences. The practical exercises were successfully completed by all technicians. Participants indicated their appreciation for the training workshop and expressed a desire to be involved in similar sessions.

Suriname:

22 technicians were trained following the train-the-trainers workshop in Grenada in August 2017. All the technicians are members of the Air-conditioning, Refrigeration & Ventilation Association Suriname (ARVAS).

This training programme is now being extended, with multiple sessions taking place from March to August 2020, for an additional 40 to 70 technicians, in particular non-ARVAS members technicians and technicians from the informal sector. Each session will last four days, with two days of theory on topics such as basic thermodynamics, the cooling system, refrigerants, alternative refrigerants (hydrocarbons, carbon dioxide), differences between alternative refrigerants and HCFC, safety aspects,and compressor replacement and instalment. The two following days will be dedicated to practical sessions.

Activity 5: Workshop and exhibition

The workshop and exhibition was intended to showcase the offer of appliances using low-GWP alternative and servicing equipment offered by regional and international suppliers. Representatives from these suppliers would have participated to present their offers and answer questions from workshop participants. It was in particular envisaged to organise the exhibition back to back with the regional expert group meeting to create synergies between the discussions with the suppliers' representatives, and those on the success and challenges of the project among shareholders.

As international suppliers expressed the desire to understand better regional market conditions and trends, market surveys for each country have been considered and started, but the lack of data available, both in the countries and from public sources, did not allow to draw any certain and conclusive results. More generally, the lack of data on the market remains a challenge to encourage international suppliers of HC equipment to increase their presence in the region. The geographical distance from markets which are more mature in terms of natural refrigerants is also seen as a barrier to the growth of trade between the region and international suppliers or manufactures. Hence, only documentation and catalogues were collected from international suppliers and no representative participated in the event.

Regarding regional suppliers, a representative from Grenz concept, a reseller of R290 appliances and RAC equipment participated remotely in the regional expert group which took place in Paramaribo, Suriname, on 5 October 2019. The representative gave on this occasion a presentation on its offer and business model, and answered the questions from participants. He indicated in particular that the recent end of the production of the 12,000 BTU units by Godrej is an issue as these models are the most popular in the country. It is supposed that Godrej stopped the production of these units due to the dynamics of its domestic market, India, where the 18,000 and 24,000 BTU units are preferred because of the very high ambient temperature.

The representative of Grenz concept further indicated that warranty is not offered by the company to customers if the appliances are not maintained by trained technicians. The manufacturer on its side guarantee the compressor for 10 years, and five years for the rest of the unit. Grenz concept currently sells in Guyana and Trinidad and Tobago, and estimates that there is a potentially large market in the Caribbean for R290 appliances. Shipping time from India is three months, therefore Grenz concept mostly operates based on stocks. The 12,000 BTU units are sold nationally for USD 900, and the 18,000 BTU for USD 1,300, both excluding transportation. The supplier's representative indicated that it would be ready to supply other countries, as the the representative from Saint Lucia in particular demonstrated strong interest.

Activity 6: Regional expert group meeting and dissemination of results

The regional expert group meeting took place in Paramaribo, Suriname, on 5 October 2019. 11 persons, including National Ozone Officers or their alternate representatives, attended the event. Two additional persons joined the meeting remotely. The attendance per country or organisation is as follows: the Bahamas (1), Grenada (2), Saint Lucia (2), Saint Vincent and the Grenadines (2), Suriname (3), Grenz concept, a supplier of R290 appliances in Grenada (1), and UNIDO (2). The topics discussed during the expert group meeting included among others the barriers to the introduction of low-GWP alternative, the curriculum and national training programs, as well as the

lessons learned of the project. The full list of participants to the regional expert group meeting is provided as annex 7.

Participants during a working session

<u>*Persistent Barriers to the introduction of low-GWP alternative:*</u>

In Suriname, R290 appliances and maintenance equipment are not present in the country to date. However, R32 equipment are available as well as R600a ones to a lesser extent. There are only two suppliers of refrigerants in the country, but they do not supply R290 gas. The main problem to the uptake of natural refrigerant in the country is the cost of the appliances, which is a complex issue to address due to the low consumption of the country.

In Saint Lucia, R290 appliances, maintenance equipment and gases are also not present in the country to date, except some R290 chillers. For the phase-out of CFCs, the government played an instrumental role in bringing alternative equipment in the country by developing collaboration with suppliers, but similar actions are still to be implemented for natural refrigerants. A majority of technicians still refuse to use R290 as a refrigerant, due to safety concerns, and even ignore that some chillers operating with R290 exist in the country.

In Saint Vincent and the Grenadines**,** R290 appliances, maintenance equipment and gases are as well not present. Further, there is a fatigue with regard to HC training and sensitisation. There are only three RAC maintenance companies in the country. Out of the four trainers trained during the train-the-trainers workshop, only one is ready to train technicians. The lack of availability of trainers locally remains an issue in organising more training sessions. The high number of private islands in the Grenadines is an additional challenge to control the equipment and technologies entering the country.

In Grenada, there is a lack of institutional and technical capacity to deal with natural refrigerants, in particular economic and fiscal barriers. The government could take further appropriate measures in this regard. Regarding availability of equipment, the situation in Grenada is different from the one in other countries. There are two suppliers of R290 appliances, all manufactured by Godrej. There are few suppliers of gases, different from the resellers of equipment. However, R290 specific maintenance equipment are not available in the country. All these suppliers embarked on alternative refrigerants supply following business recommendations and support from the National Ozone Office. There is also a need for additional awareness raising, as HC suffers from bad press and create fears among technicians. Additionally, standards and codes (in particular regarding charging procedures, room. size, brazing methods, venting, etc.) are not yet well known by the whole technician community. This should improve as training sessions are extended to more technicians. Specific technical topics, such as moisture prevention on equipment operating with R290 or R600a, are to be better addressed by the continuous training programme as technicians are not familiar with the specificities of hydrocarbons.

In the Bahamas, most if not all technicians in the country still ignore hydrocarbon use. The main barrier is the lack of equipment in the country since the market is mainly dependent on the US market. The country does not have any supplier of R290 appliances, maintenance equipment or gas.

<u>*Curriculum and subsequent training:*</u>

The curriculum is not yet officially adopted by individual countries, but it has already integrated the body of reference material available in the region to design training on the safe handling of low-global warming potential flammable refrigerants. At the regional training centre at TAMCC in Grenada, it is used in combination with training material developed as part of a project with the GIZ.

In Suriname, 22 technicians were trained following the train-the-trainers workshop in Grenada in August 2017. In Saint Vincent and the Grenadines, the training of technicians following the train-the-trainers workshop did increase their confidence in alternative technologies.

The group agreed together with UNIDO that the curriculum will be further discussed.

Other discussions:

The group had extensive discussion on the voltage and frequency for the operation of R290 air-conditioners. Currently no equipment are available for countries using 110V/60Hz mains electricity. Technicians from Suriname, Grenada and Saint Lucia further indicated that countries with 60Hz frequency cannot use appliances made for 50Hz. This is a major limitation to the intake of R290 in the Caribbean and elsewhere. Using appliances designed to operate at a frequency of 50Hz in countries having 60Hz was deemed as counterproductive, as it increases energy consumption, reduces appliance lifetime, and leads to early malfunctioning. However, it was noted that technical assessments could be carried out with R290 appliances to examine how they operate under 110V/60Hz mains electricity, and if local alternatives could be developed. Finally, it was indicated that no appliances operating at 110V/60Hz is to be expected to be developed as long as .

The group also exchanged views on the risks associated with brazing and retrofitting appliances for use with R290. Grenada indicated that the GIZ developed a step-by-step guide on retrofitting, and that if correctly done, with all the necessary safety measures to prevent ignition, retrofitting can be consider as a viable option in absence of R290 appliances in the countries. Grenada explained that, in the national training, one full day is dedicated to brazing and safety measures while brazing. Grenada however strongly discouraged against using 290 as a drop-in replacement in appliances designed for the other refrigerants. It was further noted that the MLF and UNIDO strongly advise against the retrofitting of appliances or drop-in replacement, due to the safety risks and lack of awareness on dangers of hydrocarbon use in both scenarios.

Finally, tools available to promote good servicing practices were discussed by the group. Grenada in particular presented how to use the Android application “Good Servicing: Flammable Refrigerants Quick Guide”. Grenada showed for example how to calculate the minimum floor area based on refrigerant charge, and vice versa. Grenada encouraged the group to promote the mobile application among their national technician community.

V. Financial status

Activities	Budget (USD)	Total expenditures (USD)
1. Design of training curriculum preparation and monitoring of training	30,000	28,701
2. Upgrading training centre	72,417	77,874
3. Train the trainers’ regional workshop	42,792	42,769

4. Training sessions for technicians	49,375	62,643
5. Workshop and exhibition	5,000	0
6. Regional expert group meeting and dissemination of results	35,000	21,989
Total	**234,584**	**233,976**

VI. Lessons learned and recommendations for the sustainability of the project

Some of the following recommendations were made during the expert group meeting held in Paramaribo in October 2019 and after observations from project implementation:

- Individual countries to consider legally adopting the curriculum with small adaptations for country specificity where needed;
- Take appropriate measures to ensure that the regional training center in Grenada opens to RAC training technicians of other participating countries in 2020;
- Assess on a regular basis the capacity of the regional training center in Grenada and consider the need for a second regional training center in another country if capacities are not sufficient;
- Develop appropriate mechanisms and partnerships to encourage international suppliers or manufacturers of HC equipment and tools to offer a stronger presence in the region;
- Collect and analyse RAC market data with the view to encourage international suppliers or manufacturers to offer a stronger presence in the region;
- Develop appropriate mechanisms to encourage local suppliers to distribute HC equipment and tools;
- Envisage group purchases at the regional level of HC equipment and tools for distribution to local resellers with the view to limit the impact of transportation costs;
- Consider the opportunity to create a regional refrigeration association;
- Formulate monitoring and incentive mechanisms to encourage trainers and trained technicians to increase their participation in awareness raising and capacity building exercises conducted at the national and regional levels;
- Attract additional financial support from international funding bodies for the introduction of low-GWP alternatives refrigerants, in particular to fund capacity building programmes for technicians in the region (through the regional training center in Grenada or at the national level);
- Consider developing eco-labeling schemes for cooling appliances and/or reward schemes when consumers buy green cooling appliances;
- Increase in public tenders the minimum COP required for RAC appliances so as to encourage other users to switch to more energy efficient and modern equipment such as those using low-GWP refrigerants;
- Consider the opportunity to impose fees on appliances which use high GWP refrigerants;
- Consider compulsory technical requirements for designing, constructing or retrofitting civil

buildings (offices, hotels, hospitals, schools, apartment blocks, or trade and service facilities, etc.) with a floor space above a certain size;

- Carry out technical assessments with R290 appliances to examine how they operate under 110V/60Hz mains electricity (as found in the Bahamas among others);
- Develop platforms in each country (e.g. social media, mobile messaging applications) for information sharing among technicians. Such solutions have been implemented in Grenada, and have been facilitating the dissemination of information (e.g. event, training, technical information) by the National Ozone Office and favored mutual assistance by technicians;
- Reinforce presence of RAC technicians in regional meetings, in particular in the Caribbean Network Meeting of the National Ozone Officers. In the past, RAC technicians used to participate in regional meetings. Their involvement in the Regional Expert group provided valuable technical inputs, and participants expressed the wish to benefit from their expertise on technical issues on a more frequent basis.

Annex 1: training curriculum

See next page.

CURRICULUM TRAINING ON FLAMMABLE REFRIGERANTS

"Refrigeration and Air conditioning using Flammable Refrigerants"

Summary

Disclaimer: The principles contained in this Guide are not legally binding, and following them gives no legal guarantee. A binding interpretation of legislation is the exclusive competence of the European Court of Justice. CSG also recommends to readers, when using this Guide, to always refer to the national legislation, and guidance if any, of the State they are dealing with.

Curriculum Training on flammable refrigerants

Scope

Design of a regional training curriculum for Refrigeration and A/C technicians working with HC A3 (HydroCarbon - HC) and A2L refrigerants. Training curriculum intends to provide the appropriate and practical knowledge and skills to safely and efficiently install, maintain, repair and dismantle refrigeration systems that utilize HC and to a lesser extend A2L refrigerants.

Training is to be devised with a maximum of practical skills and with the minimum of required theoretical content.

Training curricula and necessary equipment

Course details

1) Major (safety / environmental) differences between non- flammable, HC and “ A2L” refrigerants
2) Thermodynamic characteristic of Hydrocarbons as refrigerant - p/h diagram
3) Specific components for Hydrocarbons – difference between conventional components and HC specific components
4) Electronic components suitable for flammable refrigerants
5) Refrigeration and Air conditioning applications with HC refigerants
6) Recovery or Venting of HC refrigerants
7) Recovery of A2L refrigerants
8) Vacuum-Charging procedures for HC refrigerants – accuracy / repercussions for over-undercharging
9) Leak testing
10) Mechanical/compression joint connections – avoid brazing
11) Flammability and safety issues
12) Review of Local (if any) guidelines for HC refrigerants – gases
13) Review of International guidelines for the use of HC refrigerants – practical and basic
14) Transport and storage requirements
15) Documentation

Venue requirements and necessary equipment details

See Annex 1

Learning / assessment components

T – Theoretical P – Practical	**HC**
BASIC THERMODYNAMICS AND PHYSICS	
Thermodynamic properties of HC refrigerant: temperature, pressure, density, thermal capacity, log p/h diagram	T/P
Differences between HC refrigerants and HFCs	T
Characteristic of flammability of the substances, velocity of propagation, LFL, UFL, occupancy	T
Specific components for HC / A2L refrigerant in the refrigeration cycle	T/P
Oil compatibility, oil safety, requirements and oil return	T
REGULATIONS AND STANDARDS	
If available;review of local guidelines for HC (refrigerants) as well as review of international safety guidelines	T
Storage and transportation of HC refrigerant	T
Instructions to end user / customer	P
GOOD PRACTICE[1]	
State and identify the commonly used refrigerants' designation	P
How to label HC refrigerant RAC systems[6]	P
Identify appropriate tools, equipment and PPE for work on HC RAC systems	P
Recovery of A2L refrigerant (when / when not – precautions)	P
Safely removing (venting) HC refrigerant from Refrigeration or A/C system	P
Calculate the max fill weight for a refrigerant recovery cylinder for (A2L) refrigerants	P
Pressure test check direct assessment using appropriate techniques	P
Vacuming the refrigerant circuit – purpose, process	P
Charging of an HC refrigerant system without refrigerant loss (emission) – accuracy / procedure	P
Make a connection without brazing with alternative connections	P
Check the correct functioning of the safety ventilation system	P
Check the correct functioning of the safety system controls	P
HEALTH AND SAFETY REQUIREMENTS	
Safe system shutdown and isolation [6]	P
Extinguish a fire, identify the appropriate fire extinguisher	P
First aid treatment for frostbite	P
First aid treatment for fire burn	P
First aid treatment for suffocation due to breathing problems	P
Safety issues related to high pressures	T
Calculate LFL (confined space)	T
Calculate confined space risk for asphyxiation (heavier than air)	T
Check that Health and Safety rules in the refrigeration system location are respected (emergency exits, fire alarms, leak detectors…)	T
Correct use of Personal Protective Equipment	P

Assessment Structure

Structure of the Exam, tests multiple choice, written (also oral will be considered) with bank of questions, papers for the practical session, Open Book.

In Annex 2 a bank of questions is listed for flammable refrigerants (Certifications on Real Alternatives flammable refrigerants Category HC)

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[1] All practical trainings should include theoretical training

Assessment: practical organization issues

It is recommended that the following guidance is followed for the organization of Assessments:

1) The assessment should last 1 day and the candidate will be informed on the same day if they passed. The certificate will be printed and sent after approximately 2 weeks

Theoretical assessment	60 minutes i.e. 9 am – 10 am
Practical assessment	Start just after the theoretical assessment i.e. starting from 10 am . Each candidate in max 2.5 hours should perform all the activities

Theoretical assessment – examination session

2) The candidate should arrive 30 minutes before the scheduled exam time
3) Each candidate MUST have a photo ID to present to the assessor. No one will be allowed to take the exam without it.
4) All electronic devices should be turned off and left in a safe area designated
5) Maximum 20-25 candidates per class dependent on number of assessors (1 assessor/assistant every 10 candidates)
6) Multiple answers tests, 30 questions for 60 minutes duration
7) The same test among candidates with variation of questions to prevent predictability among candidates
8) Open books and specific technical tools such as calculator and pressure-temperature comparator should be available
9) NO! mobile phones or cameras
10) NO! copying or communication between candidates
11) YES! speaking to the assessor for clarification; many candidates use different words and vocabulary to identify the same concept (eg. Valves)
12) Theoretical assessment: Pass mark above 60% correct answers
13) The test could be performed orally if the candidate has asked prior to the beginning of the exam and the assessor has agreed to this arrangement

Practical Exam and Tasks

Practical assessment:

In Annex 3 there are papers to complete during the Practical session and in Annex 4 there are the Instructions

14) The laboratory should be properly equipped for performing the practical test (see Annex 1 for Venue Requirements). Measuring instruments should be calibrated.
15) There are 3 stages of assessment (1. thermodynamic parameter reading, 2. Pressure test, Vacuum, Charge, Recovery, 3. Brazing) for assessing 3 candidates at time, divided by the practical activities to speed up the process. An alternative is to combine “ thermodynamic exercise” (P/T, Superheat,

Subcool, comments) and pressure test, vacuum, recovery in one exercise and brazing in another. Increase the difficulty on brazing by adding an expansion valve, check valve or rotalock fitting.

16) Pass if candidate proves competence in performing all (100%) main RAC service technicians activities without or with only small hesitations (remember candidates could be knowledgeable but be nervous!):
    - **B)** Thermodynamic parameters reading through gauges and devices, temperature, pressure, subcooling, superheating,
    - **C)** Parameters interpretation, troubleshooting
    - **D)** Perform a pressure/leak test
    - **E)** Vacuum, charge, recovery with minimum emissions
    - **F)** System Logbook reading, understanding and completing
    - **G)** Brazing leak tight joints with proper capillary flow.

Training Material and Real Alternatives

Training material can be found at the following link which is a project financed by EU and to which Centro Studi Galileo, the Italian Association of Refrigeration and the European Association AREA has worked for Blended Learning on Alternative Refrigerants. Free of charge but with Licences to use it for commercial purposes (Enquire Licencing modalities to buoni@centrogalileo.it).

www.realalternatives.eu

Assessor Qualification and competence

Assessors and Trainers should be sufficiently skilled in the curriculum

Assessors should be unbiassed in trainees' evaluation

Annex 1 Venue requirements for training and assessment

A Venue is required both for the training and assessment sessions. It is of paramount importance that safety of teacher, students and staff is warranted.

For the theoretical section, technical teaching aids such as beamer/LCD screen, PC/Laptop and white or chalkboard are required. Adequate seating arrangements as well as air conditioning / heating and sufficient light must be provided.

As for the practical section; the venue must be well ventilated, lit and have sturdy workbenches.

Necessary equipment and components (minimum)

1) Training model HC a/c and refrigerator unit
2) Nitrogen Regulator - Cylinder of High Purity Nitrogen
3) Electronic Weighing Platform (accuracy 1 gram)
4) Electronic Vacuum gauge
5) Manifold set - Hoses with ball valves
6) Vacuum Pumps and Hose
7) Recovery Unit
8) Recovery Cylinder
9) Electronic Leak Detector
10) Proprietary Leak Spray
11) Temperature meter
12) Ammeter
13) Tools, Pipe Cutters, Pipe Deburring Tool, Pipework Expanders, Hacksaws, Brazing Rods
14) Flaring Tool
15) Personal protective equipment PPE

Annex 2 Bank of questions (#40)

Question 1 A2L

Mod 3 Eff leak test	Which system is not as suitable for a fluorescent additive leak detection system	One with a coalescing oil separator
		A trans critical system
		A cascade system
		A two stage system

Question 2 A2L

Mod 3 Eff leak test	How frequently should a hand-held electronic leak detector used for R32 be checked?	At least once per year
		There is no requirement for leak detection of R32
		The frequency depends on the charge size
		After every 100 hours of operation

Question 3 A2L

Mod 3 Press testing	What is the benefit of using hydrogen as a trace gas with nitrogen for pressure testing	It has a small molecule and diffuses more readily
		It is easily detectable
		It has an odour
		It is non flammable

Question 4 A2L

Mod 3 Leak test regime	Under the revised F Gas regulation (from 01.01.2015) how frequently would a system containing a charge of 60 tonnes CO2-equivalent of	Twice per year
		Once per year
		Four times per year
		Leak testing is not required

	refrigerant need to be leak tested?	

Question 5 A2L

Mod 3 Indirect leak testing	What is the effect on the high pressure side of a system (with no head pressure control) if it is short of refrigerant?	The discharge pressure will be lower and the degree of subcooling will be lower
		The discharge pressure will be higher and the degree of subcooling will be lower
		The discharge pressure will be higher and the degree of subcooling will be higher
		The discharge pressure will be lower and the degree of subcooling will be higher

Question 6 A2L

Mod 4 Flam refs	Why should you not use an HFC recovery machine on R1234ze?	It contains sources of ignition
		The recovery machine oil is not miscible with R1234ze
		The recovery machine will not withstand the operating pressure of R1234ze
		The low pressure switch setting will not be suitable for R600a because of its lower operating pressure

Question 7 A2L

Mod 4 Flam refs	How do you make sure it is safe to switch on a vacuum pump to evacuate an R32 system?	Use an R32 gas detector to ensure there is no Flammable refrigerant in the area
		Recover the system down onto a slight vacuum before fully evacuating the system with the vacuum pump
		Flush the area with nitrogen before switching on the pump
		Fit a long hose on the outlet of the vacuum pump to discharge the R32 away from the work area

Question 8 A2L

Mod 4 Flam refs	How do you remove as much refrigerant as possible from a condensing unit system with a charge of 800 g R1234ze?	Recover the R1234ze so the system is on a vacuum, break the vacuum with oxygen free nitrogen to pressure of 0.1 bar g
		Recover the R1234ze so the system is on a vacuum
		Vent the R1234ze outside and evacuate the system
		Vent the R1234ze outside; fill the system with oxygen free nitrogen to a positive pressure, vent and evacuate twice, fill the system with nitrogen for a third time and vent

Question 9 A2L

Mod 2 R32	What is the typical PS for the low side of an R32 system with an air cooled condenser in a 32^{O}C ambient?	19.3 bar g
		14.3 bar g
		34.2 bar g
		65 bar g

Question 10 A2L

Mod 3 Leak Points	Which document provides torque values for manually made flared joints	EN378
		The F Gas regulation
		The Pressure Equipment Directive
		EN60079

Question 11 A2L

Mod 3 Indirect leak testing	What is the effect on the low pressure side of a system (with no suction pressure control) if it is short of refrigerant?	The suction pressure will be lower and the useful superheat will be higher
		The suction pressure will be higher and the useful superheat will be higher
		The suction pressure will be lower and the useful superheat will be lower

		The suction pressure will be higher and the useful superheat will be lower

Question 12 A2L

Mod 2 R32	What is the typical PS for the high side of an R32 system with an air cooled condenser in a $32^{O}C$ ambient?	34.2 bar g
		24.8 bar g
		19.3 bar g
		120 bar g

Question 13 A2L

Mod 2 R1234ze	What is the typical PS for the high side of an R1234ze system with an air cooled condenser in a $32^{O}C$ ambient?	10.3 bar g
		19.3 bar g
		24.8 bar g
		120 bar g

Question 14 A2L

Mod 3 Leak Points	Why are flare solder adaptors used	They have a factory machined face
		They are brazed onto the pipe work
		They cannot be disconnected once fitted
		They only need to be hand tight

Question 15 A2L

Mod 3 Press testing	What is the approximate rise in nitrogen pressure if its temperature increases by $5^{O}C$?	0.7 bar
		There is no change in pressure
		7 bar
		4.75 bar

Question 16 A2L

Mod 1 Intro, Safety	The hazards of R32 include:	Mild flammability
		High flammability
		High toxicity
		Mild toxicity

Question 17 A2L

Mod 3 Leak test regime	According to the latest F Gas regulation (EU517/2014) how frequently must an R1234ze system with a charge of 300kg and no fixed leak detection system be chacked?.	It does not need to be leak tested
		Once per year
		Twice per year
		Four times per year

Question 18 A2L

Mod 1 Intro, Safety	The hazards of R1234ze include:	Mild flammability
		High flammability
		High toxicity
		Highly corrosive

Question 19 A2L

Mod 1 Intro	R32 is used in systems which traditionally use …	R410A
		R134a
		R404A
		R290

Question 20 A2L

Curriculum Training on flammable refrigerants

Mod 1 Intro	What type of refrigerant is R1234ze?	An HFC which has unsaturated carbon
		A hydrocarbon
		Carbon dioxide
		An HFC which has saturated carbon

HC

Question 1 HC

Mod 1 Restr on use HC	What is the maximum charge of R1270 that can be used on a supermarket shop floor (occupancy category A)	1.5 kg
		150 g
		It cannot be used in this application
		There is no limit

Question 2 HC

Mod 1 Intro HC	What is the predominant application for R600a?	Domestic refrigerators and freezers
		Car air conditioning systems
		Glycol chillers for process cooling
		Central plant retail systems

Question 3 HC

Mod 1 Perf HC	What compressor displacement is required for R1270 compared to that used for R404A?	Similar
		50%
		150%
		600%

Question 4 HC

Mod 2		To disperse the refrigerant safely in the event of a leak

R717 R32 R1234ze HCs	On some systems which use a flammable refrigerant, why does the condenser fan run constantly?	To avoid a build up of contamination on the condenser
		To ensure the head pressure is never excessively high
		To reduce energy consumption

Question 5 HC

Mod 4 Intro HC	Why is the charge weight accuracy more important on critically charged R1270 systems compared to HFC systems?	Because the density is less so the charge weight is less compared to a similar HFC system
		Because these systems never have liquid receivers
		Because R1270 is only used in systems with less than 150 g charge weight
		Because of the lower operating pressures

Question 6 HC

Mod 4 Flam refs HC	What is the safe R290 fill weight for a recovery cylinder which has a safe fill weight of 10 kg for R404A?	4.5 kg
		10 kg
		15.4 kg
		22 kg

Question 7 HC

Mod 4 Flam refs HC	Why should you not use an HFC recovery machine on R600a?	It contains sources of ignition
		The recovery machine oil is not miscible with R600a
		The recovery machine will not withstand the operating pressure of R600a
		The low pressure switch setting will not be suitable for R600a because of its lower operating pressure

Question 8 HC

Mod 4 Flam Refs HC	How do you avoid the risk associated with the on/off switch on a standard vacuum pump when evacuating an HC system?	Use the vacuum pump in a well ventilated area and switch on at least 3 m away from the pump
		Fit a long hose to the pump's outlet to discharge the HC away from the system
		Position the vacuum pump 3 m above the floor
		Position the pump outside

Question 9 HC

Mod 4 Flam refs HC	How do you make sure it is safe to light a brazing torch to un braze a joint on a system which operates on a flammable refrigerant?	Ensure the area is well ventilated and use a flammable gas detector to check the area
		You must not un braze connections on a flammable refrigerant system, they should be cut using a pipe cutter
		Work outside
		Purge with oxygen free nitrogen

Question 10 HC

Mod 1 Safety HC	A refrigerant which is classified in refrigerant safety group A3 has which hazards?	High flammability, lower toxicity
		Mild flammability, lower toxicity
		High toxicity, no flame propagation
		Lower toxicity, no flame propagation

Question 11 HC

Mod 1 Intro HC	What is the GWP of R600a (according to EN378)?	3
		550
		0
		6

Question 12 HC

Mod 1 Intro R290	R290 is	Propane
		Propene
		Propylene
		Iso butane

Question 13 HC

Mod 1 Restr on use HC	Which factors are used to determine the maximum charge in a comfort cooling / heating application? HC	Lower flammability level, height of the indoor unit, floor area
		Practical limit, height of the indoor unit, floor area
		Practical limit, room volume
		Lower flammability level, room volume

Question 14 HC

Mod 2 HCs	What is the approximate cooling capacity of R1270 compared to R404A?	100%
		50%
		200%
		7 times

Question 15 HC

Mod 2 R717 R32 R1234ze HCs	What is area classification (with regard to the application of flammable refrigerants)	Testing which determines the extent of a flammable zone in the event of a leak of flammable refrigerant
		Zoning of an area where invasive work on a system containing a flammable gas is to be carried out
		Determining where flammable warning diamonds should be located
		Erection of safety barriers while working on systems which use a flammable refrigerant

Question 16 HC

Mod 2 R717 R32 R1234ze HCs	Which of these devices will not ignite a leak of flammable refrigerant?	An EX "n" rated device
		An EC evaporator fan motor
		A high pressure switch
		A thermostat

Question 17 HC

Mod 4 Intro HC	What implication does the density difference between HC and HFC have?	The HC refrigerant charge weight is lower
		The system must be evacuated for longer
		The HC system must be charged with gas not liquid
		The system must be charged very slowly to prevent damage to the compressor

Question 18 HC

Mod 4 Flam refs HC	How do you make sure it is safe to light a brazing torch when working on an HC system?	Ensure the area is well ventilated and use a flammable gas detector to check the area
		You must not un braze connections on an HC system, they should be cut using a pipe cutter
		Work outside
		Purge with oxygen free nitrogen

Question 19 HC

Mod 2 HCs	What is the typical PS for the high side of an R600a system with an air cooled condenser in a 32^{O}C ambient?	6.8 bar g
		10.3 bar g
		19.3 bar g
		24.8 bar g

Question 20 HC

Mod 2 R717 R32 R1234ze HCs	What is ATEX?	A European directive which covers equipment intended for use in a potentially explosive atmosphere
		A type of enclosure which can be safely used on a system which operates with a flammable refrigerant
		An electrical device which can be safely used on a system which operates with a flammable refrigerant
		A type of system which uses a flammable refrigerant

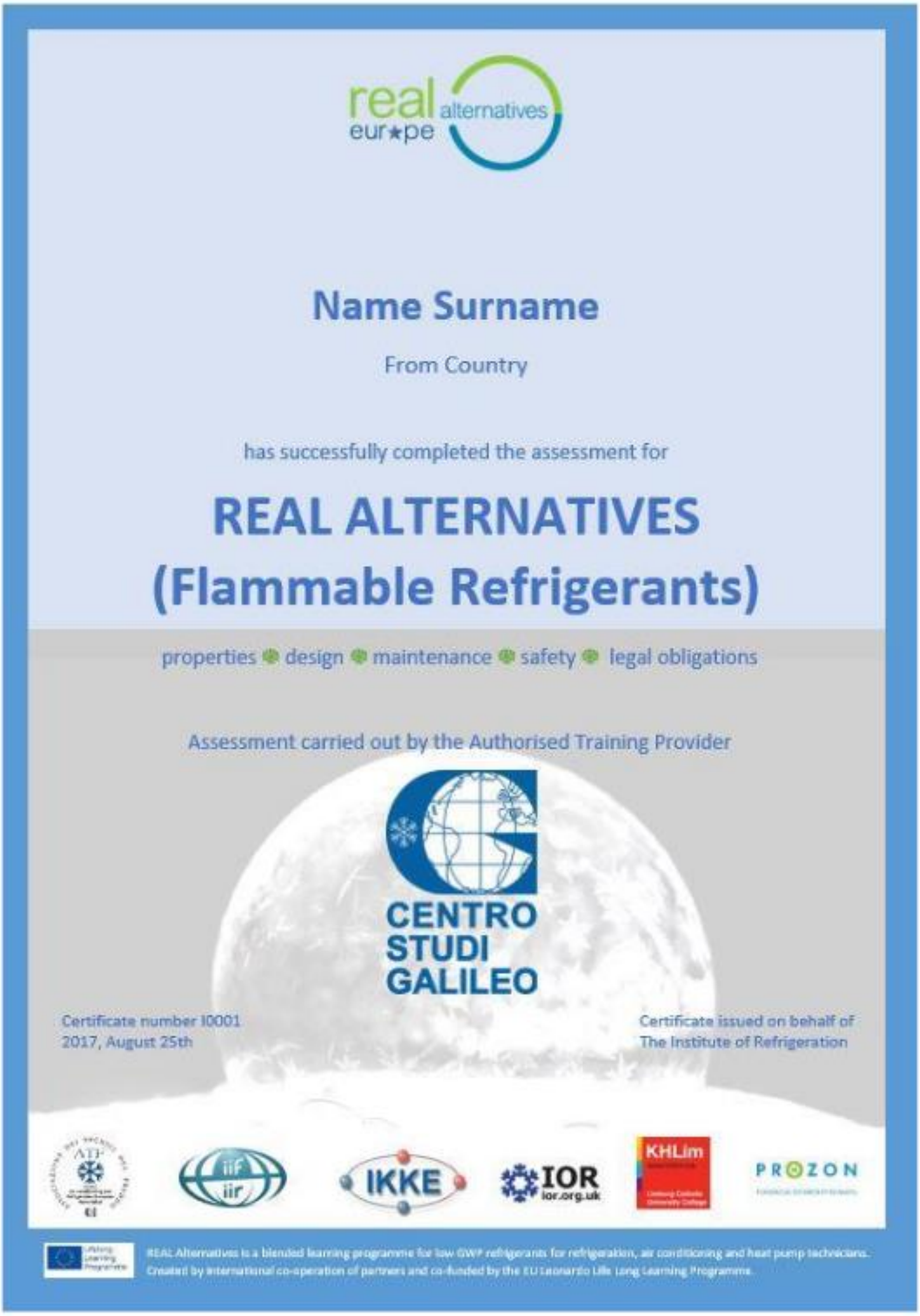
Annex 2: list of equipment, tools and material provided to the regional training centre in Grenada

Item	Quantity	Item	Quantity
4 way manifold gauge set	20	Steel brush	20
Electronic leak detector for halogenated refrigerants and blends	5	Wire stripper	20
Electronic leak detector for HC refrigerants	20	Mains tester with LED	20
Double stage vacuum pump	10	Oxy/Acetylene brazing unit	5
Digital scale	10	Metallic tool box	20
Portable charging station for R600a and HC blends	5	Cylinder with HC refrigerant R290	20
Refrigerant reclaim unit	2	HC refrigerant R600a	20
Advanced refrigerant identifier ID Pro	2	Cans HC blend refrigerant	20
Split air conditioning unit (R-22)	2	Refillable refrigerant recovery cylinders	20
Precise Electronic Thermometer	4	Set of copper tube rolls	10
Nitrogen cylinder with valve and cap	5	Packet of brazing rods	40
Nitrogen cylinder pressure regulator	5	Box of Flux	20
Set of 7 screw drivers	20	Set of filter drier for HC refrigerant	40
Set of 4 pliers	20	Set of adapters, fitting, flare nuts	20
Piercing pliers	20	Portable CO2 Fire extinguishers	5
Set of tubing tools	20	Portable Dry powder extinguishers	5
Cable reel	10	Refrigerant recovery unit with external recycling module	10
Combination wrenches set	20	Gallon of compressor mineral lubricant	10
Adjustable wrench	20	Gallon of compressor synthetic lubricant	10
Ratchet wrench	20	Pair of safety gloves refrigerant handling	20
Safety goggle	20	Pair of safety gloves for mechanical work	20
Cable knife	20	Pipe wrench 35 mm.	20
Hack saw and extra blades	20	Folding rule 2 m	20
Hammer	20		

Annex 3: list of participants to the train the trainer workshop

Name	Surname
Giltan	Baptiste
Frederick Perceival Philip	Beausoleil
Michael	Cadore
Alexander	Darville Jr
Ells	Breuno
Lance	Simpson
Henry	Frederick
Wayne	Grant
Earl Michael	Harte
Vincent	Lorde
Andrew	Miller
Alfred Tyrone	Paul
Gary	Peters
David	Ramsey
Satiesh	Sardjoe
Curtis	James
Stanley	Sovan
Milton	Spier
William	Sturrup
Jerry	Van Ommeren

Annex 4: REAL alternatives certificate



Annex 5: list of tools and material provided to National Ozone Units, National Refrigerant Associations, Vocational Schools to support the in-country training sessions

The Bahamas

Item	Quantity
Leak Detector D-400 (UN)	2
Manifold Set 4 valve UNIDO	2
Refrigerant Control Valve 1/4" flare	2
1⁄4" Charging Hose Gasket 10 pcs	2
3/8" hose gasket K10	2
Gauge HD R-600a,R-290, R22, B/PSI, C/F 80mm T-line	4
Gauge LD R-600a,R-290, R22, B/PSI, C/F 80mm T-line	4
Gauge HP R-134a,404A,410A,407C B/PSI, C/F 80mm T-line	4
Gauge HP R-134a,404A,410A,407C B/PSI, C/F 80mm T-line	4
Fieldpiece dual input thermometer ST4	2
Fieldpiece K-Type thermocoupler Bead Tip ATB1	4
Compact Clamp Meter w/Temp SC240 Fieldpiece	2
Filter copper capillair SM-20M Metric	5
Cylinder refrigerant 12.5 ltr.	2
Pair of safety gloves	10
Portable Charging unit HC, K-PGTB-A3	1
Charging Scale 0-5000 gr P&M	2
Oil 1 liter ISO32 (3GS)	5
Label Flammable Gas 100 x 100 (roll 1,000 pcs)	5

Saint Lucia

Item	Quantity
Leak Detector D-400 (UN)	2
Manifold Set 4 valve UNIDO	2
Refrigerant Control Valve 1/4" flare	2
1⁄4" Charging Hose Gasket 10 pcs	2
3/8" hose gasket K10	2
Gauge HD R-600a,R-290, R22, B/PSI, C/F 80mm T-line	2
Gauge LD R-600a,R-290, R22, B/PSI, C/F 80mm T-line	2
Gauge HP R-134a,404A,410A,407C B/PSI, C/F 80mm T-line	2
Gauge HP R-134a,404A,410A,407C B/PSI, C/F 80mm T-line	2
Fieldpiece dual input thermometer ST4	2
Fieldpiece K-Type thermocoupler Bead Tip ATB1	4
Compact Clamp Meter w/Temp SC240 Fieldpiece	2
Filter copper capillair SM-20M Metric	4
Cylinder refrigerant 12.5 ltr.	6
Pair of safety gloves	10

Portable Charging unit HC, K-PGTB-A3	1
Charging Scale 0-5000 gr P&M	2
Oil 1 liter ISO32 (3GS)	2
Label Flammable Gas 100 x 100 (roll 1,000 pcs)	5

Saint Vincent and the Grenadines

Item	**Quantity**
Manifold Set four way	10
Portable Charging unit for HC, K-PGTB-A3	5
Leak Detector for HC's D-400	10
Fieldpiece dual input thermometer ST4 including: 2 x Fieldpiece K-Type thermoc. Bead Tip ATB1	10
Compact Clamp Meter w/Temp SC240 Fieldpiece	10
Filter copper capillair SM-20M Metric	20
Flammable Gas Label	2500
Pair of safety gloves	20
Charging Scale 0-5000 gr P&M	10
Oil 1 liter ISO32 (3GS)	10

Suriname

Item	**Quantity**
Fridges (R600a)	2
Flammable Gas Label (set of 30)	2

Annex 6: lists of participants to training sessions for technicians

The Bahamas (20-22 August 2019)

The names of the technicians that paticipated in the training exercise are;

- Mr. Jerry Josey
- Mr. Deon Ferguson
- Mr. Keno Munroe
- Mr. Maurice Knowles
- Mr. Robert McKinney Jr.
- Mr. Dwight Forbes
- Mr. Refshinko Stubbs
- Mr. Kevin Gibbs
- Mr. Kashmir Colebrooke

Grenada (8-9 May 2019)

List of participants

Natural Refrigerants Workshop
T A Marryshow Community College (TAMMCC)
May 8th and 9th, 2019
ATTENDANCE REGISTER

#	Name	Company	Gender	Tel #	email
1	Amanaki Millette	Phillip's AC & Refrigeration	M	4101454	amanakimillette123@gmail.com
2	Allen Rick Lyons	Rapid Cool	M	4109620	rapdcoolgda@gmmail.com
3	Nicholas Joseph	BL International	M	4072531	
4	Chad Walcott	Total Engineering Co. Ltd	M	4560413	cwalcott@totalengineeringgd.com
5	Razzum Baptiste	Viking Engineering Co ltd	M	4222849	
6	Everton Connor	ELCICS	M	4065068	evertonconnor3113@gmail.com
7	Ian Benoit	ELCICS	M	4160616	
8	Glendon Regis	ELCICS	M	5340331	
9	Javid Mitchell	Modern Electrical Solutions	M	4232364	javidmitchell@techie.com
10	Shane Roberts	Modern Electrical Solutions	M	4141931	shane.roberts01@gmail.com
11	Arnold Fraser	Grenada Airports Authority	M	4155555160	arnoldfraser1@gmail.com
12	Kwesi Hamlet	LA Purcell/ Courts	M	5383431	ultrakool82@gmail.com
13	Devon Fraser	Courts	M	5373971	ultrakool82@gmail.com
14	Godfrey Debellotte	General Hospital	M	4495250	desmondg1691@hotmail.com
15	Ronald Mark	General Hospital	M		
16	Levon Philbert	General Hospital	M	4220975	
17	Kelly Ann Telesford	Self Employed	F	4178838	kellyanntelesford@gmail.com
18	Kenneth Stephen	STE-TECH	M	4590150	propertygrenada@gmail.com
19	David Ganpot	Ganpot's Technical Services	M	4202823	davidganpot@hotmail.com
20	Vonnet John	NEWLO	F	5342455 4236154	vonnetjohn24@gmail.com
21	Jade Pursue	NEWLO	M	4207966	jpersue@gmail.com
22	Trevor Andrew	Spice Island Beach Resort	M	4060507	
23	Karvin Johnson	Spice Island Beach Resort	M	5367077	
24	Ramesh Patrick	Grenada Elctrical/Franks Refrigeration	M	4578758	rameshpatrick917@hotmail.com
25	Jordan Paredes	Cool Breeze	M	4102192	oldwester28@outlook.com
26	Presley Thomas	Cool Breeze	M	4195246	presleythomas@hotmail.com
27	Jerry Coutain	Self Employed	M	5358284	jerrycoutain@hotmail.com
28	Aldrin Cox	James Refrigeration Services	M	4208769	aldrincox90@gmail.com
29	Britnay Frank	Grenada Electrical/ Franks Refrigeration	F	4584297	
30	Dondre Sandy	Ultra Kool	M	4199293	dondre473@gmail.com
31	Meril Fraser	Courts	F		
32	John Campbell	SGU (Observer)		4052718	jcampbell@sgu.edu
36					
37					
38					
39					
40					

List of Facilitators

Name	Company/Institution	Telephone	email
Mr. Lance Simpson	Cooling Tech Limited	534 6423	lsimpson@coolingtech.gd
Mr. Henry Frederick	Maurice Bishop International Airport	415 1198	hfrederick@mbiagrenada.com
Mr. Leslie Smith	National Ozone Unit	409 8128	Smithld31@gmail.com

Saint Lucia (4-5 February 2020)

Name of participants
Lambert Calixte
Brandon Mathurin
Keisha Lansiquot
Clemence Charlemagne
Archibald Anderson
Rudolph Felix
Sherwin Joseph
Collin Mondesir
David Charles
Daniel Jn Baptiste
Aaron Doxilly
Facilitators
Michael harte
Percival Beausoliel
National Ozone Unit
Kasha Jn Baptiste
Shanna Scott

Saint Vincent and the Grenadines (10-13 February 2020)

ATTENDANCE SHEET

1) Ronald Jessop	East Caribbean Metal Industry	Technician	wayneip@yahoo.com	593-2855
2) Cameron Julian Conliffe	AIW Fish Market	Technician	cameron.conliffe@gmail.com	530-8228
3) Lou-Anne Dover	Thompson Cooling & Electrical	Office manager	louloupeng@gmail.com	497-3060
4) Vondon Herbert	Thompson Cooling & Electrical	Technician	vondonherbert@live.com	434-9327
5) Bernard Celestine	Mustique Company	Technician	Juiceberryxs60@gmail.com	530-0138
6) Jason Raguette	AIW Fish Market	Technician	Jason24783@hotmail.com	530-4555
7) Kenny Campbell	Self Employed	Technician	Jjken21@hotmail.com	532-2181
8) Clyde Gurley	JAD	Technician	Docgurley32@gmail.com	531-3222
9) Damien Hinds	JAD	Technician	dodley@gmail.com	531-6946
10) Arthur A. Matthews Jr.	Self Employed	Technician	Mathur1318@gmail.com	431-6980
11) Zoanie Bailey	OSV	Technician	doaniebailey@gmail.com	492-7920

Annex 7: list of participants to the regional expert group meeting (Paramaribo, Suriname, on October 5, 2019)

Participant name	Participant function	Country
Ryan PERPALL	National Ozone Officer	the Bahamas
Leslie SMITH	National Ozone Officer	Grenada
Henry FREDERICK	Technician, consultant with National Ozone Office	Grenada
Kelly CYRUS (remote)	CEO from Grenz concept, RAC and R290 appliances supplier	Grenada
Shanna SCOTT	Alternate to the National Ozone Officer	Saint Lucia
Frederick BEAUSOLEIL	Technician and national supplier, consultant with National Ozone Office	Saint Lucia
Janeel MILLER	National Ozone Officer	Saint Vincent and the Grenadines
Brentin QUAMMIE	Alternate to the National Ozone Officer	Saint Vincent and the Grenadines
Cedric NELOM	National Ozone Officer	Suriname
Jerry VAN OMMEREN	Technician, consultant with National Ozone Office	Suriname
Satiesh SARDJOE	Technician, consultant with National Ozone Office	Suriname
Ozunimi ITI (remote)	Project manager, Industrial development officer	UNIDO
Guillaume CAZOR	Consultant	UNIDO

EASTERN AFRICA SUB-COMPONENT

Contents

Executive Summary

The project "Demonstration project on refrigerant quality, containment and introduction of low-global warming potential alternatives (Eastern Africa and Caribbean regions)" was planned to be implemented by UNIDO, as lead agency, and UNEP on behalf of the Governments of Eritrea, Kenya, Tanzania, Uganda, and Zambia. The demonstration project was approved at a funding level of USD 369,150 including PSC for UNIDO and USD 56,500 plus PSC for UNEP – in total USD 425,650.

It was approved in May 2016 at the 76th Meeting of the Executive Committee (ExCom) of the Multilateral Fund of the Montreal Protocol, at the funding level of USD 345,000 for UNIDO, and USD 50,000 for UNEP (excluding Project Support Cost (PSC)). For the refrigerant quality component, UNIDO allocate USD < 110,415 > and for the Caribbean component USD < 234,584 >. Preliminary project expenditures are USD < 110,181 > related to UNIDO, and USD < 0 > related to UNEP. Thus, the overall expenditure of the project is USD < 110,181 >.

The project aimed to demonstrate the availability of fake refrigerant; the lack of awareness of stakeholders; gaps in customs and legislation; and propose ways to ensure refrigerant quality in the market in Eritrea, Kenya, Uganda, Tanzania, and Zambia. The United Republic of Tanzania was selected as the lead pilot country for leading the implementation of the project due to its geographical location and the biggest by size and population among target countries.

The project included a series of activities:
i) carrying out surveys on refrigerant availability in the markets; ii) conducting a regional train-the-trainer workshop for refrigeration technicians; iii) training national for customs officers, environmental inspectors, importers, and staff from the Tanzanian Bureau of Standards in Tanzania and Eritrea; iv) equipping project stakeholders; v) establishing testing centres and; vi) supporting awareness raising among refrigeration technicians and all stakeholders.
Results of the activities are described within the report.

The project achieved all the goals as follows:

1) <u>Availability</u>: Through the surveys, it was clear that counterfake refrigerant is available in the majority of shops in project countries. Even there are shops were there are two prices for the same refrigerant, meaning better or lower quality. Also that for National Ozone Units, it is complete unknown fact, 'in this country there is no fake refrigerant'.
2) <u>Availability mimetic</u>: Refrigerant packed as R-22 were found containing several non-standard blends, expanded refrigerants, recovered refrigerant and more. The same for HFC, blends of refrigerants, hydrocarbons etc. The main source were cans and small cylinders. In general the counterfake refrigerants can be detected due to misleading information in the labels, colours of cylinder, trade names, mistakes in nomenclature, etc.
3) <u>Lack of awareness</u>: It is clear the fact that stakeholders e.g. technicians, importers, custom officers, government officers (including NOU) were not aware of counterfake refrigerant, consequences, extra costs generated – refrigerant consumption, more energy, potential compressor damage, reduce efficiency etc.
4) <u>Gaps in policy</u>: No legislation regarding refrigerant quality is available. Customs ensure that control substances are regulated, there is lack of awareness on counterfake. Since stakeholders are not aware, there is no legislation or standards for refrigerants.
5) <u>Quality assurance</u>: To ensure refrigerant quality, demonstration on the opposite was the first step. A workshop for trainers to demonstrate fake refrigerant and consequences; workshop for stakeholders, customs, bureau of standards, etc. Establishment of testing centers through the provision of tools and equipment including Ultima ID – HVAC Refrigerant Identifiers.

6) Quality assurance awareness: The project raised awareness on counterfeit refrigerants taking into account mislabelling, consequences of using fake refrigerants, potential safety risks and dangers including tips for indentifying fake refrigerants. Brochurs were developed and distributed to the technicians and other stakeholders.

Recommendations

16) The counterfake refrigerant are not only present in countries included in this Demo Project. UNIDO staff member has surveyed the situation and found the same cases in many countries. In general the same situation, lack of awareness, cheap prices offered, gaps in customs and legislation. The subject should be included in the HPMP and Enabling Activities since the consequences – more refrigerant leaking, more consumption, extra energy, etc – were demonstrated.
17) This issue needs to be tackled because refrigerant being phase out from some countries, ends in other countries under the label ‘new’. This became excellent business, just collecting recovered refrigerant, bottling and deliver. In some cases, the blends tested shows the right composition but not percentages, blends recovered and repacked in original cylinders.
18) It is required to establish testing centres, work in standards and public awareness. The counterfake refrigerant will likely be vented and more refrigerant consumed since, due to lack of awareness, the technicians blame the equipment.
19) It is important also to work with the importers and create awareness, it is clear that some of them are not aware of fake refrigerants.

I. Context and background

Context

Refrigerant supply is growing in line with the demand due to the increasing number of comfort, industrial and commercial equipment. However, low quality refrigerants of various sources and origins are finding their ways to the domestic market. This negatively affects not only the whole refrigerant market, but it also has become one of the major concerns and a serious obstacle to the development of the refrigeration-servicing sector. Contaminated, mixed or recovered refrigerants can lead to decreased cooling capacity and energy efficiency, reduced lifetime, increased servicing needs, they can damage the compressor of the equipment and end up being vented to the atmosphere.

All of the target countries are Low-Volume Consuming Article 5 countries, where the refrigerant market is small with loose standards, so low-quality substances can easily and quickly spread. Moreover, since the countries of the region have strong economic and commercial connections, refrigerants can easily cross borders. It is particularly true for Kenya, Tanzania and Uganda.

The predominant HCFC consumed in the region is HCFC-22 which is solely used in the refrigeration and air-conditioning servicing sector. The complex issue of low-quality refrigerants (contaminated, recovered, mixed) should be addressed in the first place in order to enhance the technical level of the servicing sector. For this, it is necessary to use policy instruments, monitoring mechanisms and raising awareness of dealers, technicians and end-users.

The root of the problem is that the purity of virgin refrigerant is questioned neither by the importers nor by the end-users. Most technicians assume that the refrigerant in the cylinder is "good enough" until the RAC system develops failures or cooling problems. Furthermore, even if a technician suspects the refrigerant is somehow contaminated, there is no proper mechanism/strategy to detect or avoid low-quality refrigerants.

The present proposal fits into the concept of the ongoing HPMPs: it would benefit from the established network of stakeholders and the experience gained so far. At the same time, it would give new impetus to improve efficiency and impact of the HPMP by extending its scope of activities and widening the group of stakeholders.

It should be noted that the project has an enormous relevance not only for the phase out of HCFCs but also for the phase down of HFCs. It is clear that counterfake refrigerant are available for all kind of refrigerants, including hydrocarbons. The presence of counterfake in article V countries is directly linked with the increase of consumption due to failure in the refrigeration systems and consequent recharge.

The lack of awareness at all levels, - service technicians, importers, trainers, custom officers – standards, policies and testing options are increasing the potential for more availability of fake. As mentioned before, fake refrigerant includes also ‘refrigerant phased out’ in other countries, recovered and mixed or expanded. In all cases, the refrigerant will end vented generating more ozone depletion, global warming and consumption.

Background

The quality of refrigerants available on the market in many developing countries is of major concern in relation to the development of the refrigeration servicing sector and the proper adoption of best practices. The main problems and challenges identified are mixed refrigerants on the market, fake refrigerants, i.e. substances sold as refrigerant but not in conformity with the requirements and specification related to any classified standard refrigerant, improper drop-ins i.e. some refrigerants sold as drop-ins but incapable of fulfilling the technical requirements and performing the task required, and incorrect labelling i.e. by mistake or on purpose. These discrepancies are driven by economic interests, deficiencies of the regulatory framework, insufficient and inefficient control mechanisms, and lack of technical knowledge.

The objective of the project was to demonstrate: i) the availability of fake refrigerant; ii) the lack of awareness of stakeholders; iii) gaps in customs and legislation; and iv) propose ways to ensure refrigerant quality in the domestic market in Eritrea, Kenya, Uganda, Tanzania and Zambia.

For this purpose, the project begin with surveys of refrigerant available in project countries. It was clear that the counterfake refrigerants are available in different forms. It was also clear that stakeholders were not aware of the fact.

Among other activities: surveys on quality of refrigerant; train-the-trainer workshop; training for customs officers, environmental inspectors, importers, etc; establishing testing centres; gap analysis; and awareness raising.

All the activities were completed, but more public awareness and workshops for stakeholders were missing and should be carried out in line with other projects activities.

Approval and cancellation

The project was approved for ‘Demonstration project on refrigerant quality, containment and introduction of low-global warming potential alternatives (Eastern Africa and Caribbean regions)’. Despite that, the two components are related to refrigeration service and HPMP the implementation activities were split due to regional execution and different activities and therefore the funds were also divided internally in UNIDO.

The project “Demonstration project on refrigerant quality, containment and introduction of low-global warming potential alternatives (Eastern Africa and Caribbean regions)” was submitted jointly by UNIDO, as lead agency, and UNEP on behalf of the Governments of Eritrea, Kenya, Uganda, Tanzania and Zambia. It was approved at the 76th Meeting of the ExCom of the Multilateral Fund in May 2016 (UNEP/OzL.Pro/ExCom/76/66, Decision 76/36).

UNIDO’s component (GLO/REF/76/DEM/336) was approved at USD 369,150 including PSC. From this amount, US$ 110,415 were destined for ‘Demonstration project on refrigerant quality, containment’ to be implemented in Eastern Africa region. UNEP’s component (GLO/REF/76/DEM/334) was approved at USD 56,500 including PSC. Since UNEP was not able to implement their component of the project, this was cancelled and funds returned at 82nd ExCom Meeting held in Montreal in December 2018.

> “*UNEP/OzL.Pro/ExCom/82/72*
> *115. Concerning the cancellation of the UNEP component of the global demonstration project in the Eastern Africa and Caribbean regions, the representative of the Secretariat said that, despite the best efforts of UNEP, the project had not yet been initiated, although the part being implemented by UNIDO was in its final stages. After consultations with UNEP, the*

recommendation to the Committee was to cancel the part of the project being implemented by UNEP.

(c) Regarding the global demonstration project on refrigerant quality, containment and introduction of low-GWP refrigerants in the Eastern Africa and Caribbean regions implemented by UNEP and UNIDO:

(i) To cancel the component implemented by UNEP (GLO/REF/76/DEM/334), and to note that US $50,000, plus agency support costs of US $6,500 for UNEP had already been returned at the 82nd meeting;
(ii) To extend to 31 July 2019 the project completion date for the component implemented by UNIDO (GLO/REF/76/DEM/333), on the understanding that no further extension would be requested, and to request UNIDO to submit the final report no later than the 84th meeting;"

Project components and implementation strategy

The demonstration project on refrigerant quality, containment and introduction of low-global warming potential alternatives was divided into three components:

Component 1: Policy review including detailed assessment of the current national policy frameworks. Certifying the presence of fake, mixed and/or recovered refrigerants. Detailed gap analysis on control mechanisms at the local and regional level and provision of technical advice.

Component 2: Technical assistance through provision of tools and equipment. Training of stakeholders on the importance of refrigerant quality and establishing testing centres to provide free service of identification to ensure quality and providing information on potential fake based on labelling.

Component 3: Awareness raising among stakeholders regarding the importance of refrigerant quality, related costs of using fake (operational, energy consumption, redo jobs, etc) and its relationship with the efficiency of equipment.

Strategy

The project concept included the following strategy and implementation plan. In the report it can be found that in general the project was well planned, due to different circumstances some activities were replaced.

Due to the nature of the demonstration project and the common characteristics of the target countries, Tanzania was selected as lead pilot country. While most of the activities targeted all beneficiary countries, many of the activities were implemented in the pilot country. This allowed the demonstration and monitoring of the project results at the country level, while ensuring that the experience and lessons learned are shared at a regional level offering the potential for regional replications.

II. Project objective

The objective of the project is to facilitate safer and more efficient operation of equipment in the RAC sector through the improved availability of appropriate quality refrigerants.

The objectives were slightly adapted to the needs of the project during the project implementation it may differ with those planned in the Project Concept.

- Demonstrate that fake refrigerant is widely available in the markets and the lack of awareness on the stakeholders including NOUs, service technicians, importers;
- Increase the awareness among technicians and end-users of the benefits to the RAC performances from the use of high-quality refrigerants;
- Identify the gaps in customs and legislation.
- Establish strategy to reduce the availability of fake refrigerant and provide means to test refrigerant quality;
- Foster the market availability of high-quality refrigerant;

III. Activities and Achievements

General approach

The project was planned with Tanzania as main country for the implementation activities due to the geographical location (borders with three countries included in the project), the port in Dar es Salam, the results of HPMP implementation in the country at the time. Based on that, a Tanzanian coordinator, Mr. Japhet Nidja, former Ozone Officer was selected and the project launched.

Having selected the project coordinator the implementation plan was decided and a brief mission to Kenya, Tanzania and Zambia undertaken. For the other two countries in the project, the project manager was informed and coordinated the activities. A copy of the project implementation plan can be found attached in Annex I.

The first activity was visiting the respective National Ozone Units of Kenya, Uganda, Tanzania, and Zambia. The project activities, approach and goals were defined during the visits. In addition, some refrigerant dealers were visited and a first approach for the market situation was obtained. In general, fake refrigerant, based on the packing, labels, codes and names, among others, is widely available. In some cases, they have a different price level. A copy of the mission report can be found attached in the Annex II.

Component 1: Policy incl. actual National Policy Frameworks and Gap Analysis

The project implementing activities includes the three components, the report will be focussed on the activities related to each component rather than chronological or logical order.

Context

This component was focused on the non-investment component. The planned activities were achieved with some changes but the results are considered satisfactory. The following paragraphs include the activities, the results and reports can be found in the annexes.

Activities

1. Assessments of the actual situation of the refrigerant supply chain including the quality of refrigerants available on the domestic market. Assessments of national policy frameworks were carried out for Kenya, Uganda, Tanzania, and Zambia.

2. National experts were hired in each country and survey assessments of the actual situation of the refrigerant supply chain, including the quality of refrigerants available on the domestic market were carried out. All reports were received and information shared with respective NOUs. The activity was coordinated by Mr. Japhet Kanizius, project coordinator and the report is attached as Annex III. The annex also includes a special report and country program from Kenya.

3. Samples of R-22, R-134a were randomly picked from refrigerant selling shops and tested for their qualities using refrigerant identifiers. Consequently, a general impression of the quality reliability of the supplied refrigerants in the local market was obtained. The results showed that counterfake refrigerants are available especially for HCFC-22 and HFC-134a. Detailed information on the standards and market availability of quality refrigerants is included in the mentioned report Annex III.

4. For the gap analysis, it was planned to contract Tanzanian Bureau of Standards - TBS. Some visits were paid to Ms. Agnes NJAU and the aim of the project agreed. UNIDO requested the services through the Terms of Reference, copy attached in Annex IV. The offer was received by UNIDO with budget beyond the available funding.

5. At the time of negotiation, UNIDO found out that UNEP was cancelling their participation in the project and decided to cancel the proposal. Since the gap analysis was a pillar for the project implementation, it was decided to contract national experts in Kenya and Uganda. The most relevant and accurate information had been received before from both countries.

6. The activity was carried out by Ms. Selelah OKOTH in Nairobi; Mr. Reuben LANGART in Mombasa and Mr. Paulo ODU in Kampala. A sample of the Terms of Reference for the consultant is attached in Annex IV.

7. The reports from the three experts were received and analysed. So far, the information was only shared with the respective National Ozone Units of the countries under the Demonstration Project. The socialization of the information was a component of the activities to be implemented by the cooperation agency UNEP.

8. The most relevant findings, comments and conclusions are summarized below. Table includes Gap Analysis, after proposed counter measures, conclusion and recommendations applicable to all countries under the demo project and other not only in the region.

Summary of Gap Analysis

No	Thematic Area	Gap(s) Identified
1	Policy and Legal Framework	The existing policy has inadequate statements relating to the RAC sector. This therefore fails in providing a strong guiding framework towards the growth of the sector The Controlled Substances Regulations has no provisions on use of spectrophotometer analyzer which would be essential in quality assurance The Regulations have no stringent punitive measures upon ODS/RAC gases importers in the event of shipment of fake refrigerants The Regulations have no framework for tracking movement of RAC gases once cleared at the port of entry. This makes it difficult to ascertain the end point for RAC gases declared as on transit.

2	Licensing and Licensing Conditions	While the accessed licenses show that all refrigerants are regulated, the aspect of quality control is not emphasized beyond the provision that only licensed refrigerants are allowed. There is no provision instructing the importer to ensure that certificate of conformance (CoC) is obtained prior to shipment. The use of the licensing system that has no linkage with the upcoming Integrated Customs Management System (ICMS) raises a gap in quality control as some refrigerants may easily pass the border point if due diligence is not undertaken by the Customs officials.
3	Standards	There are no easily accessible standards relating to the quality of refrigerants.
4	Enforcement	Inadequate presence of e*nvironmental inspectors* at the border points.
5	Interagency coordination	No clearly documented framework is in place regarding working relationship among the various stakeholders more specifically the regulators in the RAC sector

Proposed counter measures to prevent counterfeit/contaminated refrigerants from entry to local market

The counter measures that can be put in place include:

i. Encouraging collaboration between all the stakeholders involved thus; Anti-Counterfeit Agency, Customs, Bureau of Standards, NOUs and RAC importers Association to come up with the strategy to counter and minimize the influx of the contaminated/ counterfeit refrigerants into the local market.

ii. Encourage all importers who have not been using the Electronic Single Window Licensing System (or equivalent) to procure their goods through the system for transparency and accountability.

iii. As for lack of awareness on newly manufactured equipment containing fake / contaminated refrigerant, public awareness creation campaign to be conducted on use of quality refrigerants, on reviewed cylinder general appearance in terms of colour, labels and specifications according to UN numbers including testing of the refrigerants.

iv. Entry through illegal routes and diversion of transit counterfeits should be controlled by the sharing of intelligence information by all the relevant enforcement authorities by tracking the illegal routes and prosecuting those involved in diversion of goods on transit.

v. The dishonest importers/traders who request repackaging/refilling of contaminated refrigerants from the exporting countries should be prosecuted upon conviction. This can be done through government to government collaboration/agreement on the enforcement of the policies, standards and laws relating to prevention of contaminated refrigerants getting into the market. Both Governments could arrange meetings for the importers and exporters from the two countries to strategize on how to minimize circulation of the contaminated refrigerants in the local market. This effort will address the loopholes due to refilling /repackaging of contaminated refrigerants from country of origin by dishonest traders, as a result of requests made by importers.

vi. The NOUs to review their database of compliant RAC Importers from time to time and blacklist those that sneak contaminated refrigerants into the country.

Conclusion

Countries should put strategies in place to prevent or minimize the importation of contaminated /counterfeit refrigerants which include the enforcement of use of the *Electronic Single Window Licensing System* by all validated RAC importers.

However, there is a challenge in enforcement due to the activities of traders who import contaminated refrigerants through illegal entry ports and hence are not easy to prosecute. RAC importers reported that Contaminated / counterfeit refrigerants are popular to some traders because they are cheap, require low investment and guarantee them maximum profits.

During the process of survey, some RAC importers disclosed that some travel abroad to the source of refrigerants and influence them to refill/ repackage the contaminated/counterfeit in genuine popular branded cylinders and import them through either illegal routes/ entry points to avoid paying taxes or comprise by means of negligence/deceit of the control points and legally import.

In order to control this, there should be a Government to Government agreement /policy on standards of the export refrigerants meant for export by enforcing quality. Further this framework should explore convening of regular meetings of all RAC importers and Exporters of the countries concerned. This will call for training of the customs officers, and other inspectors involved in law enforcement. The customs officials should immediately alert the NOUs inspectors on imports of counterfeit refrigerants through illegal ports of entry.

Adequate human capacity and analyser equipment to be available in all entry points for use to test for any contamination of the refrigerants. These efforts require that any illegal entry points must be monitored through collaboration of all the regulatory agencies by deploying more personnel to man them.

To further strengthen compliance and enforcement there is a need to raise awareness among the stakeholders, the RAC Sector, Customs, NOUs, ACA, including the public on the relevant regulatory requirements on quality refrigerants.

A combination of all these efforts of regulatory, capacity building, awareness campaigns will minimize consumption of the contaminated refrigerants because the equipment owners and end users will be aware of the risk that can cause damage to their equipment.

These strategies will eventually reduce demand for these refrigerants in the local market.

Recommendations

This report was prepared by the consultants with the input of the relevant stakeholders through one to one interviews, telephone calls interviews and review of the existing legislation in coming up with the following recommendations:

i. The National Ozone Office (NOU) should ensure that it is always in touch with refrigerant importers so that trust could be developed, and hence transparency is seen to prevail and sharing of information on how to identify counterfeits refrigerants.
ii. There is need for continuous capacity building programmes for customs officers and NOUs officers. This should be well mapped out to include new officers based at border points. There is a need to include the Anti-counterfeit agency as currently their role in the RAC sector is not clear.

iii. NOUs and Customs must strengthen enforcement of refrigerants on transit. One possible solution is to consider a tracking system that must be endorsed by the importer and NOUs as well as Customs upon entry and exit of the refrigerants on transit.
iv. The inter agency Collaboration between NOU, Standard offices, Customs Department, Ports Authority and other enforcement officials needs to be strengthened in order to eliminate or minimize influx of illegal imports of contaminated/counterfeit refrigerants.
v. The NOU should ensure that refrigerant identifiers are functional, distributed and regularly provide trainings to customs officers at all entry points to increase efficiency in the identification of counterfeit refrigerants.
vi. The Anti-Counterfeit Authority should build human capacity through training among all the counterfeit inspectors.
vii. A harmonized Coding system should be embraced by Customs including use of UN number, chemical formula and ASHRAE number among others.
viii. ODS regulations should be reviewed to include all refrigerants and ensure that counterfeits refrigerants are not imported.
ix. The refrigeration and air conditioning sectors importers Association and technicians should be more involved in awareness campaign to minimize counterfeit refrigerants being imported into the local market.
x. NOU or Environment Authorities must ensure that the refrigerants are specified before endorsing the importing permits. This could be done by creating awareness of possibilities of repackaging of refrigerants, brand identification, labelling and colour codes.
xi. Provide enforcement officers with the necessary skills and equipment to identify, monitor and control imports of contaminated refrigerants. Incentives/awards to customs officers who manage to seize counterfeit refrigerants should be given incentives by way of rewards for their seriousness in work
xii. Develop brochures and flyers that should be displayed at all border points that can guide Customs and NOUs on chemical composition of the various refrigerants during analysis.
xiii. Strengthen the network for RAC technicians that would make it possible to avail information on quality of refrigerants to the regulators since they have direct contact with these refrigerants during servicing and maintenance works.
xiv.

Please note that the reports were shared with NOUs from Eritrea, Kenya, Uganda, Tanzania and Zambia. Since project funds were reduced and this activity was intended by the Cooperating Agency, UNIDO could only share the reports and advice to find the best way to implement in their own countries.

Training on refrigerant quality

Component 2: Technical assistance through provision of tools and equipment.

This component was focused on the investment component. The results reached mainly the trainers in project countries and, in some cases, refrigeration technicians. The planned activities were achieved with interesting results and an innovative approach. The results are satisfactory for UNIDO and, based on received comments, for the involved NOUs. The following paragraphs include the activities, the results and reports can be found in the Annex V.

Context

1. There are two main reasons for the wide availability of counterfeit refrigerants in the market, not only in those countries under the present project. The first is the absence of awareness among stakeholders on the availability of fake refrigerants in the market and, the second, the lack of testing methods for the technicians.

2. Lack of awareness is an asset for *fake refrigerant dealers* and the consequences were demonstrated during project implementing activities. Good refrigeration practices and procedures with the best available tools can be applied, however, the fake refrigerant spoil the efforts. At the end, more refrigerant is released, efficiency is reduced and energy consumption increased, among other potential consequences. Refrigeration technicians, in general, consider that the refrigerant is ‘good enough’ even if they have paid for ‘cheap gases’.

3. In line with the absence of awareness, once the issue is addressed, it is required to deal with the lack of testing facilities or tools. This is a challenge since refrigerant identifiers are expensive and delicate tools and to establish a testing centre is also difficult.

4. Prior to the project approval, a testing centre had been established in Asmara, Eritrea. At the time, one of the main issues in the country was the availability of contaminated refrigerant in the country and lack of testing centre. As HPMP component, the service for testing refrigerant was offered in the National Ozone Unit office. The results at the time were remarkable and fake refrigerant was drastically reduced.

5. Once the testing centre was operating, before purchasing refrigerants the condition of previous testing in some cases was established. Since this is an LVC country and the number of stakeholders is manageable, the refrigerant tested as contaminated was returned to the supplier.

6. As a consequence, after some meetings, the importers in Eritrea decided to request ‘certificate of origin’ and some quality assurance documents for the refrigerant.

Activities

1. The first activity was to provide all countries with Refrigerant Identifiers Ultima id. Pro. The quantity of identifiers were decided based on the size of the country and the needs as per agreement with respective NOUs. The table below was used for the supplier at the delivery time.

Component 2. Table 1. Distribution of refrigerant identifiers.

Country	# of Units	Contact person	Email	Address	Telephone
Eritrea	1	Kibrom WELDEGEBRIEL National Ozone Officer	kibromaw@gmail.com	Ministry of Land, Water & Environment Asmara Eritrea	290.0049525
Kenya	2	*To be delivered to UNIDO office in Kenya.* Emmanuel KALENZI (UNIDO Representative)	E.Kalenzi@unido.org	P.O. Box 41609 United Nations Avenue Nairobi KENYA	+254 207624369
Tanzania	2	Zainabu KUHANWA National Ozone Officer	zaikuhanwa@yahoo.com	Vice President's Office P.O. Box 5380, Dar-es-Salaam Tanzania	+ 255 222113857
Uganda	1	Margaret AANYU National Ozone Officer	maanyu@nemaug.org	National Environment Management Authority (NEMA), NEMA-House, Kampala. Uganda.	256 (0)414 251064 /5 /8
Zambia	2	Mathias BANDA National Ozone Officer	mbanda@zema.org.zm	Environmental Management Agency, Corner Suez and Church Road, Lusaka 10101, ZAMBIA.	260 211254023 /59

2. Following the success case in Eritrea, it was agreed with all NOUs involved in the project that a testing centre was required. In each country the conditions differ and based on that, centres were created in Training Centres, NOU offices, Refrigeration Technicians Associations or even refrigeration dealers. The testing service was agreed to be provided for free. In some countries like Kenya and Tanzania, two testing centres were established.

3. A workshop for training of trainers and government officials in refrigerant quality was held in Tanzania in February 2017. For this training, 20 participants, in the main trainers from seven countries attended. The participants from non-demo project countries were financed by the respective HPMPs. A list of participants, including the trainers can be found below.

	Name	Country	Comment
1	Kamthunzi Marvin	Malawi	Trainer
2	Peter Kiarie Nyagah	Kenya	
3	Joseph Kibet Rugut	Kenya	
4	Stephen Kanyoni K	Kenya	
5	Raymond Sichembe	Zambia	
6	Kelvin Kwila	Zambia	
7	Stephen Ngoma	Zambia	
8	Paulo Odu	Uganda	Associate trainer
9	Mohammed Kanyike	Uganda	
10	Basile Sebulikoko	Rwanda	
11	Alphonse Dushimimana	Rwanda	
12	Wabi Marcos	Benin	

13	Codjo Dedji	Benin	
14	Robinson Swai	Tanzania	
15	Scholastica Mbena	Tanzania	
16	Daudi Kadinda	Tanzania	
17	Said Mziwanda	Tanzania	
18	Haji Maalim Sinani	Tanzania	Local participant (Kibaha)
19	Victor A. Ngowi	Tanzania	Local participant (Kibaha)
20	Japhet Kanizius	Tanzania	UNIDO national expert

4. The aim of the training was to demonstrate the availability and consequences of contaminated or fake refrigerant in the system. For this purpose, the training started with the concept of good practices, good refrigerant management and introduction of alternatives. A copy of the Agenda and certificate can be found in the annex V.

5. Since the core of the workshop was to demonstrate the consequences of the fake refrigerant, three kinds of refrigerant were used in three HCFC based brand new mini spilt air conditioners of 12,000 BTU. For this First HCFC-22 original from the system, which was tested and approved. The second was charged with R-290 after recovery of HCFC-22 and the third was charged with contaminated HCFC-22 purchased locally, as pure HCFC-22, for the training. *(It should be noted that as a component of the training of trainers, the safety use and introduction of hydrocarbon as refrigerant was also included. The activity included good refrigeration practices, demonstration of HC as refrigerant using HC based equipment and fake refrigerant and its consequences). (It was also cleared that retrofit from HCFC-22 to HC is not recommended, and if the case, it will be under the responsibility of the user).*

6. Based on the refrigerant identifier, the contaminated HCFC-22 contained 80% HCFC-409A (R-22/R-124/R-142b) with (60%/25%/15%) and 10% air and 10% other gases. As it can be seen in the table below, taken from Honeywell refrigerants, the liquid density and boiling point of R-22 and R-409A are quite similar, therefore it can be easily mimetized. It is to be noted that the lubricant type differs, for HCFC-22 mineral oil is recommended and for HCFC-409A Alkylbenzene.

Genetron® Product	ASHRAE Number	Refrigerant Type	Refrigerant Class	Typical Lubricant Used*	Liquid Density (lbs/ft³)** 0 °F	80 °F	Boiling Point °F
Genetron 11†	11	Single Component	CFC	MO	98.2	91.9	74.7
Genetron 12†	12	Single Component	CFC	MO	90.6	81.5	-21.6
Genetron 13†	13	Single Component	CFC	MO	76.9	49.0	-114.7
Genetron 22	22	Single Component	HCFC	MO	83.6	73.9	-41.5
Genetron 23	23	Single Component	HFC	POE	72.0	–	-115.6
Genetron 123	123	Single Component	HCFC	AB	97.9	91.1	82.1
Genetron 134a	134a	Single Component	HFC	POE	84.4	74.9	-14.9
Genetron 422D	422D	Blend	HFC	MO	82.2	70.9	-45.7
Genetron MP39	401A	Blend	HCFC	AB	82.8	73.9	-27.3
Genetron MP66	401B	Blend	HCFC	AB	82.8	73.8	-30.2
Genetron HP80	402A	Blend	HCFC	AB	82.7	71.0	-56.1
Genetron HP81	402B	Blend	HCFC	AB	82.1	71.3	-52.6
Genetron 404A	404A	Blend	HFC	POE	75.8	64.7	-51.2
Genetron 407C	407C	Blend	HFC	POE	81.0	70.6	-46.5
Genetron LT	407F	Blend	HFC	POE	79.9	69.2	-50.9
Genetron 409A	409A	Blend	HCFC	AB	84.3	75.4	-30.0
Genetron AZ-20®	410A	Azeotropic Mixture	HFC	POE	77.2	65.6	-60.6
Genetron 500†	500	Azeotrope	CFC	MO	79.6	70.9	-28.5
Genetron 502†	502	Azeotrope	CFC	MO	86.9	75.4	-49.3
Genetron 503†	503	Azeotrope	CFC	MO	73.6	–	-126.0
Genetron AZ-50®	507	Azeotrope	HFC	POE	76.3	64.9	-52.1
Genetron 508B	508B	Azeotrope	HFC/PFC	POE	72.1	–	-125.3

7. The parameters were verified once the units were commissioned and several times, as can be seen in the report for trainers and some experts in the Annex V. After ca. 2 hours working, the conditions of the first and second units were stable as expected. The performance with HC-290 can be stated as little better and in this case was just to demonstrate how to operate this kind of refrigerant.

8. The third unit was consuming ca. 35% more energy based on the design, the efficiency of the system drop ca. 30%. Most importantly, the compressor became so hot that it was decided to stop the system and recover the refrigerant. After the procedure, the system was cleaned without using HCFC-141b, in this case with high efficient filters.

9. From the report of the main trainer, Mr. Marvin Kamthunzi, the conclusions and some technical comments were extracted for the present report:

Practical session: *Practical covered three days of the workshop interspaced with theory presentations. There were 3 new min-split units designed for use with R22. The participants were then divided in 3 groups.*

- *Group 1: install and operate pure R22*
- *Group 2: use unknown and assumed R22 (fake)*
- *Group 3: replace R22 with R290 (refrigerant grade)*

Refrigerant charging:

- *Unit design and pre-charged R22 – 583 gm;*
- *Fake refrigerant unit – as R22 – 583 gm;*
- *Unit for R290 (42% of R22 charge) 203 gm.*

Outcome: After several readings of various parameters, results were as follow:

- *Unit charged with fake refrigerant depicted highest temperature (82°C)*
- *R22 unit registered 62°C*
- *R290 unit had discharge temp of only 41°C*

It was also observed that:

- *R290 unit had lowest evaporator off coil temp of 14.3°C followed by R22 unit at 15°C and fake at 18°C.*
- *Overall power consumption was lowest for R290 unit at 974 watts followed by R22 at 1339 watts and fake at 1935 watts.*
- *The capacity (output) of the units was 12000 Btu/hr. this shows that on Energy Efficiency Ratio:*

R22 gives 8.96, Fake gives 6.20 while R290 is at 12.32 BTU per H per watt input.
The fake refrigerant was later identified to contain about 80% R409A, 10% air and 10% some unknown trace gases. Air in a system is considered a contaminant and results in high compressor head pressure resulting in high power consumption. Running for a long time on this refrigerant would eventually damage the system. Besides, R409A is HFC and could not work with mineral oil (lubricant) that is used in HCFC systems like the one with R22.

<u>Conclusion</u>

At the end of the 'Train-the-Trainer workshop (4 days for technicians and 2 days for non-technical (back to back)) the participants assured UNIDO, Demo Project coordinator that they would use the knowledge gained and would also share with those they work with in order to positively and effectively contribute to their respective countries' efforts to phase out HCFCs and promote environmentally friendly technologies including Carbon Dioxide, Hydrocarbons, Ammonia etc.

On fake refrigerants, the participants found it very useful and informative as a few countries in the region reported to have experienced unexplained equipment failures that were never thought to have been caused by use of fake and or contaminated refrigerants. In this regard, the Refrigerant Identifier has become an invaluable tool to counter fake refrigerants. There are also a number of falsely labelled refrigerants in order to conceal the real type of chemical contained.

Participants further reiterated their desire to build capacity within their respective fields through training so as to keep pace with the changing technologies.

The two day Non-technical group also requested training to last at least three days. After using the refrigerant identifier they felt UNIDO should assist Tanzania Bureau of Standards and Customs with similar equipment for use in strategic locations to effectively control fake refrigerants as a means of refrigerant quality control.

10. In addition, a training for Customs Officers, Border Police, Ministry of Environment staff, Tanzania Bureau of Standards, importers and other relevant staff was held back to back with the training of trainers. The report from Mr. Kamthunzi includes the results of this workshop.

11. The same activity, training of trainers including test of fake refrigerants was carried out in Eritrea in June 2019. The results do not differ much from those from the demonstration in Tanzania. The report from the trainer, Mr. Kamthunzi, is attached in the annex V. Some comments and conclusion extracted from the report are below:

Practical session: Practical was for one day of the workshop period in each location interspaced with theory presentations. There were 2 new min-split units designed for use with R22. The participants were then divided in 2 groups.

- *Group 1: install and operate pure R22*
- *Group 2: install and operate with unknown and assumed R22 (fake)*

Refrigerant charging:

- *Unit design and pre-charged R22 – 910 gm;*
- *Fake refrigerant unit – (as R22) – 910 gm;*

Comments:

- *Unit charged with fake refrigerant depicted highest compressor temperature (109 and 95°C)*
- *R22 unit registered compressor temperature of 84 to 92°C*
- *R22 split unit was run for a longer period than the one with assumed fake. This was due to the fact that group 2 had to recover original refrigerant, weigh and recharge with deferent refrigerant.*
- *The assumed contaminated/fake refrigerant was actually mixture of R22, R134a and 409a (50%, 45%, and 5%) since the available cylinders had pure refrigerant composition, though contaminated/fake refrigerants are available in certain places in the country.*
- *HFC 134a, 409a are not compatible with mineral oil used with HCFC 22. This may explain the rise in compressor casing temperature. Running this system for longer period, say full day, would have resulted in oil degradation and compressor failure.*
- *R 134a, though not suitable as retrofit alternative to R 22, is a low pressure refrigerant and therefore the other recorded parameters cannot be used for comparison. Fake refrigerant would have showed the high pressures and temperatures associated with characteristics and therefore corresponding higher energy consumption.*
- *Availability of suitable alternative to R22, for example R 290 would have shown favourable (lower) pressures/temperatures and therefore lower energy use.*

Conclusion

At the end of workshop in both Asmara and Massawa, Stakeholders and technicians, the participants assured NOU that they would use the knowledge gained and would also share with those they work with in order to positively and effectively contribute to efforts to phase out HCFCs and where available and cost effective, promote environmentally friendly technologies including Carbon Dioxide, Hydrocarbons, Ammonia and other L-GWP alternatives.

*On fake refrigerants, the participants found it very useful and informative. Some reported unexplained equipment failures that could not have been linked to use of fake and or contaminated refrigerants. The pamphlet provided by UNIDO**, ‘REFRIGERANT CAN BE COUNTERFEIT!’** came at the right time as well.*

In this regard, the Refrigerant Identifier has become an invaluable tool to counter fake refrigerants. There are also a number of falsely labelled refrigerants in order to conceal the real type of chemical contained. However, for Eritrea, they only have two working units and therefore more would be required.

Follow up action

For continuation of the training objectives the NOU should ensure that trainers have access to equipment and specialized tools, so as to provide meaningful and effective training in a professional manner. It is encouraging though, to UNIDO to note, that those trained last year, *have been able to conduct training workshops, to train others, at least twice locally to date already.*

Measures are to be taken for effective public awareness involving government agencies, importers, end users and technicians on influx of counterfeits. It is through government involvement that suitable registration and regulations can be enacted and implemented in order for those with lawful authority to enforce compliance.

Some of the participants deliver reports with lessons learned and recommendation. The following summarized of some of the reports:

Peter Nyagah - Kenya

I wish to express my appreciation for the chance to take part in the regional training in Tanzania starting on the 20-2-2017 to 24 -2-2017. The training was very helpful. We learnt several things such as:-
-how to detect fake refrigerants
-measuring performance parameters using pure and fake refrigerants
-how to use the refrigerant analyzer
exchange of experiences from various countries.
I look forward to participating in more of such trainings in the future
Too I would request that one of those analyzers be stationed at NITA Mombasa because it is more strategic and has the most interaction with the refrigeration industry.
Regards

Mr. Rugut – Kenya

1. The demonstration through practical means for the use of fake/wrong type of refrigerant in a designated system affect the sector adversely.
2. Awareness of the presence of impure gases in the market.
3. We need to pass this knowledge as fast as possible.
4. Availability of testing and proving equipment is paramount.
5. A follow up in how to place control systems especially views from the RAC techs is the way to speed this up.

RECOMMENDATION
I take this opportunity firstly to give my sincere thanks to Vice President's Office and UNIDO for my nomination to attend this workshop; I have acquired new knowledge and skills towards my career. It is therefore, this workshop has prepared me to share acquired knowledge, skills and experience with my fellow RAC Technicians and Artisans.
Secondly, the workshop duration was not enough for the participants to cover the materials given; therefore, I am laying a special request that the preparations of this kind of workshop(s) should consider the adequate time to meet the planned contents.

Prepared By: Said Mziwanda, Tanzania

RECOMMENDATIONS
To be in a good position the authority concerned should be provided:

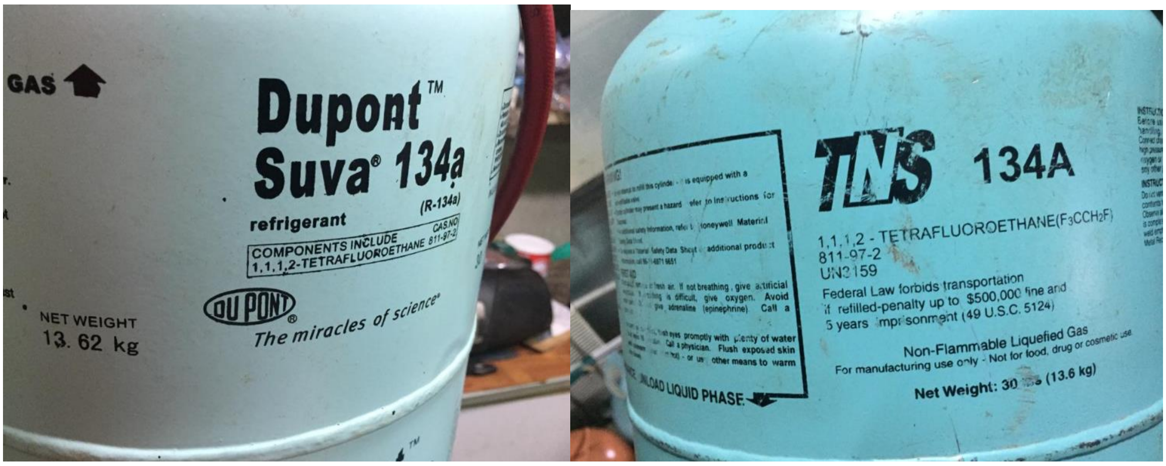
- *standby generator before*
- *adequate time of training which is relevant with the materials provided*

- *adequate tools and equipment for recovery, recycling, reclamation, and refrigerant handling containment etc*
- *several workshops be completed within a short time*

IMPLEMENTATION PLAN IN MY DAILY WORK
The phase-out of unwanted refrigerant like R22 and introduces (in the market) new refrigerant, like R290, is a global strategies and the aim is to protect the ozone layer. The following is the implementation plan which I thought will work

(i) *to inform or educate the Centre Management to be aware of the refrigerant quality*
(ii) *to prepare / purchase new refrigerants*
(iii) *to involve other staff and trainees concerning protection of ozone layer*
(iv) *to prepare schedule of removing unwanted refrigerant and charging new refrigerant*

Mr. Kadinda, Tanzania



'Dupont' Suva and R-134A

Component 3: Awareness Raising including Information Dissemination

This component was planned to be implemented by the Cooperating Agency. Unfortunately, it was not possible to carry out the activities and UNIDO took over and redistribute the funds and activities to complete the project in the best possible way.

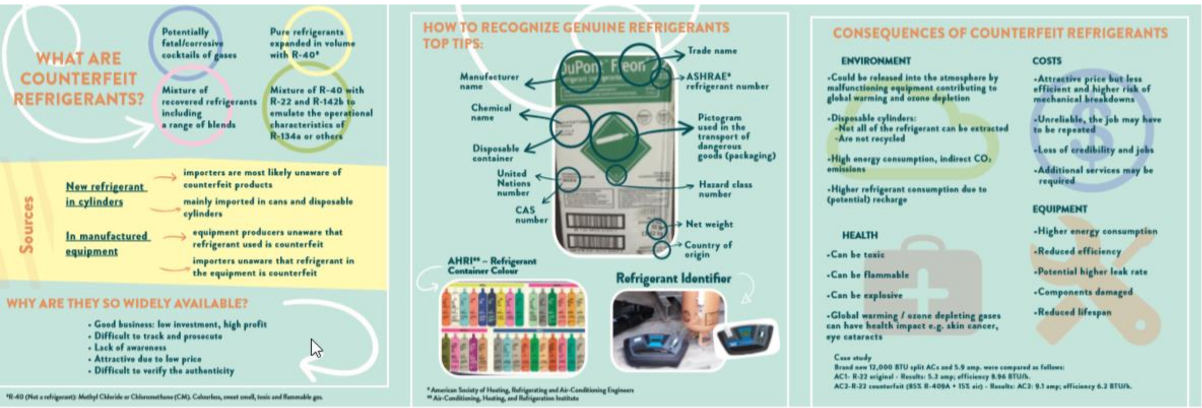
Context

The awareness and information dissemination is as relevant as the previous components. One of the main conclusions of the present report is the need of public awareness for the stakeholders. A second important final step is sharing information with not only the National Ozone Units but other institutions and policy makers. The report includes only the activities undertaken by UNIDO which unfortunately could not fulfil the plan.

Activities

1. The main activity carried out for public awareness was the design and print a brochure with information related to Counterfeit Refrigerants. The design was shared with some of the Ozone Officers, trainers and stakeholders involved in Demo Project and other.

2. Below the English version of the brochure, a Spanish version was also completed. In the Annex VI copies of the brochures can be find.



3. Copies were delivered to the respective NOUs Eritrea, Kenia, Tanzania, Uganda and Zambia for distribution. More than 200 copies and file to be reprinted if required were sent. Each country has the right to distribute the brochures as per they own criteria.

4. The complementary activities related to this component are included in the report of trainings held in Tanzania and Eritrea. Unfortunately, this component could not be completed.

Replace for R-134a and R-600

IV. Financial report

The demonstration project was approved at a funding level of USD 369,150 including PSC for UNIDO and USD 56,500 plus PSC for UNEP – in total USD 425,650.

The project "Demonstration project on refrigerant quality, containment and introduction of low-global warming potential alternatives (Eastern Africa and Caribbean regions)" was approved as Global including two regions. Based on that, the funds received by UNIDO were divided as follows:

1. Demonstration project on refrigerant quality and containment - Eastern Africa region. US$ 110,415
2. Demonstration project on introduction of low-global warming potential alternatives Caribbean region US$ 134,585

The present report includes only information related to the first component related

Upon project completion, the estimated project expenditures are USD <110,181> related to UNIDO's component, it is to be noted that UNEP's component was returned with balance of expenditures equal cero USD <0>. Thus, the overall cost estimate of the project is USD <110,181>. Any balances will be returned to the Multilateral Fund after financial completion.

At the time of presenting this report almost 100% of the funds approved for UNIDO - East Africa component have been committed and spent and 98% delivered. The table below shows the budget and actual expenses.

Activity	Planned Expenditures (US $)	Actual Expenditures As of Sep 2019 (US $)	Disbursement As of Sep 2019 (US $)	Funds available As of Sep 2019 (US$)

a. International experts	12,000	12,289	12,289	-289
b. Project management	5,000	2,031	2,031	2,969
c. National experts	25,000	24,886	24,620	114
c. Workshops	30,000	30,947	28,919	-947
d. Equipment	35,000	37,633	37,633	-2,633
e. Subcontract public awareness	3,000	2,395	2,395	605
f. Contingencies	415			415
TOTAL	**110,415**	**110,181**	**107,888**	**234**

The funds spent in equipment were used to purchase the refrigerant identifiers and room air conditioners used for the workshops as indicated in component 2 of the present report. A total of 8 identifiers Ultima Id Pro were purchased and delivered as per table 1 in Component 2. It also includes 5 mini-split units of 12,000 BTU, fake refrigerant and other materials and tools purchased for workshops.

V. Conclusions and recommendations

This paragraph does not include the conclusions already inserted above from the national and international experts. The present conclusions are from the project findings and implementation activities.

Conclusions

1. The first conclusion is that lack of knowledge from all stakeholders, even Implementing Agencies, on the fact that Counterfake or contaminated refrigerant is widely available in the market. It cannot be stated that ‘all over the world’ but it is more and more available.

2. Nowadays, the web commercial pages increased the availability of this kind of refrigerant. It is possible to find and purchase many kind of refrigerants at different prices without any restriction.

3. The project was implemented in direct cooperation with the experts in the countries, the involvement of NOU and local technicians was the main factor for the success. In cooperation with the project manager, many local refrigeration dealers were visited and different kind of refrigerants with misleading labeling and packing were found.

4. The demonstration carried out during workshops was one of the most important activities. With this, the technicians understood the consequences they can expect using the counterfake refrigerant. It was clear that the good refrigeration practices and proper use of tools are useless if the refrigerant has not standard quality.

5. Among the consequences of fake refrigerant can be listed the following:

   a) More energy consumption, indirect CO_2 emissions.
   b) Damage of components, compressor burnout, equipment to be cleaned.
   c) Reduce of equipment life spam.
   d) Lost of efficiency in the system.
   e) Can be flammable or toxic.

f) Cannot be recycled or reclaimed.
g) Potential increase in refrigerant consumption due to recharge.
h) Potential increase of leaks, if higher pressure refrigerant charged.
i) Unreliable, the job may have to be repeated. Loss of credibility for the technicians.
j) Counterfake refrigerant will end vented releasing ODS and GWP gases.

6. The couterfake refrigerant are widely available among other due to the following reasons.

   a) It is a profitable business.
   - In some cases it is matter just of bottling recovered refrigerant. This include all kind of pure of blend refrigerants that can be contaminated by particles, other gases, acidity etc. or unbalanced blends.
   - It is also possible to expand pure refrigerants with no-standard gases like R-40.
   - Just recovered phase-out gases bottled and reselled.
   - More and more examples can be found in the market.
   b) Difficult to track and prosecute.
   - As per the results of surveys included in the present report. In some cases, customs allow refrigerants which are not banned. For customs, the quality is not a requirement.
   - Refrigerant are not entering the countries through the regular ways.
   - Refrigerant are not properly declared in customs
   - No country of origin, no proper import licences.
   - More and more examples
   c) Lack of awareness
   - This can be the most important conclusion. In general, the concept is that there is only one quality, even if refrigerant of the same denomination is available at quite different prices in the same market.
   - Even importers, seems to be, are not aware on the refrigerant quality.
   - Stakeholders are unaware of quality and consequences.
   - Good refrigeration practices and, in general, training does not include the refrigerant quality as subject.
   d) Attractive due to low price
   - Price drive market.
   - It is repacked in some countries and distributed in low quantities
   e) Difficult and expensive to verify authenticity
   - One of the first activities implemented in the project.
   - Refrigerant identifiers should be also provided to training centres

7. The refrigerant identifiers are very expensive but delicate tools. So many units have been distributed all over the article 5 countries and are damaged. The refrigerant identifiers are designed to be used for gas and includes a device to be used for liquid. One of the issues is that if couterfake refrigerant is being tested, the identifier can be used with liquid refrigerant and the consequences are well known after some uses. It is recommended to emphasize the uses to use always the identifier with the liquid testing device and also with the small 'capillary valve' included and seldom used.

8. As per the brochure prepared by UNIDO, there are some tips on how to identify counterfake refrigerants:

   a) Lower or upper case: E.g. R-134a is different to R-134A or R-141b to R-141B, and R-410A to R-410a, inclusive R-600 is not R-600a and R-600A does not exist.
   b) Small letter is used for single refrigerant to indicate change in chemical composition. R-134 is different than R-134a.

c) Capital letter is use to indicate the composition of the blend R-410A, R-508B or R-401C. Eg. R-409A (60% R-22/25% R-124/15%R-142b) and R-409B (65% R-22/25% R-124/10%R-142b)
d) Brand names: Dupont can be found in some cylinders and it is DuPont. Genatron is used instead of Genetron.
e) General appearance of the cylinders: Some cylinders or cans are scrapped, repainted, soiled or damaged. Some are out of dimension or even renamed.
f) AHRI colour code: The colour code is a good guidance, sometimes same refrigerant is available in cylinders of two different colours.
g) Misleading advertising: from R-600a or R-290 non-flammable to ‘replace for’ can be found in the market.
h) The brochure include some tips on how to recognize genuine refrigerants. It is to be noted that not all should be included, but it can be used as guidance. Some tips are: manufacturers name; trade name; ASHRAE refrigerant number; chemical name; UN number; CS number; country of origin; net weight.

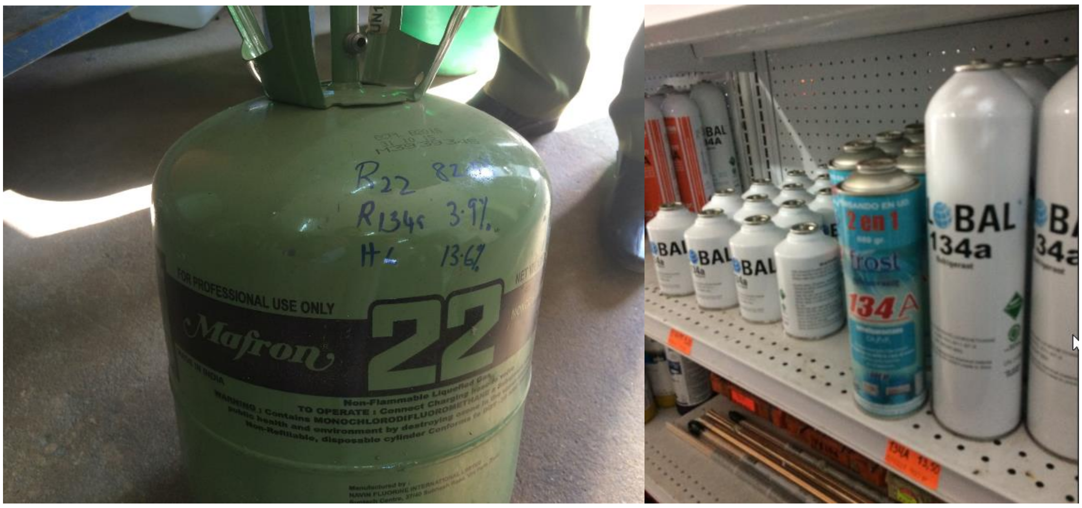
9. The lack of knowledge on the refrigerant quality is also found in the custom officers. In general, the training is focused in the substances and licensing systems but the general aspects of the packing and labeling is not included.
10. The best way to stop the counterfeit refrigerants is through the training of technicians and public awareness. The brochure also includes some tips on this issue: - Check the packing or cylinder based on described; if possible, test the refrigerant; report counterfeit refrigerant to enforcement agencies, refrigeration service technicians association, relevant authorities; do not accept counterfeit (it is for your own safety); no demand, no offer; public awareness, spread the word; low enforcement, policy and standards.
11. Project manager have found counterfake refrigerant in many countries beyond those included in the present demonstration project. Even, in some countries, the refrigerant available in the training centres was first externally verified and then tested, the results showed that there is clear relation between packing and containment. In many cases contaminated refrigerant was found and good examples to teach on ways to identify potential fake refrigerants based on the label.
12. Conclusion of the project implementation:
    a) Due to geographical distribution, the project was indirectly implemented in two parts. The main was for the neighbor countries Kenia, Uganda, Tanzania and Zambia and the second for Eritrea. In both cases the same activities were implemented and the results are summarized in the present report.
    b) The support received from the National Ozone Units from Kenia and Uganda was very valuable for the project implementation.
    c) The lack of funds for public awareness and information dissemination jeopardize the project implementation plan. Since the activities from UNIDO side were well advanced, the project was redirected and completed in the best possible way.

Recommendations

The recommendations given are intended to be applicable and not a wish list which would require big investment and impossible activities.

1. In the training activities for trainers and technicians, is should be included the subject of fake refrigerants. The basic tips for identification, the testing options with or without identifiers and the demonstration with refrigeration units, hopefully new refrigerant identifiers should be included.

2. Wherever possible, a testing centre should be established. It should provide the service for free and have statistic information on counterfake refrigerant available in the country. At least one testing centre should be located in the main city and second in a port city if the case. Training centre is a good option, however, every country can find the best venue for this purpose.
3. Public awareness at all levels is the most important tool to combat the counterfake refrigerants. Since so many environmental treats are included in the fact that counterfake refrigerant is entering the markets, it is a good opportunity to join national public awareness campaigns to protect the environment.
4. It is required to include the basic information and provide brochures, like the one designed by UNIDO, to the custom officers. It will be necessary to include the requirements in the check lists.
5. The brochures were design in English and Spanish language. Some copies have been delivered to countries were UNIDO is implementing projects. It can be distributed in other countries or at least copied and adapted to the local requirements.
6. It is time to work on standards for refrigeration, as already included in the Enabling Activities for the Kigali Amendment. The standard should not be only for HFC but for all kind of refrigerant, labeling and packing.



Composition for R-22 and R-134A and R-134a

ANNEXES

Final Report

Demonstration project on refrigerant quality, containment and introduction of low-global warming potential alternatives (Eastern Africa and Caribbean regions)

Annex I. Agreed Work Plan for the project implementation.

Tanzania_Workplan _UNIDO Assignment

Annex II. Report of joint mission Project Manager and Project leader.

Mission report Zam-Kan-Tan JN Sep

Annex III. Reports of:

Standards and Market Availability of Quality Refrigerants in Tanzania, Kenya, Uganda and Zambia)

Tanzania_UNIDO Assignment_DEMO

Standards and market availability of Quality Refrigerants in Kenya

Standards and Market Availability o

Country program Kenya

Country program Kenya Oct 16 -.docx

Annex IV. Reports on gap analysis

Reports on gap analysis

UNIDO FINAL SURVEY REPORT.doc

ODU's Survey June 19.docx

Refrigerant Survey_Gap Analysis

REFRIGERANTS SURVEY IN NAIROBI

Annex V. UNIDO Brochures

Refrigerant can be Counterfeit! English version

Brochure_Gas_En.pdf

!Los refrigerantes también los falsifican! Spanish version

Brochure_Gas_Sp.pdf

Annex V

Final Report on the Project

Decision 76/35 of THE EXECUTIVE COMMITTEE OF THE

MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL

Development of Regional center of excellence for training and certification and demonstration of low-global warming potential alternative refrigerants in Eastern Europe and Central Asia

Submitted by the Russian Federation

As of December 2019

CONTENT

Introduction

EXECUTIVE COMMITTEE OF THE MULTILATERAL FUND FOR IMPLEMENTATION OF MONTREAL PROTOCOL at its Seventy-sixth Meeting (Montreal, 9-13 May 2016) approved (Decision 76/35) the demonstration project for the Eastern Europe and Central Asia region on development of a Regional center of excellence for training and certification and demonstration of alternative refrigerants with low-global warming potential (hereinafter referred to as Regional Center), with allocation of funds in amount of US $591,600, plus agency support costs of US $75,076 (total amount US $666,676.00).

In line with Decision 72/40 the allocated funds came from the annual contribution of the Government of the Russian Federation to MLF for 2016 (against the MLF invoice in amount of US $5,290,344.00). The Executive Committee of MLF requested the Government of the Russian Federation to complete the Project within 36 months of its approval (May 2016) and accordingly submit the final report. As a matter of fact the money was wired by MLF to the Implementing agency in July 2017.

According to the Trust Fund agreement between the United Nations Industrial Development Organization (UNIDO) and the Government of the Russian Federation dated 31 August 2017 UNIDO has been implementing the Project in 2017 – 2019.

Objectives of the Project and deliverables

The overall objective of the project is to improve the technical capacity of the refrigeration and air-conditioning sectors in the countries of the Region (Eastern Europe and Central Asia) and consequently facilitate:

- overcoming the barriers on the way to introduction of low-GWP refrigerants;
- improving service practices used on the national level, and
- reducing the level of F-gas emission from the existing refrigeration and air-conditioning equipment.

As result the trained national technicians and designers will enhance their awareness, understanding and promoting introduction of new approaches to energy efficient design and operation on their national market in domestic, commercial and industrial refrigeration and air-conditioning systems.

This project sets up the training and assessment facilities at the Regional Center for the benefit of the countries of the Region, on the basis of using of curriculum document and certification program for the national level corporate employees performing maintenance, servicing or manufacturing of products and equipment relying on or containing F-gases and/or low-GWP refrigerants in line with the requirements of article 10 of (EU) № 517/2014, Directive 2006/40/EC; Regulations (EC) № 303/2008, (EC) № 306/2008 and Regulation (EC) № 307/2008. The Regional Center acts also as a demonstration hub and knowledge base for alternative refrigerant technology especially for safe handling, application and related systems design using low-GWP refrigerants.

The main deliverables of the Project are as follows:

1. Center of Excellence is established and put into operation with fully equipped training and assessment facilities.

2. Training and certification programs and technical advisory services of the Regional Center are developed and accredited under Real Alternatives certification system.

3. A common draft F-gas regulation harmonized with (EU) No. 517/2014 was developed and published as e-version in Russian and English languages for dissemination among partner countries of the Region.

4. Demonstration Project showing utilization of low-GWP refrigerants and energy efficient design is in place and accessible for conducting study tours and analysis.

5. Common curriculum was developed for providing vocational and academic studies covering refrigeration and air-conditioning service practices.

By collocating the practical training and job certification with the development of expertise in design and systems operation, the Regional Center will be able to provide excellent opportunities for private and public organizations to demonstrate new and innovative technology and the latest refrigeration and air-conditioning systems, components, controls and operating practices. The operating model is therefore based on public-private partnerships where mutual benefit can be derived to achieve the common objectives of improving current practices, performance, energy efficiency and climate impact of refrigeration and air-conditioning systems.

Financial statement as of December 2019

	Component	Funds approved, USD	Disbursement, USD
1	Infrastructure of the Regional Center	128,500	138,697
2	Operation of the Center	39,600	45,347
3	Adaptation and Printing of UNIDO Programmes and Manuals (English and Russian)	51,500	55,500
4	Development of Online Interactive Courses (English and Russian)	58,500	62,500
5	Pilot Refrigeration Plant Based on Natural Refrigerants	214,000	188,261
6	PR Activities	8,500	8,500
7	Internet-portal of the Project (in Russian and English)	28,500	30,295
8	Management, Office	62,500	62,500
	Total:	**591,600**	**591,600**

Main activities and key outcomes

Planning Activity (as per initial project document)	Outputs or service delivered	Outcomes observed
Deliverable 1: Center of Excellence is established and put into operation with fully equipped training and assessment facilities	– With support from the Russian Federation the host side (Ministry of Nature Protection of the Republic of Armenia) nominated the beneficiary for location and establishment of the Regional center of excellence; – Bidding procedures implemented to choose the Contractor/ Service Provider; – The instructors of the Regional center of excellence received training in Moscow on stands operation; – Works completed on production,	Regional center of excellence with training and assessment facilities was put into operation.

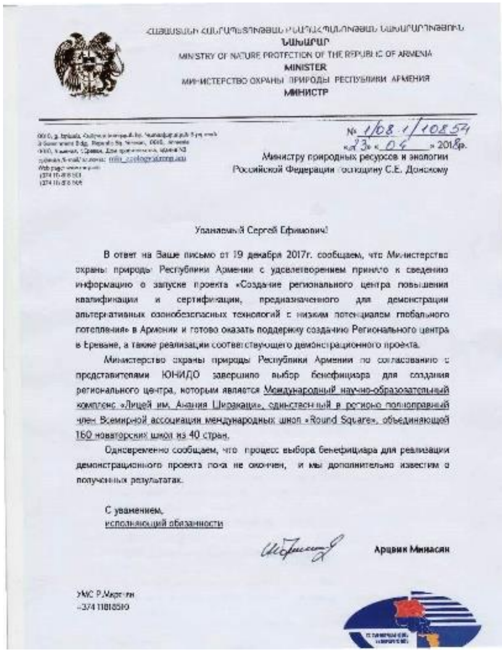
Planning Activity (as per initial project document)	Outputs or service delivered	Outcomes observed
	delivery and installation of equipment at the Regional Center of excellence; – The launching ceremony was held on September 18, 2019. It was a part of the session of the Interstate Ecological Council of the Commonwealth of Independent States (CIS) which was attended by representatives of Environmental ministries, UNIDO, RAC associations and NOUs representatives, technical experts communities and Lyceum students; – 5 trainings were conducted; a new contract was signed to conduct trainings in the Regional Center for 45 technicians representing the Eastern Europe and Central Asia countries.	
Deliverable 2: Training and certification programs and technical advisory services of the Regional Center are developed and accredited under Real Alternatives certification system.	– Bidding procedures implemented to choose the Contractor; – Major part of work on developing training programs and technical advisory services were carried out before December 31, 2018; – Website http://hvaccenter.am/ was created for remote online learning; – 5 trainers were certified (F-gas + Real Alternatives); – The Regional Center was accredited under the Real Alternatives certification system.	Training Center is accredited under the internationally recognized EU certification system of Real Alternatives.
Deliverable 3: A common draft F-gas regulation harmonized with (EU) № 517/2014 was developed and published as e-version in Russian and English languages for dissemination among partner countries of the Region.	– A set of documents on F-gas regulation was translated into Russian (working language in the Regional Center); – Proposal based on F-gas regulation for simplification of certification reasonable for the countries of the Region was developed; – Each country of the Region is expected to consider national regulations harmonization after ratification of the Kigali Amendment.	A set of useful documents was compiled and then translated into Russian language to facilitate development of national regulation and certification systems in the countries of the Region.
Deliverable 4: Demonstration Project showing utilization of low-GWP refrigerants and energy efficient design is in place and accessible for conducting study tours and analysis.	– – The host side (Ministry of Nature Protection of the Republic of Armenia) defined the beneficiary for development of demonstration project; – UNIDO carried out tender procedures to choose the Contractor/ Service Provider; – Works on production, supply and installation were carried out; – The Regional Center launching	Implementation of this Demonstration Project resulted in presenting real benefits from using hydrocarbon refrigeration system to enhance safety

Planning Activity (as per initial project document)	Outputs or service delivered	Outcomes observed
	ceremony was held on September 18, 2019; – Demo-project "Hydrocarbon refrigeration system for typical fruits and vegetables storages" is aimed at improvements in the field of safety, energy efficiency (by 34% on the demo-project site). – The information events were held in September 2019 for Armenian HVAC&R representatives and government officials and in December 2019 for technicians from Turkmenistan.	and energy efficiency with aim to spread replication widely.
Deliverable 5: Common curriculum is developed for providing vocational and academic studies covering refrigeration and air-conditioning service practices.	– Bidding procedures implemented to choose the Contractor/ Service Provider; – All procedures and works under the Contract were completed.	Common curriculum of the Regional Center is developed for providing vocational and academic studies.

Description of outcomes

OUTCOME 1: Center of Excellence is established and put into operation with fully equipped training and assessment facilities.

The Ministry of Nature Protection of the Republic of Armenia nominated the International Scientific-Educational Complex of "Shirakatsy Lyceum" for location and functioning of the Regional center of Excellence.



MINISTRY OF NATURE PROTECTION OF THE REPUBLIC OF ARMENIA
MINISTER
МИНИСТЕРСТВО ОХРАНЫ ПРИРОДЫ РЕСПУБЛИКИ АРМЕНИЯ
МИНИСТР

№ 1/08.1/10854
«23» «04» 2018г.

Министру природных ресурсов и экологии Российской Федерации господину С.Е. Донскому

Уважаемый Сергей Ефимович!

В ответ на Ваше письмо от 19 декабря 2017г. сообщаем, что Министерство охраны природы Республики Армении с удовлетворением приняло к сведению информацию о запуске проекта «Создание регионального центра повышения квалификации и сертификации, предназначенного для демонстрации альтернативных озонобезопасных технологий с низким потенциалом глобального потепления» в Армении и готово оказать поддержку созданию Регионального центра в Ереване, а также реализации соответствующего демонстрационного проекта.

Министерство охраны природы Республики Армении по согласованию с представителями ЮНИДО завершило выбор бенефициара для создания регионального центра, которым является Международный научно-образовательный комплекс «Лицей им. Анания Ширакаци», единственный в регионе полноправный член Всемирной ассоциации международных школ «Round Square», объединяющей 160 новаторских школ из 40 стран.

Одновременно сообщаем, что процесс выбора бенефициара для реализации демонстрационного проекта пока не окончен, и мы дополнительно известим о полученных результатах.

С уважением,
исполняющий обязанности

Арцвик Минасян

"Shirakatsy Lyceum" was founded in 1990 to reveal gifted children, manage their education and study their gift problems. Since October 2009 the "Shirakatsy Lyceum" has been officially recognized as a regional one, and since 2010, it has been a sound member of the World Association of International Schools «Round Square» (network of 150 innovative schools located in 40 countries on five continents). More than 300 graduates from "Shirakatsy Lyceum" continued their studies at leading world universities such as Harvard, Cambridge, Sorbonne, Oxford, Stanford, Lomonosov, Massachusetts, Tokyo, Beijing, and London universities.

The Regional center of Excellence is equipped with the following training simulators and equipment:

- CO_2-based refrigeration machine;
- HC-based refrigeration machine ("HC-based refrigeration machine" and "Retrofit to HC refrigerants");
- Training simulator "Welding and soldering. Supply and exhaust ventilation";
- Training simulator "Principles of refrigeration machine operation. Azeotropic refrigerants";
- Training simulator "Principles of refrigeration machine operation. Zeotropic refrigerants";
- Training simulator "Refrigerants. Types. Identification. Recovery and regeneration";
- Training simulator "Refrigeration machine. VRF";
- Training simulator «Refrigeration machine. Chiller & fan coil unit»;
- The furniture and office equipment have been supplied in the following scope: desks for students and a trainer, chairs for students and a trainer, desk for a trainer, lap tops, interactive whiteboard, racks for the back office, safety and warning signs, first-aid kits, consumables and tools;
- Training courses and software installed on the laptops to enable simultaneous training of 15 HVAC system specialists.

Fig. 1 Main class-room equipped with the state-of-the art training simulators

The Regional Center was launched in September 18, 2019. The launching ceremony was a part of the session of the Interstate Ecological Council of the Commonwealth of Independent States (CIS) countries. It was attended by more than 50 participants: ministers and deputy ministers of CIS countries, representatives of UNIDO, HVAC&R associations and companies, technical experts and students.

Fig. 2 Participants of the launching ceremony

Fig. 3 A ribbon-cutting ceremony

(from left: Erik Grigoryan, Minister of Environment of the Republic of Armenia, and Sergey Yastrebov, Deputy Minister of Natural Resources and Environment of the Russian Federation)

OUTCOME 2: Training and certification programs and technical advisory services of the Regional Center are developed and accredited under Real Alternatives certification system.

The Regional Center was accredited under the internationally recognized certification schemes (Real Alternatives) and accessed to the learning programs for technicians working in the refrigeration, air conditioning and heat pump sector, designed to improve skills and knowledge in safety, efficiency, reliability and containment of alternative refrigerants in English and Russian languages.

Fig. 4-6 Training process and handing of certificates

The accreditation scope of supply includes the following:

- learning booklets for individual self-study delivered as pdf downloads;

- e-learning modules that mirror the learning booklets;

- practical training course design;

- assessments and certification for individuals;

- a train the trainer programme and licensing of training providers;

- programme website.

5 trainers were trained and certified under F-gas and Real Alternatives certification systems.

The National Lead agreement was signed. The Regional Center as a National Lead will provide learners with access to the Real Alternatives materials, conduct trainings and assessment exams.

The level of equipment in the Regional Center was highly praised by the Centro Studi Galileo (Italy), which conducted the accreditation assessments with following remarks:

- The HVACR training center is very well equipped with several RAC didactical units (e.g. AC split, unit with f-gases, equipment with CO_2 and with HCs, etc). The technological relevance of the equipment is high. The disposition of the training equipment in the center allows the best task performance. There is also a vast, up-to-date and useful stock of reserve equipment, tools, and consumables.
- The five participants were motivated, very well prepared and highly skilled. They possess a remarkable theoretical knowledge and the motivation to perform the practical tasks; this allowed carrying out the training and assessments smoothly and rapidly. Many questions and comments raised by the participants allowed for a stimulating debate at the end of each session. The younger participants demonstrated a promising attitude and interest for the activity. All participants passed the three assessments with remarkable grades, higher than average.

Additionally, the Regional Center signed a special agreement on cooperation with the related Moscow training Center. So now the Regional Center can provide additional training courses for learners and grant them with safety and skills certificates (such as electrical safety, works at heights, pressure receptacles and soldering skills) valid on the territory of Russia and Eurasian Economic Union states.

OUTCOME 3: A common draft F-gas regulation harmonized with (EU) №517/2014 was developed and published as e-version in Russian and English languages for dissemination among partner countries of the Region.

The set of F-gas documents directly related to the training and certification issues were translated into Russian:

- Regulation (EU) № 517/2014 of the European Parliament and of the Council dated 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) № 842/2006 Text with EEA relevance;
- Commission Regulation (EC) № 1516/2007 dated 19 December 2007 establishing, pursuant to Regulation (EC) № 842/2006 of the European Parliament and of the Council, standard leakage checking requirements for stationary refrigeration, air conditioning and heat pump equipment containing certain fluorinated greenhouse gases (Text with EEA relevance);
- Commission Implementing Regulation (EU) 2015/2067 dated 17 November 2015 establishing, pursuant to Regulation (EU) № 517/2014 of the European Parliament and of the Council, minimum requirements and the conditions for mutual recognition for the certification of natural persons as regards stationary refrigeration, air conditioning and heat pump equipment, and refrigeration units of refrigerated trucks and trailers, containing fluorinated greenhouse gases and for the certification of companies as regards stationary refrigeration, air conditioning and heat pump equipment, containing fluorinated greenhouse gases (Text with EEA relevance);

These documents were taken into account when certification training courses had been developed and introduced.

The countries of the Region will consider the process of harmonization of national legislation and regulation after their ratification of the Kigali Amendment. The Regional Center is now ready to provide advisory services and technical assistance regarding implementation of needed harmonization of legislation and regulation on a request of any country of the Region. The Interstate Technical Council of National Refrigeration Associations has been established to accelerate this process.

OUTCOME 4: Demonstration Project showing utilization of low-GWP refrigerants and energy efficient design is in place and accessible for conducting study tours and analysis.

Demo-project «Hydrocarbon refrigeration system for typical fruits and vegetables storages» was implemented in Province of Kotayk, Armenia. Old-fashioned cooling system using CFC-12 as refrigerant was replaced with secondary refrigeration system using R290 (propane).

Fig. 7 Hydrocarbon refrigeration system installed in Province of Kotayk, Armenia

The new cooling system installation provided benefits in terms of safety, energy efficiency, reduction of life-cycle costs and opportunity for wide spreading replication.

Description of benefits considered while conducting study tours are as follows.

Safety

Refrigerant charge is 6 kg. Considering the fact that R290 is a highly flammable matter, the following fire safety measures have to be taken:

- all spark-hazardous electrical components are located beyond protecting casing and are installed in a separate control switchboard;
- all components installed in a protecting casing are explosion-proof;
- a protecting case has an internal alarm system with R290 leakage detector, which in case of refrigerant leakage isolates the refrigeration plant;
- new unit is installed outdoor as specified by fire safety requirements.

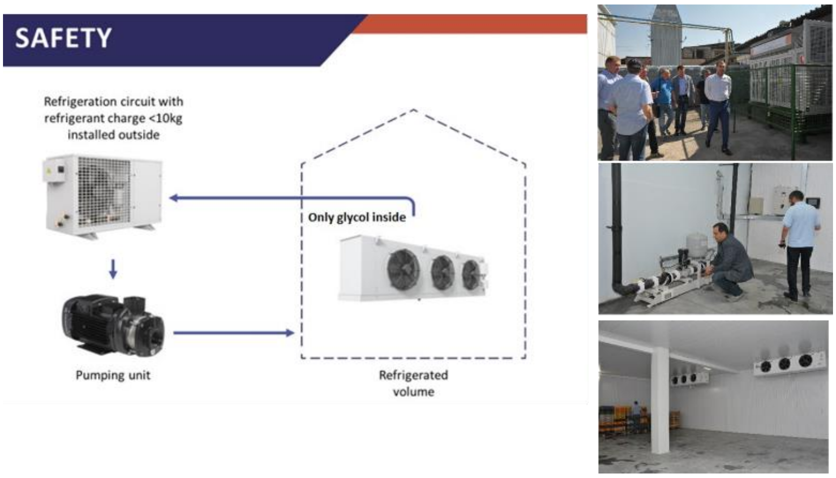
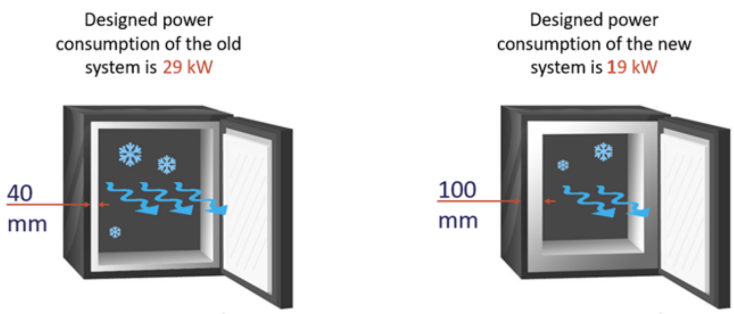


Fig. 8 Example of safety location of equipment

Energy efficiency



High energy efficiency is ensured by lower refrigeration load through enhanced heat insulation, condenser of larger size and automation system maintaining minimum condensing pressure. As result energy efficiency has improved by 34%.

Fig. 9 Comparison of energy efficiency between new and old-fashioned systems

Reduction of life-cycle costs

The life-cycle costs include initial (capital) expenditures, cost of electrical energy and repair and maintenance costs. Average operation time before overhaul is taken as 10 years.

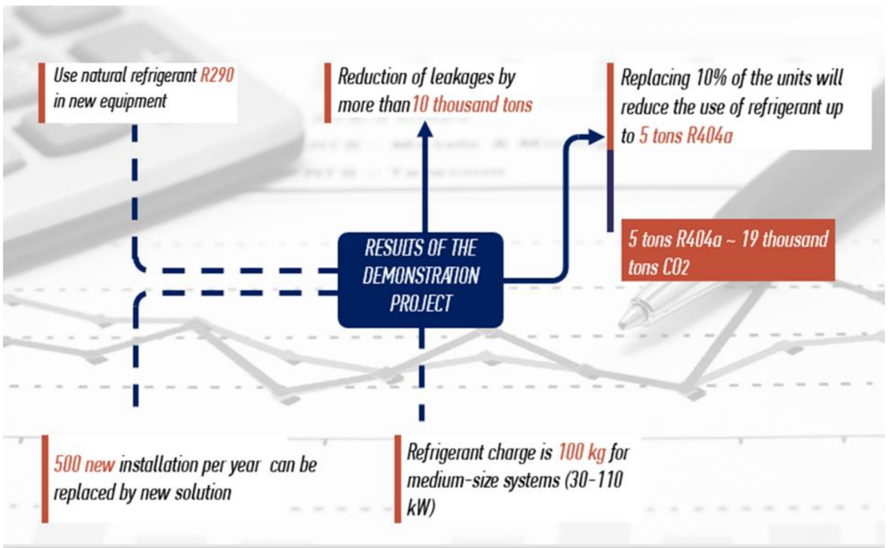
Solution	Initial expenditures, USD	Electrical energy		Repair and maintenance cost, USD/y	Total in 10 years, USD
		kWh/y	USD/y		
Old equipment*	0	52 000	9 360	112 000	213 600
R404a central system	105 000	43 545	7 838	3 000	213 381
Proposed solution	125 000	34 525	6 215	500	192 145

*Cost of operation of old equipment includes overhaul with possible purchase of R12 in future.

Fig. 10 Sample calculations and comparison of life-cycle cost

10 years later the proposed solution will enable to save USD 21,236 as compared to R404a central system and USD 21,445 as compared to the "old-fashioned" equipment.

Opportunities for wide spreading replication



This demo-project has some technological advantages: factory assembly, easy for installation, parameters are maintained without service personnel, materials are available and maintenance costs are low.
Up to 500 new installations per year can be replaced by using this solution in the countries of the Region (Eastern Europe and Central Asia).

Fig. 11 Opportunities for replication of this solution

All visitors of the Regional Center and potentially interested parties in the countries of the Region are invited to undertake site visit and see an example of successfully implemented project showing safety and energy efficiency of the proposed solution on the basis of natural refrigerants.

The system operation parameters are transmitted in real time and recorded for further analysis and studies. Thus, the Demonstration Project serves as a platform for promoting natural refrigerants solutions in the countries of the Region.

OUTCOME 5: Common curriculum was developed for providing vocational and academic studies covering refrigeration and air-conditioning service practices.

The common curriculum for vocational and academic studies covering refrigeration and air-conditioning practices is based on use of internationally recognized programs.

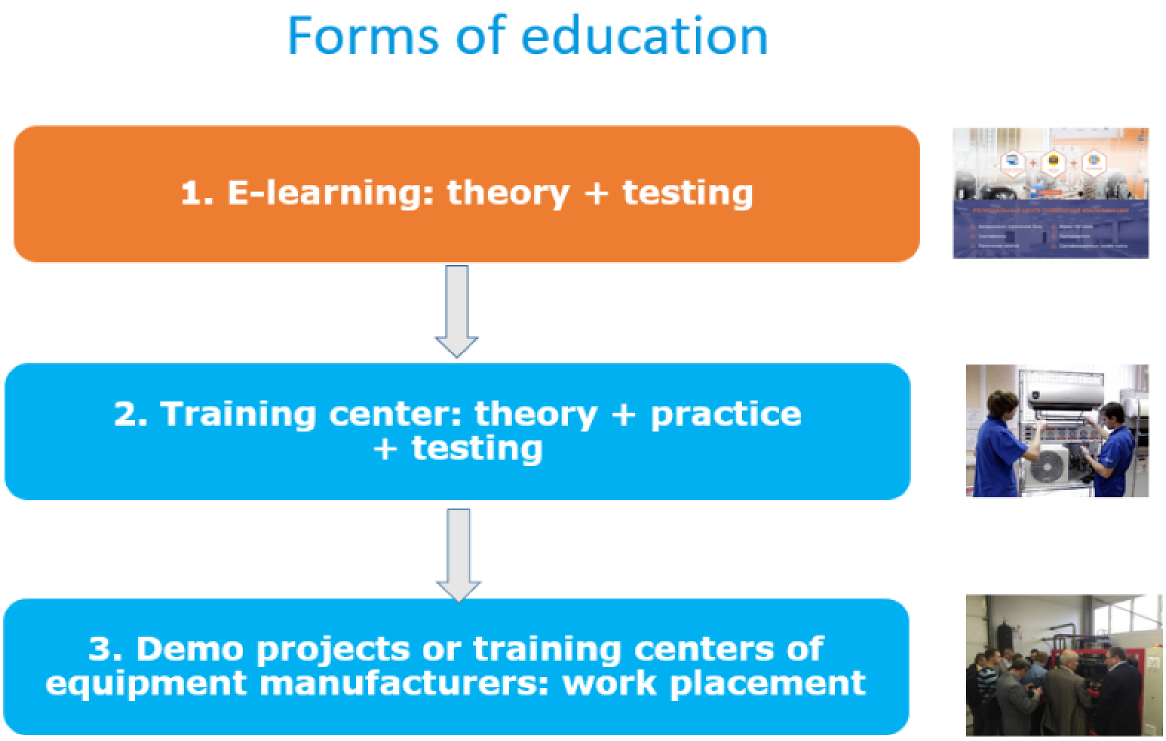


Fig. 12 A scheme used in the Regional Center for development of common curriculum

The forms of education include first e-learning: theory + testing, then coming to Armenia and in-depth study of theory, practice and testing at the Regional Center. The final process of consolidation of knowledge includes undertaking practice on site of demo-project or/and at the training centers of equipment manufacturers and partners facilities.

The Regional Center provides a wide range of training programs for different target audience given in the table below:

Title of program	Forms of education	Target audience	Trainers	Certificate
Real Alternatives learning program	E-learning on https://www.realalternatives.eu, theory, practice, assessments and certification for individuals	HVAC&R specialists	Certified Regional Center Trainers	Real Alternatives
F-gas certification course (4 category)	E-learning on hvaccenter.am, theory, practice, assessments	Technicians and other	Certified Regional	European F-gas, if

	and certification for individuals	HVAC&R specialists	Center Trainers + independent assessment procedure	necessary
Use of natural refrigerants in various sectors	E-learning on hvaccenter.am, theory, practice and advisory services	Customers and HVAC&R specialists	Certified Regional Center Trainers, Regional Center partners	Not applicable
Safe use of ammonia refrigeration systems	E-learning on hvaccenter.am, theory, practice at Regional Center and advisory services	Customers and HVAC&R specialists	Certified Regional Center Trainers, Regional Center partners	Not applicable
Safe use of hydrocarbon refrigeration systems	E-learning on hvaccenter.am, theory, practice at Regional Center and demo-project and advisory services	Customers and HVAC&R specialists	Certified Regional Center Trainers, Regional Center partners	Not applicable
Safe use of carbon dioxide (CO_2) refrigeration systems	E-learning on hvaccenter.am, theory, practice at Regional Center and demo-project and advisory services	Customers and HVAC&R specialists	Certified Regional Center Trainers, Regional Center partners	Not applicable
Ozone layer protection and climate change legislation	E-learning on hvaccenter.am, theory, practice at Regional Center	Customers, government officials and HVAC&R specialists	Certified Regional Center Trainers, NOU experts	Not applicable
Design and operation of carbon dioxide (CO_2) refrigeration systems	Theory and practice at Regional Center	Customers and HVAC&R specialists	Regional Center partners	Not applicable
Danfoss training courses: 1) Refrigeration fundamentals 2) Danfoss compressors 3) Danfoss automation systems 4) Industrial refrigeration 5) Commercial refrigeration	Theory and practice at Regional Center	HVAC&R specialists	Regional Center partners	Danfoss certificates

The training package includes:

- Curriculum of training courses;
- Online training course;
- Training manual;

- Training presentations for theoretical classes of the course;
- Practical training course design;
- Assessments and certification for individuals (where applicable).

Gender issues

The equal rights of women and men were provided through the whole project cycle.

A key role in the project implementation was played by UNIDO Country Representative and Head of Ozone office, National Ozone Focal Point for Armenia.

The percentage of women-managers in the beneficiary institution has increased to 50% and it is higher than in average in an ordinary organization in Armenia.

The Regional Center ensures equal rights and equal access to its services for women and men. It encourages women's participation in trainings by popularizing women in Trades and Technology together with the Regional Ozone Network for A 5 Countries in the Region of Eastern Europe and Central Asia.

PR activities and cooperation with other projects

The PR activities of the project included arrangement of special events, participation in relevant meetings and information dissemination.

The Project participants repeatedly discussed issues related to development of the Regional Center of excellence at the meetings of Ozone Officers Network for the region of Eastern Europe, Caucasus and Central Asia and community events held in Moldova, Georgia, Belorussia and Turkey in 2017-2018. The issues related to the Regional center of excellence vision and training programs under development, as well as the unified concept of the regional certification system were under discussion.

Representatives of refrigeration associations and working groups also met in Moscow (more information can be found on website: http://www.ozoneprogram.ru/eng/news/refrigeration_associations_in_moscow/) to discuss among other issues the development of a regional certification structure and certification concept.

The Project participants held numerous meetings with representatives of the Ministry of Nature Protection of the Republic of Armenia, project`s beneficiaries, local stakeholders and Armenian RAC Association.

The Interim Project report was submitted for consideration at a workshop on activities of the Russian Federation in area of International Development held at the Russian Embassy in Yerevan on January 30, 2019.

The launching ceremony was a very important PR-event and organized as a part of the session of the Interstate Ecological Council of the Commonwealth of Independent States (CIS). It was the important event for Armenia, Russia and other CIS countries and was widely covered by mass media including TV and governmental and HVAC association websites, e.g.:

- http://www.mnr.gov.ru/press/news/v_armenii_po_initsiative_i_pri_finansovoy_podderzhke_rf_otkrylsya_regionalnyy_tsentr_povysheniya_kva/
- http://www.mnp.am/en/post/4185
- https://www.youtube.com/watch?t=4s&v=3lE3M1tEfdY&app=desktop
- http://www.rshp.ru/index.php?option=com_content&view=article&id=673:2019-09-25-04-15-51&catid=62:2009-08-28-05-54-21&Itemid=2
- https://armenpress.am/arm/amp/988505
- https://news.am/arm/news/534091.html
- https://168.am/2019/09/18/1175278.html
- https://enews.am/news/5d821d110a975a6f105e8c84
- https://www.tert.am/am/news/2019/09/18/mnp/3096706
- https://assets.danfoss.com/documents/DOC320841040091/DOC320841040091.pdf (page 10)

The Regional Center was also presented at Europe and Central Asia (ECA) network meeting held in Kiev on 24-25 September, 2019.

Project implementation delays

The project was approved in May 2016. The implementation period was expected to be 36 months after the project approval therefore it should have been completed by June 2019. But funds were allocated to the Implementing Agency (UNIDO) in September 2017. So actually financing of the Project activity was commenced with delay of one year. Therefore December 2019 can be considered as early estimated completion of the Project (36 months will expire in September 2020). It means the project is completed faster than planned.

Other factors causing minor delays of the Project commencement and accomplishment are as follows: delays in defining beneficiaries for the Regional Center of Excellence (till 23.04.2018) and in implementation of the Demonstration project (till 18.07.2018) were caused on the host side (Ministry of Nature Protection of the Republic of Armenia), mostly due to replacement of beneficiary for the Demonstration project (till 02.11.2018), resulting in rescheduling of bidding procedures terms and bidding tasks adjustment.

Long-lasted repair works in the premises of the Regional Center were carried out by the beneficiary to prepare the required classrooms and make installation of training stands (all works were competed only in February 2019). These delays were caused mostly due to some political reforms and decision maker replacements in the Republic of Armenia.

Project sustainability evidence

Development concept

The Development concept for the Regional Center provides its management with important information on the educational market in the countries of the Region, the promising directions of development of the Regional Center, its partners, training programs, potential customers, pricing, staff and other important issues. The development concept was under discussion as one of key issues with the Regional Center management.

Governmental support and official partners

The Regional Center is supported by the Ministry of Environment of the Republic of Armenia and the National Ozone Unit of the Republic of Armenia. The Regional Center has five partners and cooperation with them on the basis of signed partnership agreements as follows:

- The Danfoss Group manufactures products and provides services used in cooling food, air conditioning, heating buildings, variable frequency drives, gas compressors and powering mobile machinery.

- NORD is a Russian manufacturer of CO_2 and Hydrocarbons systems.

- Rossoyuzkholodprom is a Russian HVAC association working closely with the Russian government.

- Vercont-service is a Russian HVAC training-center, established with technical assistance of UNIDO. It works successfully without governmental support, that is important for success in exchange of experience.

- IMEI helps the Regional Center to get safety certificates valid on the territory of Russia and other Eurasian Economic Union states.

The Center provides an open platform for potential partners to contribute to operation of the Regional Center in return to fair exposure of their goods and services and testing and demonstration of products and systems. They are also interested in supporting the HVAC sector globally and fostering research activities, including practical application of testing results (environmentally-safe techniques of handling refrigerants), energy-efficiency performance, and many other issues incorporated into certified academic programs.

Trainings held in the Regional Center

A few trainings have been conducted since the establishment of the Regional Center.

The first training event for trainers started immediately after the launching ceremony. Five trainers were trained and certified under F-gas and Real Alternatives (CO_2, HC) program.

Fig. 13 Training process

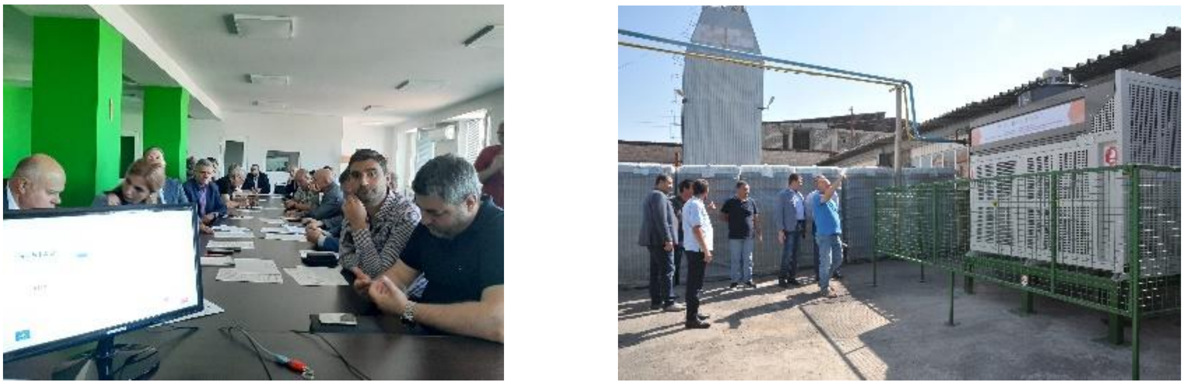


Fig. 14 Training course in class and on site

The second training course was held with the partners of the Center. It was dedicated to its development and the demo-project key features. More than 30 participants, including partners of the Regional Center, HVAC specialists and Regional Center representatives attended the second training event.

The third training event was carried out in October 2019 immediately after the Prom Expo exhibition held in Yerevan, with assistance of Danfoss company (official partner of the Regional Center). A group of 17 participants represented HVAC&R specialists and trainers from Armenian technical colleges and universities.

Fig. 15 Course leavers with certificates handed

The fourth training course was held in November and December 2019 for technicians from Turkmenistan in amount of 15 participants. They received Regional Centre certificates and safety certificates valid on the territory of CIS countries (electrical safety, work at heights, pressure receptacles, soldering).

Fig. 16 A group of course leavers from Turkmenistan with certificates handed

The fifth training course was carried out in December 2019 for Armenian technicians in amount of 15 participants representing Armenian RAC. All of them received Real Alternatives certificates.

Fig. 17 Training process in a classroom

As result of the Regional Centre activity it was contracted in the end of 2019 to conduct training courses in early 2020 for minimum 45 technicians representing the countries of the Region of Eastern Europe and Central Asia.

Initiation of F-gas certification for participants from the countries of the Region

The Interstate Ecological Council of the Commonwealth of Independent States (CIS) addressed this issue of F-gas certification for the countries of the Region at its session in Yerevan in September 2019. The states of the Region which are not yet a Party of the Kigali amendment to the Montreal Protocol including the Russian Federation will initiate F-gas certification after ratification of the Kigali Amendment.

Recommendations

- Additional funds to be allocated to continue and develop the Project success and enable the countries of the Region to direct their technicians to the Regional center in Yerevan for certified training

The original Project budget was proposed by the Russian Federation in amount of USD 852,600 excluding 13 % of Agency Support Costs. The budget was expected to cover expenses for both development of the Regional center and further conducting training and certification of expected and considerable number of technicians from the countries of the Region.

The originally proposed budget of the Project was reduced more than by 30 % and the budget approved amounted to USD 591,600 excluding 13% Agency Support Costs. Nevertheless the main tasks of the Project have been performed but substantial reducing of the budget resulted in considerable cutting-down of total number of trained technicians representing the countries of the Region.

Therefore the Russian Federation suggests that some needed additional funds to be allocated to complete the Project component related to enabling the countries of the Region to direct their technicians to the Regional center in Yerevan. The funds can be allocated as Phase 2 of the Project and covered from the Russian Federation contribution to MLF for 2020 paid and wired in full amount of USD 7,782,333.00 in December 2019.

- Customers training is a key target

The refrigeration systems owners and potential customers are real decision-makers on the local markets. They make a final decision what to "buy" and "which system to install". It is strongly recommended to concentrate efforts on customers training in similar future projects implementation.

- Commencing Project implementation shall be provided by timely allocation of funding in order to avoid any delays

The Project implementation period should be determined from a moment of receiving sufficient funds by Implementing Agency.

- Country situation assessment shall be a subject of proper investigation

There is a need in more proper assessment of the country situation. For example, a lack of vocational schools and universities, qualified specialists, co-financing sources as well as temporary political instability in Armenia at the period of implementation of the Project (obviously this factor cannot be predicted or expected) can result in delays in the schedule of implementation.

Final Report

DEMONSTRATION PROJECT FOR THE PHASE-OUT OF HCFCS BY USING HFO AS FOAM BLOWING AGENT IN THE SPRAY FOAM APPLICATIONS IN HIGH AMBIENT TEMPERATURES
SAU/REF/76/DEM/27

2020

Table of contents

1. Objective

Demonstrate benefits from the use of the HFO-1233zd(E) and HFO-1336mzz(Z), which have very low GWP in replacement of HCFC-141b with water, in terms of lower GWP and CO2 release and insulation properties in the PU spray foam insulation sector;
Demonstrate the easy applicability of the technology and, consequently, the replicability of the results;
Demonstrate that lower cost structure as compared to other alternatives can be obtained by means of lower foam density and lower thermal conductivity;
Objectively analyze, if the incremental operating cost could be reduced overall in similar future projects by means of using optimized water / physical foam blowing agent applied in the foaming process;
Objectively analyze, if the incremental capital cost at the System Houses can be utilized by means of lesser focus on the flammable gas detection and ventilation. In particular, the extensive exhaust ventilation in the countries with hot climate may result in unexpected costs in the air-conditioning production area during the hot summer periods.

Table 1-1 – HFO Foaming agent

Common Name	**HCFC-141b**	**Formacel® 1100**	**Solstice Liquid BA™**	**Forane® 1233zd**
		1336mzz(Z)	1233zd(E)	1233zd(E)
Chemical Formula	CH_3CFCl_3	Cis-CF_3-CH=CH-CF_3	Trans-CICH=CH-CF_3	Trans-CICH=CH-CF_3
Molecular Weight	117	164	130.5	130.5
Boling Point (°C)	31.9	33	19	19
Gas thermal conductivity (W/mk)	8.8	10.7	9.52	9
Foam Properties	Good	Very good	Very good	Very good
Flammable Limits in air (Vol %)	5.6-17.7 (Effectively none-flammable)	None	None	None
GWP (100 years ITH)	725	2	1	1
TLV (ppm)	500	500	800	Not disclosed

Price (US$/kg)	2.0 – 4.0	?	USD 9 - 13	?
Manufacturer		Chemours (Formerly DuPont and Dow)	Honeywell	Arkema

2. Companies selected (background/application)

HCFC-141b is used by Sham Najd International in in-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate foam (PIR) for insulating and water proofing walls, ceilings, roofs, suspended ceilings and floors at the construction sites and industrial sites in the Kingdom of Saudi Arabia. Thus, Sham Najd was solely selected to phase-out HCFC-141b within this demonstration project by converting to HFO foaming agent technology due to its willingness and availability to act simultaneously as a demonstration project. The chosen technology is a non-ozone depleting and low GWP foaming agent. This HFO technology, which is a definitive alternative under the Montreal Protocol and additionally has a positive impact on climate, is in compliance with Decision XIX/6.

Replacing HCFC-141b in spray foam in the Kingdom of Saudi Arabia (KSA) presents an opportunity and technical challenge, making it worthy of a demonstration project. The preliminary 2014 HCFC consumption estimates show that 600 MT of HCFC-141b or 66 ODP tonnes were consumed in 2014 for spray foam in the Kingdom of Saudi-Arabia (these figures include import of pre-blended polyurethane systems). Also, in 2014, the Ministry of Municipal and Rural Affairs of KSA has made thermal insulation compulsory for all new buildings in the 24 districts of the country covering 80% of the populations. The addition of thermal insulation in new building is expected to reduce 40% of energy use in air conditioning. Today, air conditioners account for 70% of electricity consumption in the region and with 1.5 Million new homes needed to keep up with the population growth, energy demand is anticipated to double by 2030 if energy conservation measures are not put in place.

3. Technologies Considered and selected

3.1. Alternative technologies considered

In accordance with the 2014 report of the rigid and flexible foams technical options committee, there are numbers of alternatives that are available to replace the use of HCFC 141b in rigid polyurethane foam. Several foaming technologies, including the following, are used as alternate technology:

- Cyclopentane
- HFC-245fa
- HFC-365mfc/227ea

- HFC-134a
- Methyl formate
- CO2 (Water)
- u-HFC
- Liquid unsaturated HFC/HCFC (HFOs) as emerging technology (subject for this demonstration project)

3.2. Commercially Available Options

Option	Pros	Cons	Comments
Cyclopentane & n-Pentane	Low GWP	Highly flammable	High incremental capital cost, may be uneconomic for SMEs
	Low operating costs		
	Good foam properties		
HFC-245fa, HFC-365mfc/227ea, HFC-134a	Non-flammable	High GWP	Low incremental Capital Cost
	Good foam properties	High Operating Cost	Improved insulation (cf. HC)
CO2 (water)	Low GWP	Moderate foam properties -high thermal conductivity-	Low incremental Capital Cost
	Non-flammable		
Methyl Formate/Methylal	Low GWP	Moderate foam properties -high thermal conductivity-	Moderate incremental capital cost (corrosion protection recommended)
	Flammable although blends with polyols may not be flammable		

3.3. Emerging Options

Option	Pros	Cons	Comments
Liquid Unsaturated HFC/HCFC (HFOs)	Low GWP	High operating costs	First expected commercialization in 2013
	Non-flammable	Moderate operating costs	Trials in progress
			Low incremental capital cost

The Indicative assessment of criteria for commercially available options as well as emerging alternatives in PU foam is provided in the table below:

3.4. Assessment of criteria for commercially available options

	c-pentane	i-pentane n-pentane	HFC-245fa	HFC365mfc/ 227ea	CO_2 (water)	Methyl Formate
Proof of performance	+	++	++	++	++	+
Flammability	---	---	++	+(+)	+++	--
Other Health & Safety	0	0	+	+	-	0
Global Warming	+++	+++	--	---	++	++
Other Environmental	-	-	0	0	++	-
Cost Effectiveness (C)	--	---	++	++	++	0
Cost Effectiveness (O)	++	+++	--	--	+	+
Process Versatility	++	++	+	++	+	+

Assessment of criteria for Emerging Technology options

	HFO-1234ze(E)	HFO-1336mzzm(Z)	HFO-1233zd(E)
	Gaseous	liquid	Liquid
Proof of performance	0	+	+
Flammability	++	+++	+++
Other Health & Safety	+	+	+
Global Warming	+++	+++	+++
Other Environmental	+	+	+
Cost Effectiveness (C)	++	++	++
Cost Effectiveness (O)	--	--	--
Process Versatility	+	+	+

3.5. IOC comparison between major alternatives during demonstration project formulation

IOC	HCFC-141b			HFO-1233zd			Methyl Formate			Water-blown / Formic Acid		
	Formula	%	Cost/kg	Formula	%	Cost/kg	Formula	%	Cost/kg	Formula	%	Cost/kg
Polyol	100	44,29%	2,70	100	46,08%	2,70	100	37,88%	2,70	100	37,95%	2,70
B.A	15,8	7,00%	2,70	7	3,23%	11,00	9	3,41%	2,70	3,5	1,33%	2,70
MDI	110	48,72%	2,70	110	50,69%	2,70	155	58,71%	2,70	160	60,72%	2,50
Total	**225,8**	**100,00%**	**2,70**	**217**	**100,00%**	**2,97**	**264**	**100,00%**	**2,70**	**263,5**	**100,00%**	**2,58**
Thermal conductivity mW/mK			**21**			**21**			**23**			**31**
Foam density			42			42			42			42
Equivalent cost USD			**2,70**			**2,97**			**2,96**			**3,81**
Total PU consumption 2015	400000	27,99	1080000	400000		1187097	400000		1182857	400000		1522577
IOC / year USD						**107097**			**102857**			**442577**

3.6. Selection of alternative technology for the Demonstration project

The technology chosen has been HFOs due to the following:

Spray foam is used to insulate, provide air sealing and improve structural strength in buildings. The insulation potential of spray foam is dependent upon the insulating gas in the cells of the polyurethane foam. In addition to the insulation performance, polyurethane foams used for the insulation purpose require inherently superior dimensional stability and resistance to fire.

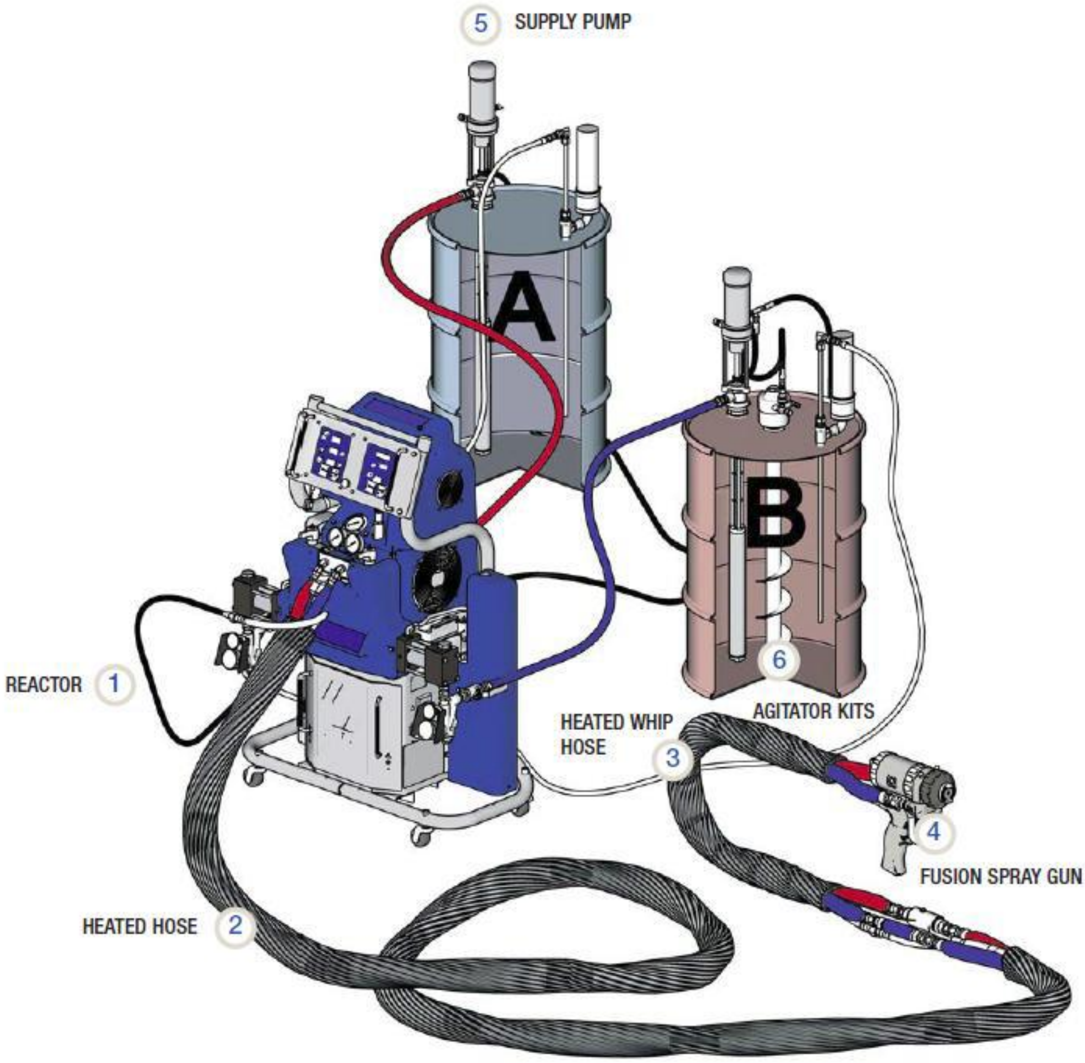
The current zero ODP options for replacement of HCFC-141b in foam applications include hydrofluorocarbons (HFCs) and hydrocarbons. Both HFCs and hydrocarbons are characterized by increased thermal conductivities compared to the HCFC, resulting in inferior insulation performance.

Few alternatives exist for replacing 141b in spray foam. Hydrocarbons are not a viable alternative for spray foam, and HFC-245fa and HFC-365, while viable, have high global warming potential (GWP). Also, the low boiling point of HFC-245fa and the flammability of hydrocarbons and HFC-365mfc present significant challenges to refrigerants processing and handling that are critically important in spray foam applications. On the other hand, foam blowing agents HFO-1233zd(E) and HFO-1336mzz(Z) have very low GWP, both less than 5, and HFO-1233zd (E) is claimed to be even less than 1. These molecules are also non-flammable and stable liquids at ambient temperatures. The HFO-1233zd(E) is already commercialized and HFO-1336mzz(Z) was expected to be commercially available from the year 2016. However, during the project implementation it was found out impossible to obtain it in such quantities which would have facilitated full-scale demonstration project. Thus, only blowing agent HFO-1233zd(E) has been tested in this demonstration project.

4. Modification of production

The foaming agent technology did not require new foaming equipment. All testing was performed with Sham Najd existing equipment (Graco E-XP1 Applicator).

Graco E-XP1 Applicator



5. Technical evaluation

Testing of the spray foam system SHPU 45 FSSL-50 from Covestro, UAE. The testing took place at Sham Najd's Labor camp & Warehouse area on 13 through 15 March 2017.

The spray foam testing operation was conducted by means of Sham Najd's existing Graco Reactor E-XP1 spray foaming machine and using the Fusion Air Purge Plural-Component Spray Gun.

The testing started on 13 March 2017 by means of spraying the standard non-fire rated spray foam system PS 105 H 40 Winter from KSA local system house SUCCO. The test results are provided in the table 1 and 2.

Testing was continued on 14 March 2017 with Covestro's HFO-1233zd blown SHPU 45 FSSL-50 fire retarded foam system. The test results are provided in table 1 and 2. All tests were conducted as follows:

Table 5-1. Test Results from the first samples in March 2017

Density	Approx. 43-47	ASTM D1622
Compressive strength	> 0.1 MPa	ASTM D 1621
Fire rating (DIN4102-1)	B2	DIN 4102
Fire rating Butler Chimney	Above 50%	ASTM 3014
Thermal Conductivity	≤0.024 W/m°K (10°C) ≤0.029 W/m°K (35°C)	ASTM C518
Dimensional Stability -20°C/+70°C, 48 hrs	Max 1%	ASTM D2126

Table 5-2. Thermal conductivity at 10°C

System	Density kg/m3	Compressive strength MPa	Dim. Stability % Max allowable 1%	Thermal conductivity W/mK @ 10°C	Aged thermal conductivity 21 days @70°C W/mK	Butler Chimney test ASTM 3014
SHPU45FSSL-50 (HFO-1233zd)	40.8	0,298	0.85	0.0210	0.0267	81.9%
PS 105 H 40 (HCFC-141b)	57.8	0,406	0.81	0.0248	0.0296	52.0%

Table 5-3. Thermal conductivity at 35°C measured two weeks after production

System	Density kg/m3	Compressive strength MPa	Dim. Stability % Max allowable 1%	Thermal conductivity W/mK @ 10°C	Aged thermal conductivity 21 days @70°C W/mK	Butler Chimney test ASTM 3014
SHPU45FSSL-50 (HFO-1233zd)	44.5	0,350	0.85	0.0246	0.0273	81.9%
PS 105 H 40 (HCFC-141b)	57.8	0,406	0.81	0.0275	0.0298	52.0%

Table 5- 4. Physical properties measured after 18 months from applying the foam on the roof. The samples were stored next to the test roof for easier testing purpose

Property		Unit	Average	Typical	Assessment of 18 months foam
Foam Density	EN 1602	kg/m^3	48,7	47	Typical value for roof insulation
Thermal Conductivity λ_{10} (+10°C)	EN 13165	mW/mk	26,1	26	Increased from 21 to 26.1, but understandable due to 18 months ageing at the construction site
Aged Thermal Conductivity (21days +70°C) λ_{10} (+10°C)	EN 13165	mW/mK	26,8	27	Shows that foam has kept insulation well
Thermal Conductivity λ_{35}(+35°C)	EN 13165	mW/mk	28,2	28	Increased from 24.6 to 28.2, but understandable due to 18 months ageing at the construction site
Aged Thermal Conductivity (21days +70°C) λ_{10} (+35°C)	EN 13165	mW/MK	28,9	29	Shows that foam has kept insulation well
Compression Behavior	EN 826	kPa	352	300	Similar to original 298 kPa -> 352 kPa (improved), which is typical that physical foam properties improve during the first months, upon all foam has after polymerized. The compression strength of PUR/PIR products remains constant with time if there is no air diffusing into the cells (ageing). If air diffusion is characteristic of the product then the compression strength will increase with time. The level of this increase will increase with the level of closed cells present, i.e. this increase will be the highest with level CCC4 (>90%) and least with level CCC1 (<20%).
Tensile Strength	EN 1602	kPa	183	150-200	This is typical for sprayfoam
Dimensional stability (3 days +70°C)	EN 1605	%	+0,66	±1	Excellent
Dimensional stability (10 days +70°C)	EN 1605	%	+0,69	±1	Excellent
Reaction to Fire Butler Chimney Test	ASTM 3014	%	91,1	80-90	Very good, practically IMPROVED FROM 81.9% to 91.1%
Reaction to Fire B2 Test	DIN 4102	cm	10,5	10-11	Has kept the fire rating well (15 cm max)
Water Vapor Resistance	ISO 12572	(m^2 s Pa/kg)	$10,5*10^9$	$8\text{-}12*10^9$	This is a typical value, and means that about 10 g water vapor goes through the 2 cm thick foam within 24 hrs, when there is 50 RH% humidity difference at 20 deg centigrade
Closed Cell Content	ISO 4590	%	93,3	90	Similar to HCFC-141b based foams
Closed Cell Content Corrected	ISO 4590	%	97,4	95	Similar to HCFC-141b based foams

Table 5-5. Following characteristics were studied due to high ambient temperature

Characteristic	Observations
The maximum concentration of HFO in the polyol to be used without pressurization of polyol vessel	12%
Impact to surfactants and catalysts	It was noticed that special package was to be introduced. Honeywell, the foaming agent supplier, was able to provide necessary package.
Pre-mixed polyol storage at the System House or Enduser's own storage	Five months during November 2016 to March 2017 did not cause any reactivity changes
Surface of the polyurethane as a product	The surface had somewhat more of pinholes compared to baseline foam formulation. However, it is meeting the customer expectations
Dimensional stability of sprayed foam	The tested foam system's dimensional stability in regard to baseline was somewhat reduced, however acceptable and meeting the spray foam standards. In regard to the most important direction against rise, the stability was good
Evaluate the correct timing for laying the protective coating for surface	The protective layer was sprayed on the foam just like on the baseline case (1.5 cm per pass)
Evaluate the performance of existing standard coating spray materials' applicability for the new product	Performance is the same

6. Commercial Evaluation

Commercial evaluation has been prepared basing on actual foaming results. If considering the thermal conductivity remains the same with HCFC-141b and HFO-1233zd the phase-out cost of HCFC-141b with present foaming agent prices the phase-out of HCFC-141b will cost USD 3.18/kg HCFC-141b. The actual laboratory tests displayed better results for HFO-1233zd based foam and in such case the phase-out cost of HCFC-141b were USD 0.52/kg.

Table 6-1 – Commercial Evaluation / IOC

Commercial Evaluation / IOC	HCFC-141b			HFO-1233zd			Water-blown / Formic Acid		
	Formula	%	Cost/kg	Formula	%	Cost/kg	Formula	%	Cost/kg
Polyol	100	38,46 %	2,46	100	38,17 %	2,70	100	37,95 %	2,80
B.A	20	7,69 %	4,00	12	4,58 %	9,50	3,50	1,33 %	2,46
MDI	140	53,85 %	3,50	150	57,25 %	3,50	160	60,72 %	3,50
Total	260	100,00 %	3,14	262	100,00 %	3,47	263,50	100,00 %	3,22
Aged Thermal conductivity mW/mK	29.8			28.2			31		
Required foam density			45			45			52
Equivalent cost USD			3.14			3.47			3.87
IOC (USD/kg HCFC 141b)						4,30			1,07
IOC (USD/kg HCFC 141b) considering change in thermal conductivity and foam density						0.33			9,53

7. Environmental impact

The project impact on the environment was studied for both chemicals i.e. HCFC-141b and HFOs. The CO_2 emission before conversion (using HCFC-141b as blowing agent with Global Warming Potential of 725) is expected as 20,282.68 metric ton per year whereas after conversion to HFO with GWP 1, it is estimated 17.32 metric ton per year. The net impact on the environment is positive. The CO_2 emission is expected to be reduced by 20,282.68 MT after implementing the new technology at Sham Najd. In whole KSA respectively the impact will be 434,643.00 CO2 MT/ year. The ODP phase-out at Sham Najd is 3.08 ODP tonnes and respectively in KSA 66 ODP tonnes. The net effect calculation is provided in the table below:

Table 7-1 – Environmental impact

Name of Industry Sham Najd	Substance	GWP	Phase out amount MT/ year	Total equivalent warming impact CO2 eq. MT/ year	ODP HCFC-141b	Total ODP
Before Conversion						
Total CO_2 emission in M tonnes	HCFC-141b	725	28	20,300.00	0.11	3.08
After Conversion						
Total CO_2 emission in M tonnes	HFO-1233zd	1	17,32	17.32	0	0
Net Impact				20,282.68		3.08
Before conversion Kingdom of Saudi Arabia						
Total CO_2 emission in M tonnes	HCFC-141b	725	600	435,000.00	0.11	66
After Conversion		1	357	357	0	0
Total CO_2 emission in M tonnes				434,643.00		66

8. Additional information

Table 8-1 – List of chemicals

Product	Supplier	Price USD / Kg
HFO-1233zd - Solistice LBA	Honeywell	9.50-15.00
Dabco 2040	Evonik	27.95
Dabco 203	Evonik	13.75
Tegostab B84711	Evonik	8.70
MDI	Sadara (Dow Chemicals' joint venture in KSA)	6.75 SAR USD 1.80

Since the spray foam systems are now available locally in KSA, there will be further local spray foam system use by Sham Najd and other spray foam applicators like Al-Babtain and customers of SUCCO and Saptex.

The SUCCO's actual field testing was conducted during early 2018 with Al-Babtain spray foam applicator for roofing of Honeywell's store area roofing. This testing was not actually connected to this Demo project but demonstrating the local Foam System Houses availability to provide foam systems, which facilitate phase-out of HCFC-141b.

Workshop with all results was held in June 2019. This workshop provided detailed information from the results in Jeddah, Riaydh and Damman.

Table 8-2 – Demo project results were presented at Foam Sector workshops during 22-25 June 2019 at Jeddah, Riyadh and Damman / Al Khobar

Place of venue	Presentations	Subjects	Audience
Jeddah Riaydh Damman	Saptex System House	Alternative foaming agent for spray and pour-in-place applications	Spray applicators 15 Construction consultants 4 National Ozone Unit UNEP
	Succo System House	Foaming results and challenges experienced in the foam formulations and expectations with PU spray foam	
	Sham Najd - Spray Applicator	Comments on the Demo Project	
	Jundi – System House	Experience in the use of natural and flammable foam blowing agent	

	UNIDO International Consultant	1st: Foaming with HFO foaming agents- Solstice LBA and Opteon 1100 2nd: Foaming results with hydrocarbons and other blowing agents 3rd: Foam cost calculations	
	Momentive	Foam formulations	
	Honeywell	4th Generation Blowing Agents	

9. Conclusion

The phase-out of HCFC-141b in Sham Najd will reduce the total CO_2 emission and ODP emissions by a significant margin. The conversion will facilitate the phase-out cost-effectively. The same approach can be applied to the whole KSA and the surrounding region respectively.

Spray foam for roofing in the KSA where the insulation demand is growing will require superior insulating and water-proofing properties and ability to be monolithically apply to all shapes and types of surfaces.

According to the field testing and resulting laboratory testing, the spray foam formulation with HFO-1233zd foaming agent appears to have a high potential to replace HCFCs and HFCs as it has very similar technical and physical attributes and has a very low GWP and zero ODP factor.

Following conclusive characteristics can be noted:

1. The end spray product is matching HCFC-141b blown spray foam in many aspects, such as adhesion, thermal conductivity, dimensional stability, paint-ability, overall foam density and compression strength;
2. Lesser amount of HFO-1233zd can be mixed due to the boiling point of polyol mix will also be lower than boiling point of HCFC-141b blown foam;
3. Storage of mixed polyol needs to be kept at max 28 degrees of centigrade - > needs upgrade of polyol mix storage room air-conditioning;
4. On construction sites, the drum storing of polyol by the spray foam applicators require shelters;
5. HFO-1233zd needs to be kept in pressure vessels;
6. HFO-1233zd needs to be mixed in the temperature-controlled mixing vessel (reactor), temperature less than 18 °C, or to use in-line pre-mixer unit;
7. HFO-based foam system needs special additives in order to avoid deterioration of ageing performance of the polyol mix, see the chemicals to be purchased.

8. Cost of foam system is presently higher than HCFC-141b blown foam. However, it is expected to be balanced within few years.

Advantages:

1. Better foam performance in the cold weather period season (lower boiling point);
2. HFO-1233zd provides future foam formulation without concern of use limitations;
3. Very low Global Warming Potential (GWP) of 1;
4. Non-ozone depleting;
5. Nonflammable (ASTM E-681), VOC exempt (per U.S. EPA) and
6. Facilitate required improved energy efficiency for the future constructions and buildings and can be used for improving old buildings to meet present insulation requirements.

Budget

Total budget approved 96,250 USD

Expenditures: **94,000 USD** (2019), which contains of:

Consultancy services and travels -	28,000 USD
Equipment/Chemicals –	48,000 USD
Workshop and laboratory test -	18,000 USD

Other notes

Response to MFS comments on Interim Report of HFO demonstration project in PU foam Saudi Arabia

1. At the 80th meeting, the Executive Committee agreed to extend the project completion date to 31 December 2018, on the understanding that no further extension of project implementation would be requested, and to request UNIDO to submit the final report no later than the 83rd meeting (decision 80/26(i)). The Secretariat notes from the present report that substantial progress has been achieved in the implementation of the demonstration, but that some activities (i.e., scale field testing and dissemination workshop) have not taken place yet. We would appreciate the following clarifications on the remaining activities to finalize the project:

(a) Please provide the characteristics of the scale field testing planned (specific tests planned, how many tests in how many enterprises, formulations to be used, duration of these tests and additional information expected);

Response: It is tentatively, and as per the project document intention to conduct the field testing only by the company Sham Najd. Intention is to obtain foam systems from KSA SHs SUCCO and Saptex. In the project document it was foreseen only Saptex, but during implementation of this project and System House projects, SUCCO appears to have the most experience in the foam formulation development. The laboratory formulations are already in place, and those are to be field tested.

(b) Please confirm estimated date of completion of all pending activities;

Response: It is foreseen that testing would be completed and results available by October 2019.

(c) Given that these reports are going to be used by other Article 5 countries as reference when implementing projects, we would appreciate that the final detailed report of the demonstration is presented to the 84th meeting, including the result of the remaining tests, any conclusions or additional information emerging from the workshop, and additional details requested the comments below.

Response: The final report is projected to be available by October 2019.

Formulations

2. Please clarify the origin of the formulation used to test HFO-1233zd(E). Was it developed by Covestro for the demonstration project, or is it a commercially formulation available to any systems house?

Response: All foam formulations details are always System Houses' own developments and secrets and based on their polyols in use. However, the additive suppliers (for instance Evonik and Momentive) and the foaming agent suppliers (Honeywell and Chemours) have R&D support available, and they actively provide their experience to the formulators at System Houses. In the case of the Spray Demo project first phase the formulation was fully developed by Covestro, and not available to any other source.

3. Kindly inform if all the tests were done with a formulation containing pure HFO-1233zd(E) or if there were also tests with formulations reduced with water. If that was the case, please also provide the results and how the foam with reduced formulations compare with pure HFO-1233zd and HCFC-141b-foam?

Response: The HFO-1233zd formulations are always substantially reduced with water. The HFO-1233zd content as foaming agent is from 8 to 12 % in polyol formulation high ambient temperature countries. Due to HFO-1233zd's low boiling point, it is not really possible to formulate cost-effectively polyol mixture, which could keep blowing agent fully soluble. The testing has shown that blowing agent start boiling strongly, and the hot climate conditions preclude this kind of high content HFO-1233zd formulations.

The below tables are providing information from the laboratory test. It is to be noted that the HCFC-141b foam was not most suitable for the comparison. However, it was only available.

System	Density kg/m3	Compressive strength MPa	Dim. Stability % Max allowable 1%	Thermal conductivity W/mK @ 10°C	Aged thermal conductivity 21 days @70°C W/mK	Butler Chimney test ASTM 3014
SHPU45FSSL-50 (HFO-1233zd)	40.8	0,298	0.85	0.0210	0.0267	81.9%
PS 105 H 40 (HCFC-141b)	57.8	0,406	0.81	0.0248	0.0296	52.0%

System	Density kg/m3	Compressive strength MPa	Dim. Stability % Max allowable 1%	Thermal conductivity W/mK @ 35°C	Aged thermal conductivity 21 days @70°C W/mK	Butler Chimney test ASTM 3014
SHPU45FSSL-50 (HFO-1233zd)	44.5	0,350	0.85	0.0246	0.0273	81.9%
PS 105 H 40 (HCFC-141b)	57.8	0,406	0.81	0.0275	0.0298	52.0%

Tests undertaken and results

4. Thank you very much for Table 1 listing the tests undertaken. Kindly inform why other typical tests such as adhesion strength (ASTM D-1623), water absorption or closed cell content (ASTM D-2856) were not included. Could they be included in the next measurements?

Response: These above-mentioned tests were to be conducted, but misunderstanding with the UAE Test laboratory, they were not able to conduct all tests. These tests will be conducted for the next test.

5. Table 2 can be considered a clear summary of the results. However, it does not contain all the information that other Article 5 countries will need as reference. We would appreciate if for the final report you could include for each of the tests listed, a brief description on how the test was done (how many times, at what temperature,

relative humidity and other conditions) and how you interpret the results found. Please feel free to include Annexes for additional tables, where necessary.

Response: The following testing will be included:

- European in-situ formed sprayed PU foam standard EN 14315;
- Thermal resistance and thermal conductivity
- Measurement of lambda values (thermal conductivity W/mK)
- Ageing of lambda value
- Reaction to fire of the products
- The reaction to fire classification of the products shall be determined in accordance with EN-13501-1 and using data obtained from tests carried out according to procedures EN ISO 11925-2 and EN 13823
- Dimensional stability under specified temperature and humidity conditions
- Dimensional stability under specified temperature and humidity conditions shall be determined in accordance with EN 1604
- Reaction profile and free-rise density
- Durability characteristics
- Durability of reaction to fire against ageing/degradation
- Durability of thermal resistance against ageing/degradation
- Durability of compression strength against ageing/degradation
- Closed cell content
- Short-term water absorption by partial immersion
- Compressive stress or compressive strength

All tests above will be conducted according to EN 14315 (Thermal insulating products for buildings — In-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products)

6. Kindly inform if the characteristics of the foam were measured again several weeks after, in order to obtain information on aging. It has been observed in several of the demonstration projects that some of the characteristics of the alternative foam may vary over time in a different way than HCFC-141b-foam. If this was measured, please include it in the final report. If this was not done, please explain the reasons and kindly consider undertaken additional measurements.

Response: We understand this need, and it is foreseen.

7. It is understood from the demonstration that no modifications were required to the foam dispenser for the application of HFO-1233zd(E) in spray foam applications. Is there any instance in which a modification to the spray foam equipment would be needed or it can be inferred that in general no changes are needed?

Response: The evaluation was done with relatively new Graco Spray foam unit, which has very good control on the pressure, mixing and heating of hoses. Thus, it can be used as such.

8. The conclusion section indicates that mixed polyols needs to be stored at maximum 28 degrees Celsius. The reasons are not explained in the report.

Response: Boiling point of the HFO-1233zd is so low that it will cause evaporation / boiling of the chemical. It is not azeotropic mixture with polyol.

9. The conclusions also indicate that HFO-1233zd should be mixed in the reactor at a temperature lower than 18 degrees Celsius. The reasons are not explained in the report.

Response: Boiling point of HFO-1233zd is 19.5 °C, and in order to avoid loss of the blowing agent during mixing process, it needs to be mixed preferable at 15°C

10. What have been identified as the main challenges to introduce HFO-1233zd(E) in spray foam application in Saudi Arabia?

Response: Ambient temperature, shelf-life of the polyol mixture, high price and motivation to the SH's due to the availability of HCFC-141b formulations and bulk.

11. Kindly include in the final report an independent technical review.

Response: Will be budgeted and included as requested.

Cost

12. What is the cost of the additional surfactants and catalysts required for the application of HFO-1233zd(E)? Please also provide an explanation on why they are required.

Response: The Evonik catalyst – emulsifier - silicone surfactant package, having the commercial product names;

- Dabco 203
- Dabco 2040 and
- Tegostab B8471

This optimized catalyst package through extensive and multi-year testing is recommended by Evonik and HFO-1223zd supplier Honeywell for spray foam formulators, when using HFO-1233zd as foam blowing agent, and this catalyst package provide self-life for polyol blend for more than 8 months. Thus, UNIDO Demonstration project needs to follow these recommendations.

Name of chemical	kg	USD/ kg	One drum	Description	Other information
Dabco 2040	200	27,50	5 500,00	Dabco 2040 catalyst is a low odor amine used to enhance cure and adhesion to substrate in HFO-blown spray foams.	
Dabco 203	200	13,20	2 640,00	Dabco 204 catalyst can help customers achieve between 6 to 8 months of polyol blend stability when used with HFO-1233zd(E). Dabco 203 catalyst performs similarly to Polycat 204 catalyst, but brings the added advantage of having a low water content, providing additional flexibility to formulators.	Typical uses levels of Dabco 203 catalyst / Dabco 204 catalyst are 2-4% by weight on the polyol side. The product can be used in conjunction with other catalysts to optimize system stability, overall reactivity as well as back-end cure speed. Recommended co-catalysts for HFO based systems include: Dabco® 2039 catalyst, Dabco® 2040 catalyst.
Tegostab B8471	200	8,25	1 650,00	TEGOSTAB® B 8471 acts as a silicone surfactant. Offers foam stabilization. Used in polyurethane rigid foam for construction applications.	Improves stability in formulation.

Momentive package is including following.

- Silicone L5107
- DMEA
- DMCHA
- Catalyst A-1 (Momentive)
- Potassium Octoate from Momentive

13. Is the formulation in Table 5 the one used in the demonstration project (Covestro HFC-1233zd blown SHPU 45 FSSL-50)?

Response: Yes.

14. Is the price of pure HFO-1233zd(E) in Saudi Arabia US $9.50/kg as indicated in Table 5?

Response: Seems to be that price in smaller quantities is USD 15,000 / MT. So, price has not been reduced as expected. In the case of Demo material from Covestro, UNIDO purchased foam as a system, and foam individual chemicall prices were not revealed.

15. Kindly explain how the IOC value of US $0.52/kg was obtained?

Response: From the calculation below, foam cost USD /kg difference is USD 0,04/kg. However, when thermal conductivity is considered, the HFO-1233zd foam USD 0.52/kg lower in cost.

Commercial Evaluation / IOC	HCFC-141b			HFO-1233zd			Water-blown / Formic Acid		
	Formula	%	Cost/kg	Formula	%	Cost/kg	Formula	%	Cost/kg
Polyol	100	38,46 %	2,46	100	38,17 %	2,70	100	37,95 %	2,80
B.A	20	7,69 %	4,00	12	4,58 %	9,50	3,50	1,33 %	2,46
MDI	140	53,85 %	3,50	150	57,25 %	3,50	160	60,72 %	3,50
Total	260	100,00 %	3,14	262	100,00 %	3,47	263,50	100,00 %	3,22
Aged Thermal conductivity mW/mK	29,8			27,3			31		
Required foam density			45			45			52
Equivalent cost USD			3,14			3,18			3,87
IOC (USD/kg HCFC 141b)						4,30			1,07
IOC (USD/kg HCFC 141b) considering change in thermal conductivity and foam density						0,52			9,53

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Construction Product Testing Laboratory

August 21th 2019

UNIDO UDITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

Yuri SOROKIN
Industrial Development Officer Montreal
Protocol Division VAGRAMERSTR. 5 VIENNA
AUSTRIA

TEST REPORT

Physical Properties of Sprayed PIR Foam							Typical
Property		**Unit**	**1.**	**2.**	**3.**	**Average**	**value**
Foam Density	EN 1602	kg/m^3	48,9	48,4	48,9	48,7	47
Thermal Conductivity λ10 (+10ºC)	EN 13165	mW/mk	26,1	26,0	26,1	26,1	26
Aged Thermal Conductivity (21days +70ºC) λ10 (+10ºC)	EN 13165	mW/mK	26,7	26,4	27,3	26,8	27
Thermal Conductivity λ35(+35ºC)	EN 13165	mW/mk	27,3	28,6	28,7	28,2	28
Compression Behaviour	EN 826	kPa	351	345	359	352	300
Tensile Strength	EN 1602	kPa	172	229	149	183	150-200
Dimensional stability (3 days +70ºC)	EN 1605	%	+0,60	+0,63	+0,74	+0,66	±1
Dimensional stability (10 days +70ºC)	EN 1605	%	+0,68	+0,63	+0,76	+0,69	±1
Reaction to Fire Butler Chimney Test	ASTM 3014	%	88,7 93,8	88,5 93,9	93,8 88,1	91,1	80-90
Reaction to Fire B2 Test	DIN 4102	cm	10 11	11 10	11 10	10,5	10-11
Water Vapour Resistance	ISO 12572	(m^2 s Pa/kg)	$10,7*10^9$	$9,8*10^9$	$11,0*10^9$	$10,5*10^9$	$8-12*10^9$
Closed Cell Content	ISO 4590	%	93,6	92,8	93,4	93,3	90
Closed Cell Content Corrected	ISO 4590	%	97,6	97,1	97,5	97,4	95

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Annex VII

Promoting Low-GWP Refrigerants for Air-Conditioning Sectors in High Ambient temperature Countries Phase II (PRAHA-II)

2019

Project Report

Project supported by the Multilateral Fund of the Montreal Protocol

UNITED NATIONS ENVIRONMENT - UNEP

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGNIZATION - UNIDO

Disclaimer

While the information contained herein is believed to be accurate, it is of necessity presented in a summary and general fashion. The decision to implement one of the options presented in this document requires careful consideration of a wide range of situation-specific parameters, many of which may not be addressed by this document. Responsibility for this decision and all its resulting impacts rests exclusively with the individual or entity choosing to implement the option. UNIDO, UNEP, their consultants and the reviewers and their employees do not make any warranty or representation, either expressed or implied, with respect to the accuracy, completeness or utility of this document; nor do they assume any liability for events resulting from the use of, or reliance upon, any information, material or procedure described herein, including but not limited to any claims regarding health, safety, environmental effects, efficacy, performance, or cost made by the source of information.

Acknowledgments

The project team would like to acknowledge the assistance given by the governments and the National Ozone Units of the countries participating in the PRAHA project for their support in the implementation of the project phases and their assistance in facilitating communication with the different stakeholders.

We also acknowledge the independent International Technical Review Team that assist the project team in reviewing the project report. The team includes:

- Dr. Abdelaziz, Omar (Zewail City of Science and Technology, Egypt);
- Eng. Almatouq, Yaqoub (Environment Public Authority - Kuwait);
- Prof. Chakroun, Walid (University of Kuwait);
- Dr. Olama, Alaa (Independent Consultant - Egypt);
- Prof. Peixoto, Roberto (MAUA University - Brazil);
- Mr. Wang, Xudong (Air Conditioning, Heating and Refrigerating Institute - USA); and
- JRAIA team of experts

We acknowledge the contribution of the Air Conditioning, Heating, and Refrigeration technical Institute (AHRTI) and the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) for their cooperation in the conduction of the optimization and risk assessment elements of the project.

Acknowledgement also goes to the "Technology Providers" for providing components and advice

Refrigerant Providers: Chemours, Daikin, and Honeywell.
Compressor providers: Emerson.

We recognize the efforts by Optimized Thermal System (OTS) in the optimization elements and the AHRI members who were part of the optimization project monitoring team. We also recognize the efforts of the JRAIA members in their assistance and especially in conducting teleconferences at late hours.

Special thanks to Prof. Chakroun, Walid who supported PRAHA-II in the designing and evaluating the content of the optimization element of the project.

Project Team

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ACRONYMS

AC	Air Conditioning
AHRI	Air Conditioning, Heating, and Refrigeration Institute
AHRTI	Air Conditioning, Heating, and Refrigeration Technical Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BTU/hr	British Thermal Unit per Hour
CHEAA	China Home and Electrical Appliance Association
EGYPRA	Promotion of Low-GWP Refrigerants for the AC Industry in Egypt
ETA	Event Tree Analysis
EVX	Electronic Expansion Device
FMEA	Fault Measurement and Effects Analysis
FOA	First Order Analysis
FTA	Fault Tree Analysis
GWP	Global Warming Potential
HAT	High Ambient temperature
HC	Hydrocarbon
HCFC	Hydro Chloro Fluoro Carbon
HFC	Hydro Fluoro Carbon
HFO	Hydro Fluoro Olefin
HOC	Heat of Combustion
HX	Heat Exchanger
IPR	Intellectual Property Rights
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
kW	Kilowatt
lbs	Pounds
LFL	Lower Flammability Limit
MCHX	Micro Channel Heat Exchanger
MOP	Meeting of the Parties
OEWG	Open-Ended Working Group
RACHP	Refrigeration, Air-Conditioning, and Heat Pumps
TFHX	Tube Fin Heat Exchanger
TXV	Thermal Expansion Valve
UA	Thermal Conductance
UFL	Upper Flammability Level

Executive Summary

PRAHA Has Turned into a Process!

PRAHA-I created an awareness about the challenges faced by high ambient temperature (HAT) countries and offered stakeholders in HAT countries support in building their technical knowledge of the alternatives technologies as well as practical support through the building and testing of several prototypes using lower-GWP refrigerants.

PRAHA-I concept of testing prototypes at high ambient temperatures pioneered other testing and research programs which eventually tested more alternative refrigerants than the few refrigerants that were still in the development stage when PRAHA-I was launched. In Addition, PRAHA-I also helped component manufacturers, especially compressors, to start building and testing dedicated compressors for the new alternative refrigerants that are capable of delivering sustained energy efficiency levels at HAT conditions.

The main result of PRAHA is that it went beyond the level of being an individual project with specific planned outcomes and outputs, PRAHA turned to be a **PROCESS** at different levels: governmental, local industry, institutional as well as for the international technology providers.

PRAHA-II is a continuation of the process with specific goals that are aligned with the findings of PRAHA-I. The two main findings of PRAHA-I are that, 1) there are viable alternatives at HAT conditions which need optimized equipment design to perform and deliver the energy efficiency minimum requirements, and 2) that there is a concern about safety of the mostly flammable alternative refrigerants that calls for a special risk assessment model for the HAT countries.

PRAHA-II Elements

PRAHA-II had three main elements: 1) to build the capacity of the local industry in designing and testing products using efficient lower-GWP flammable refrigerants; 2) to evaluate and optimize the prototype built for PRAHA-I; and 3) To build a risk assessment model for the high ambient temperature countries.

Each element has its components and events and was designed to give maximum exposure to the stakeholders, both the industry as well as research institutions and the government, on the latest technology and the developments that are happening worldwide. All three elements were designed to benefit the maximum number of stakeholders.

PRAHA-II Main Findings

PRAHA-II delivered tangible and beneficial results on all three main elements.

- **Capacity Building**: The capacity building element was successful in providing a platform of cooperation between governments, research institutes, industry associations, and the industry in general and became a process for the sharing of information and results among the different stakeholders. The experience of working on PRAHA-I gave UN Environment and UNIDO the confidence that international stakeholders support the goals of the project and that the outcome will be beneficial to all and beyond economic gains. Simultaneous to the efforts by the PRAHA project to create awareness about HAT challenges and the work done through the different symposia held in the HAT countries that were participating in the PRAHA project, the local industry themselves started to directly evaluate and examine long term alternatives which reflect the level of built awareness and attention gained to the wise selection of alternatives.

- **Design Optimization**: The original scope and schedule were modified during the project as new findings and challenges surfaced. The original baseline test data was used for comparison with tests done on the optimized units built according to the modeling work done even though the latter tests included measurements and metrics not typically performed in energy certification tests of the type done under PRAHA-I.
  A resume of the conclusions:
  - For systems operating in considerably higher temperatures (greater than 46°C), the resultant impact on performance must be considered since performance will degrade as compared to operating under more temperate conditions.
  - The design assessment through modeling provided good insights on adequate component design and/or selection for proper system functioning when using novel refrigerants;
  - Rebuilt and tested units exhibited a considerable reduction in power consumption at the high ambient test condition (46°C) as compared to the original test data. This indicates the importance of proper compressor selection.
  - Because of the differences in saturation curves from the simulation analysis, refrigerant with wider saturation curves tend to result in systems with higher efficiency and less charge when no modifications to the hardware are made. The results showed however, that by making appropriate component selection, such as compressors with larger displacement volumes and higher mass flow rate, the cooling capacities and overall performance of the other refrigerants were of the same order of magnitude.
  - Refrigerant fractionation as evidenced by the leak tests, does not appear to be a great concern since less than 2% change in cooling capacity was observed after the system's re-charge.
- **Risk Assessment**: The work on risk assessment required resources beyond the traditional RACHP expertise that is allocated for typical conversion/demo projects. The different usage and servicing practices used in the region needed to be considered in order to assess the risk of using flammable refrigerants. The initial concern about the effect of high ambient temperature on the increased risk of ignition was removed and the main focus is on actual practices. The recommendation is for HAT countries to continue the risk assessment based on actual situations and reduce the risk by implementing various measures that are verified such as minimizing ignition probability. In addition, the risk assessments of other stages matching cultural and lifestyle aspects should be studied.

The Way Forward

In general, PRAHA-II outcomes will be of benefit to all 35 countries defined by the Montreal Protocol Parties at the OEWG-37, 2016 as "High Ambient Temperature Countries". A HAT symposium scheduled for March 2020 will convey these results to representatives from those countries. UN Environment and UNIDO intend to transform the PRAHA initiative into a live process with continuous feedback and support to HAT countries.

1. Background and Project Main Elements

Background

The 69th meeting of ExCom approved PRAHA-I with the aim to support assessing the feasibility of lower-GWP refrigerants suitable for high-ambient temperature countries and in particular for air-conditioning applications. UN Environment and UNIDO worked with local industries, international technology providers and national ozone units in these countries to do such assessment through an agreeable independent process that included in its core component building and testing 18 different prototypes and comparing them with respective baseline units which are available from the local industry using mainly HCFC and high-GWP HFC such as R-410A. The process of building and testing the prototypes was completed in 2015 and the final report was released in January 2016. PRAHA included additional components for assessing the technology transfer barriers, energy efficiency implications and economics of alternatives in addition to assessment of district cooling opportunities to reduce dependency on high-GWP alternatives and technologies.

The key finding of PRAHA-I show the potentials and challenges to promote the use of lower-GWP alternatives. Furthermore, many of the non-testing components under PRAHA, like assessing standards and codes and promoting technology transfer, were not thoroughly completed due to two main reasons; the commercial availability of the lower-GWP alternatives in the high-ambient markets and limited resources available to complete the work needed. The findings also pose important queries about what is left to be done in order to make the deployment of low-GWP alternatives possible at high-ambient temperature countries.

PRAHA-I Key Findings

The non-testing components under PRAHA-I assessed technological, economic and energy efficiency aspects in conjunction with high ambient temperature with the following key findings:

I. There are potential alternative refrigerants that are close, or in some cases better, in performance and efficiency compared to baseline refrigerants (HCFC_22 and R-410A) that are worth further investigation. With further product engineering (design and optimization) those alternatives can be strong candidates for replacement of HCFC-22;

II. There is a need to develop the R&D capacity of the local air-conditioning industry in high ambient temperature countries in terms of the design and optimization of products using lower-GWP alternatives with their specifics characteristics, such as flammability, higher operating pressures, temperature glide, etc.;

III. Economic and technology transfer barriers Intellectual Property Rights (IPR) will continue to be issues for some time before international and regional markets stabilize on a limited group of candidates that are sustainable compared to the current long list of options being examined;

IV. Due to the nature of those alternatives and the consequent safety issues, a comprehensive risk assessment model needs to be tailored to the needs of A5 countries, in particular for high ambient temperature conditions. Such a model needs to address manufacturing, placing into market, servicing and the end-of-life of the equipment;

V. There is a lack of institutional programs that address alternative technologies to reduce the dependency on high-GWP alternatives in high ambient temperature countries. This is clearly reflected by the market directions during the phase-out of HCFCs;

VI. The process of improving energy efficiency (EE) standards for air-conditioning application in high ambient temperature countries is progressing at a much quicker pace compared to the process of assessing and selecting alternative refrigerants. A smart approach is needed to jointly consider addressing EE and lower-GWP alternatives in order to avoid promoting higher-GWP alternatives that are commercially available at this stage of time.

Figure 1 summarizes the main findings from PRAHA-I.

Technical Feasibility of low-GWP Alternatives

- *Comparison to commercially existing options i.e. HCFCs & high-GWP HFCs*
- *Relation to Energy Effeceincy programs Directives*

Safety consideration and and Availbility of Materials

- *Risk assessment of A2L and A3 alternatives in industry and service*
- *Availability and cost of alternatives and components*
- *Technology transfer and IPR considerations*

Research and Development Capacities

- *Knowledge and capacity of industry to design with lower-GWP alternatives*
- *Related research programs at global, regional and national levels*

Contribution of District Cooling

- Size and potentiality of district cooling applications
- Use of lower-GWP refrigerants or not-in-kind technologies in district cooling applications

FIGURE 1: MAIN FINDINGS FROM PRAHA-I

The Project

UN Environment and UNIDO approached the Multilateral Fund seeking support for stage-II of PRAHA which is designed to address the priority areas identified in PRAHA-I. The Executive Committee of the Multilateral Fund of Montreal Protocol approved, in its 76th meeting in May 2016, stage-II of the project which is now called PRAHA-II.

The main objective of the project is to maintain the momentum generated by PRAHA-I and advance the technical capacities of stakeholders to enable the adoption and use of lower-GWP sustainable technologies for high ambient temperature countries by supporting the decision-making process related to the acceptance and promotion of lower-GWP refrigerants and advancing the technological capabilities of the local industry to design with those refrigerants.

In consultation with the project stakeholders, several areas were identified that would require further work in order to ensure putting the process of alternative refrigerants' deployment on the right track and address all technical, technological and economic concerns of both industry and policy makers. The areas identified and envisaged to be part of PRAHA-II fall under two components with three distinct elements as shown in **Error! Reference source not found.**. The three elements of PRAHA-II are detailed b elow.

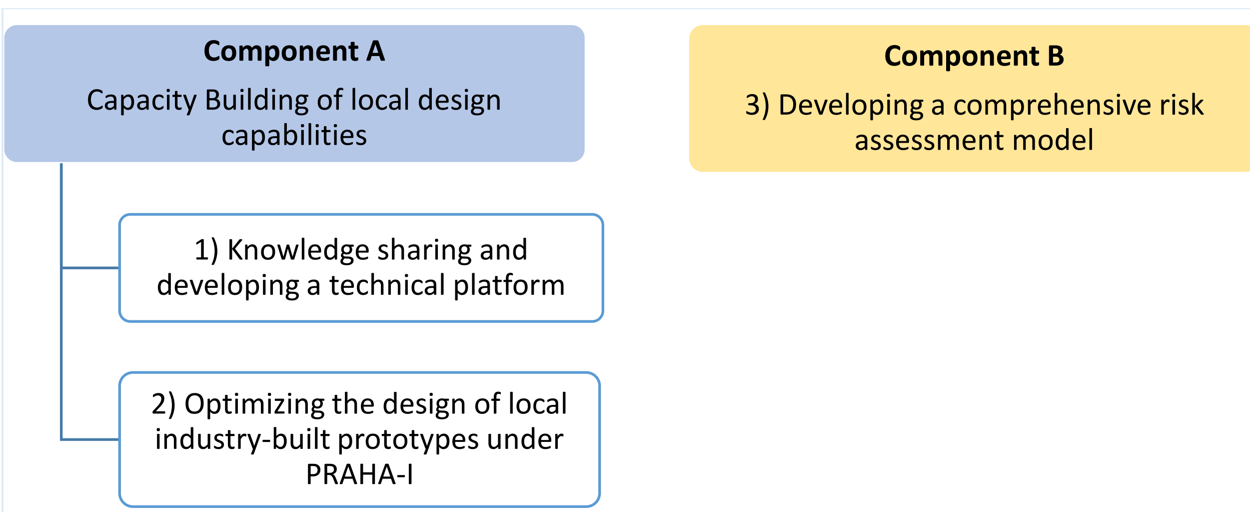


FIGURE 2: OUTLINE OF PRAHA-II

Under Component A, Capacity Building, there are two elements**:**

I. **Building the capacity of R&D sectors in designing with low-GWP alternatives through knowledge sharing and developing a technical platform**
There are three technology schools when it comes to design air-conditioning units, excluding chiller systems, with low-GWP alternatives:

- Designing with HFC-32, which is quite established by the Japanese industry;
- Designing with HC-290, which is at an acceptable level of maturity in China and in other countries;

- Designing with HFO/HFC blends which is just starting to be implemented in different places around the globe.

II. **Optimizing the designs of PRAHA-I prototypes to meet/exceed the baseline designs:** This includes several elements using prototypes of PRAHA-I that had good results and candidate refrigerants that are promising. Prototypes showing unexpectedly poor results will also be evaluated to identify shortcomings.

Component B aims at developing a comprehensive Risk Assessment Model: This includes designing, developing and examining a risk assessment model suitable for use pattern and operating conditions for high ambient conditions and in particular for the GCC region.

2. Capacity Building through Knowledge Sharing and developing a Technical Platform

The concept behind this element is to benefit from the experience of the most advanced industry for each technology in building the capacity of the local R&D in high ambient temperature countries. This includes attending special courses, workshops and conferences discussing these technologies, as well as field visits to manufacturing centers in countries pioneering the technologies.

The three centers of technology for the three main types of lower-GWP refrigerants are Japan, China, and the United States. The Japanese industry is leading in HFC-32 technology for the residential air conditioning sector (apart from Variable Refrigerant Flow -VRF) and is the most proliferated technology in terms of market penetration even though it does not have the lowest GWP. The Japanese market is fully transitioned into using this technology and all Japanese manufacturers are currently producing products using HFC-32. These companies, and other, are building HFC-32 products outside Japan and are marketing them in other markets including some of the HAT countries. The HFC-32 program was conducted in cooperation with Japan Refrigeration and Air Conditioning Industry Association (JRAIA) with input from the Japan Society of Refrigeration and Air Conditioning Engineers (JSRAE) and the industry.

The Chinese industry have an established HC-290 technology and have successfully implemented several conversion projects under UNIDO/UNEP. . Even though the products are not widely available globally, the potential for this technology is very promising due to the many advantages that HC-290 offers in terms of energy efficiency and low-GWP characteristics. The draw-back of high flammability was the main concentration of the capacity building efforts for the stakeholders. The HC-290 program was conducted in cooperation with the Chinese Household and Electrical Appliances Association (CHEAA) and the Chinese industry

The North American industry is leading in the field of unsaturated HFC technology, also referred to a Hydrofluoroolefin (HFO) technology. Although most of the lower-GWP HF0 refrigerants are still not widely available globally, test results have shown some promising alternatives with good performance. The HFO training program which was designed in cooperation with the Air Conditioning, Heating, and Refrigeration Institute (AHRI) which represents the industry in the US with involvement from and the technology providers, i.e., refrigerant and compressor manufacturers.

The capacity building efforts had two tracks: TRACK-I capacity building for the manufacturers of PRAHA-I, and TRACK-II knowledge sharing with different stakeholders at regional and global events

2.1. Track-I: Capacity Building for the Manufacturers of PRAHA-I

The objective of this track is to expose the manufacturers of PRAHA-I to the three technologies through factory visits, study tours, specialized courses, and special events. The purpose is to see firsthand how the technologies have developed in the three centers and how to apply them locally in terms of design, production capabilities, and after sales support.

This track included two study tours, one to Japan and one to China which also included events that were specially designed for PRAHA. In Japan, a risk assessment workshop to explain the Japanese model for A2L refrigerants and the data needed for building the model; and in China a special workshop on A3 refrigerants that attracted input from local and international resources and included participants from other HAT countries.

The HFC-32 study tour objective was to provide participants with a good background about designing and working with lower-GWP refrigerants with A2L low-flammability characteristics. The tour included plants visits, the risk assessment workshop, as well as attending the JRAIA International Symposium on "New Refrigerants and Environmental Technology".

The plant visits took place at Daikin facility in Shiga and the Mitsubishi plant in Shizuoka. Both plants produce HFC-32 based units and have been in production for a couple of years with hundreds of thousands of units installed. The plant visit included explanation of the charging and testing facilities where special precautions are needed. Participants were able to view the special measures taken for the safe handling of flammable refrigerants including storage.

The one-day workshop was conducted by JRAIA at their premises in Tokyo. The subject was risk assessment of A2L refrigerants for residential and commercial equipment. The information provided was detailed and included a review of the risk assessment work conducted by JRAIA; a presentation of key requirements for design; risk assessment for residential & commercial split type air conditioners and VRF during installation and maintenance; and safety guidelines during charging and servicing. Presenters were from Daikin, Panasonic, and Mitsubishi.

The symposium took place in Kobe Dec 1 & 2, 2016: The program provided in-depth information about global efforts to transition to lower-GWP refrigerants including research, regulation, design, safety, components, and energy conservation. The symposium also included a session on new refrigerants and their systems.

The HC-290 study tour objective was to provide in-depth knowledge of HC-290 with visit to a production plant, a building with an HC-290 installation, a special workshop, plus visit to China Refrigeration Expo to attend a one-day roundtable organized by UN Environment and other associations billed as Ozone2Climate Industry Roundtable (O2C).

The visit to AUX factory near Ningbo allowed the participants to view the special measures taken to manufacture equipment working with A3 flammable refrigerants. Factory personnel provided an overview of the R&D work and planning as well as sharing some information on the availability of products and their comparison to those operating with high-GWP refrigerants.

A visit to a facility with more than 1,100 units running on HC-290 was also arranged. The facility is a student dormitory for over 2,000 students in several buildings and all rooms are fitted with mini-splits running on HC-290. The units have been in operation for over two years and no incidents or major problems were reported. Participants were given a presentation by the management and maintenance staff and had the chance to interact with students and gauge their experience living in a facility with units running with an A3 refrigerant.

Workshop on Designing, Production and Installation with HC-290 in the Air Conditioning Industry was organized for PRAHA in collaboration with the Chinese association CHEAA and the Ozone authority of China, FECO. The workshop was enlarged to include other participants from China who joined the expanded PRAHA team. The expanded team included participants from Egypt, Tunisia and Vietnam. The agenda of the two-day workshop included presentations by research facilities, universities, and Refrigeration, Air Conditioning and Heat Pump (RACHP) component and equipment manufacturers.

The workshop focused on risk assessment and other measures related to hydrocarbons and HC-290 in particular. Presentations included a review of international standards and what is needed to enable the new flammable technologies to be adopted by the residential and commercial AC sector; conversion of a production line for the manufacturing of R290-based RAC equipment; and the performance of HC-290 in high ambient conditions. Other presentations discussed the installation and servicing of equipment with flammable refrigerants; reducing charge amount; and a review of R&D work by the manufacturers on A3 refrigerants.

The O2C Roundtable was organized by UN Environment, UNDP, FECO, and CHEAA and covered subjects on policy to promote alternative technologies, global trends, challenges and opportunities for the industry, and solutions for the cold chain and logistics. The PRAHA team presented the challenges in phasing out HCFCs in the countries with higher ambient temperature. Participants had the chance to visit the China Refrigeration Expo in Shanghai, one of the largest for RAC equipment.

The HFO experience in the United States included a course on "*New ASHRAE-Classified Refrigerants to Meet Society's Changing Needs*" by the ASHRAE Leaning Institute (ALI) was offered to several PRAHA stakeholders who were attending the ASHRAE conference and AHR expo. The course discussed the properties of refrigerants and the history of development of synthetic refrigerants and delved into a detailed discussion on flammability and the safe uses of refrigerants. International standards and agreements governing refrigerants and flammability were discussed.

The participants were also invited to a one-day workshop by the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) on *"Sustainable Technologies for Stationary Air Conditioning"* which aimed to familiarize participants with climate-friendly and cost-effective air conditioning technologies which have proven their applicability to replace high-GWP HFCs.

PRAHA-II team presented on "Challenges at High Ambient Temperature" with discussions on the effect of high ambient on the design and operation of air conditioning systems, energy efficiency of refrigerant alternatives, and safety when using flammable refrigerants. The presentation also included highlights from the four research projects testing low-GWP refrigerant alternatives at different temperatures and a comparison of the results. The presentation concluded with a brief description of the work done on PRAHA-II.

The key outcomes from this element of PRAHA-II were in providing information on risk assessment work for both A2L and A3 refrigerants; informing on the availability of new components and new products running with lower-GWP refrigerants; viewing of operating production lines handling A2l and A3 flammable refrigerant; experiencing an actual installation with more than 1,100 HC-290 units installed; and acquiring information form specially designed workshops, seminars, and courses.

2.2. Track-II: Sharing with the different stakeholders at regional and global events

PRAHA-II expanded beyond the original PRAHA-I participants. PRAHA started by inviting members from EGYPRA, the Egyptian Project for Testing Low-GWP Refrigerant Alternatives, to events and study tours. The addition of EGYPRA was a natural one as both projects have similar goals in testing alternative refrigerants on prototypes built by the local industry. EGYPRA participants joined the study tour to Japan in November 2016. The study tour to China in April 2017 was joined by participants from Tunisia and Vietnam; Pakistan was also invited but could not join.

The workshop in Japan was built for the PRAHA and EGYPRA participants. In China, the workshop included, other than EGYPRA, Tunisia, and Vietnam, many participants from China. It also included NGOs, and global researchers. There were close to a hundred participants and the workshop turned into a large forum on the research and development of A3 refrigerants.

Awareness building about HAT and the PRAHA project has been a constant element of PRAHA. The PRAHA-I final report lists the programs and the events which PRAHA launched or participated in. The HAT series of symposia is but one example of the awareness building achievements of PRAHA.

With PRAHA-II, the campaign continued with PRAHA taking advantage of the presence of its managers or consultants to continue the message and update stakeholders, the industry, and the Parties on the developments and the latest technological information related to HAT or to the research at HAT.

PRAHA appears in websites both by UN Environment and UNIDO. Some examples:

https://www.unido.org/our-focus/safeguarding-environment/implementation-multilateral-environmental-agreements/montreal-protocol/finding-climate-friendly-ways-cool-down

PRAHA has truly helped in spreading awareness on HAT challenges and opportunities. The continuous awareness of the challenges and the opportunities of the HAT regions has made HAT a permanent subject to be added to the Decisions of the Parties and is a part of every Task Force study and report. HAT now is a full chapter of the 2018 RTOC Assessment Report.

Table 1 shows events and functions where PRAHA either organized special/program in their margins, joined as keynote presentation or organized a dedicated event about the subject.

TABLE 1: PRAHA PARTICIPATION IN INTERNATIONAL EVENTS

#	Date	Event
1	Jan 2016	Special Session at ASHRAE Winter Conference
2	Mar 2016	Special Session at West Asia/Africa Joint Network Meeting
3	July 2016	Special Session at OEWG-38
4	Aug 2016	Training Course at IIR Gustav Lorentzen Conference
5	Sept 2016	Special Session ASHRAE-AUB Efficient Building Design Conference
6	Dec 2016	Special Workshop on Designing with A2L Refrigerants

#	Date	Event
7	Jan 2017	ASHRAE Winter Conference and AHR expo
8	Jan 2017	CCAC Sustainable Technologies for Stationary AC Workshop
9	April 2017	Special Workshop on Designing with A3 Refrigerants
10	Oct 2017	International Workshop on Risk Assessment for HAT
11	Nov 2017	Special Session at CCAC Workshop at MOP-30 on Opportunities, Challenges, and Experiences with Transitioning to Low-GWP Alternatives
12	Jan 2018	Special Session at OzonAction First Interregional Networks' Meeting
	Oct 2018	Flammable Refrigerant Research and Planning Conference
13	Jan 2019	ASHRAE Winter Conference
14	Feb 2019	Special Session at OzonAction Second Interregional Networks' Meetings
15	March 2020 *(Planned)*	6th International Symposium on Alternative Refrigerants for High Ambient Temperature Countries

2.3. Conclusion from the Capacity Building Element

The experience of working on PRAHA gave UN Environment and UNIDO the confidence that international stakeholders support the goals of the project and that the outcome will be beneficial to all beyond economic gains. On the other hand, and simultaneous to the efforts by the PRAHA project to create awareness about HAT challenges and the work done through the different symposia held in the HAT countries that were participating in the PRAHA project, the HAT countries themselves were bringing up the issues at the different meetings of the Parties whether at the Open-Ended Working Group (OEWG) meetings or the Meeting of the Parties (MOP).

The capacity building element was successful in providing a platform of cooperation between governments, research institutes, industry associations, and the industry in general and became a process for the sharing of information and results among the different stakeholders.

3. Optimization of PRAHA-I Prototypes

This component includes several elements using prototypes of PRAHA-I that had promising results. Prototypes that showed unexpectedly poor results will also be examined to identify shortcomings. The exercise includes mainly three stages of work on the prototypes, plus a leak analysis stage:

a. Analyzing the design of PRAHA-I prototypes: a physical inspection and analysis of prior experimental results, plus a first order assessment of component and refrigerant performance.
b. Design optimization of PRAHA-I prototypes including: acquiring performance maps for components (compressors, fans) that are more suitable for the application; evaluating alternate heat exchanger design configurations; performing detailed engineering optimization to match or exceed the baseline unit performance within an acceptable design space set forth by an expert committee. This may include installing new upgraded compressors, for same refrigerants used in PRAHA-I, and which were not available at the time PRAHA-I prototypes were built; or compressors for refrigerants not tested under PRAHA-I; if so required.
c. Testing new refrigerants emerging since PRAHA-I using prototypes of PRAHA-I with change/upgrade of compressors.
d. Analyzing leak-recharge effect on performance for high glide alternatives.

3.1. Contracting the Activities

PRAHA first contact was with Oak Ridge National Laboratory (ORNL) who had performed their own testing at HAT conditions on two units with two different baseline refrigerants.

Unfortunately, due to legality issues and differences in the contractual practices commonly followed by UNEP, the contract between UNEP and ORNL did not materialize in spite of several attempts to find out solutions.

PRAHA team managed to negotiate and contract with The Air Conditioning, Heating and Refrigeration Technology Institute (AHRTI), the research arm of (AHRI) to take over the task as an internationally independent institute with relevant experience in conducting similar work i.e. AREP project (Alternative Refrigerants Evaluation Programme) and having access to several reputable testing and research centers within North America where the prototypes from PRAHA-I were being stored since end of PRAHA-I project. AHRTI, finally, selected Optimized Thermal Systems (OTS) as the most capable and sound research center for completing the planned work within the required timeline and budget.

3.2. Scope of Work

The scope of work that is covered by AHRTI's contractor OTS includes five activities as follows:

Activity 1: Analyzing the Design of PRAHA-I Prototypes

This task involved the following:

- Physical inspection
- Prior experimental results assessment
- First order assessment of component and refrigerant performance
- Development of validated model
- Detailed assessment of why the performance is "good, i.e. as designed" or "bad, why it did not perform as designed"

Activity 2: Design Optimization

Design optimization study for select units using the heat pump design model for available prototype units. This entailed:

- Acquiring performance maps for components (compressors, fans) that are more suitable for the application
- Evaluating alternate heat exchanger design configurations
- Performing detailed engineering optimization to match or exceed the baseline unit performance within acceptable design space set forth by an expert committee. This may include installing new upgraded compressors, for same refrigerants used in PRAHA-I that were not available at the time PRAHA-I prototypes were built; or compressors for refrigerants not tested under PRAHA-I; if so required.

Activity 3: Prototype Units Fabrication

AHRTI, in coordination with UN Environment, selected a subset of prototype units and modify them as per the design optimization study. This involved heat exchanger modification, compressor replacement, expansion valve fine-tuning, fans and blower replacements, etc. All components were from standard production lines.

Activity 4: Evaluation of the Optimized Prototypes

Optimized prototypes were tested in the multi-zone environmental chamber to evaluate their performance according to ASHRAE Standard 37 at relevant indoor and outdoor conditions (AHRI 210/240 "A" condition, ISO 5151 "T3" condition, hot and extreme conditions)

Activity 5: Analyzing Leak-Recharge Effect for High Glide Alternatives

The impact of leak-recharge effect on the performance of alternative refrigerants with high glide was experimentally evaluated.

Activity 6: Reporting and Data Management

AHRI submitted a peer-reviewed project report prepared by OTS.

3.3. Deliverables

The key deliverables/results to be achieved are:

a) Evaluation of prototypes tested under PRAHA-I
b) Optimized PRAHA-I prototypes: three units chosen
c) Analysis of leak-recharge of high glide alternatives on system performance
d) Report summarizing the project findings.

3.4. Matrix

The work to be done is shown in the matrix Table 2. The work is in five phases:

- Evaluation of the prototypes;
- Optimization of selected prototypes;
- Building some of the units per the optimized design;
- Testing for a number of refrigerants;
- Leakage assessment.

The selection of units for the various activities as well as that of the refrigerants was done the PRAHA team in coordination with the AHRTI based on:

- For Activity 1, all units needed to be evaluated.
- For Activity 2 for the modeling activity of optimization, the team chose one unit from each application, i.e. window, decorative split, and ducted split. An extra decorative split unit running with HC-290 was also added since decorative splits are the most abundant in the market and the team felt it important to have two splits optimized, one with HC-290 and one with alternatives to R-410A. The team also tried to balance the refrigerants choosing both alternatives to HCFC-22 as well as R-410A. At the time of selection, there was no clear trend or indication from the industry as to which refrigerants would be commercialized. One of the refrigerants originally selected had to be dropped at the request of the supplier.
- For Activities 3 & 4, the window unit with HC-290 was chosen to be re-built and tested. These activities for the window unit had to be dropped for reasons mentioned under **Challenges and Modifications**. For the decorative and ducted splits units 6 and 10, the team chose to work with the same refrigerant alternatives as in Activity 2. Activities 3 and 4 finally worked on one decorative split (unit 6) and one ducted split (unit 10).
- For Activity 4, leak analysis, all the zeotropic blends used in activities 3 and 4 were planned to be tested.

For the unit numbering system, units 1 to 3 are window units, units 4 to 9 are decorative splits and units 10 to 12 are ducted splits.

TABLE 2: MATRIX OF ACTIVITIES FOR THE PROTOTYPE OPTIMIZATION ELEMENT OF PRAHA-II

		Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
Unit	**Type**	**Phase I data analysis**	**Optimization**	**Build per optimization**	**Test per build**	**Leak analysis**
1	Window	L-20 (R-444B)	R-444B			
			R-454C			
			R-290	HC-290*	HC-290*	
			R-457A			
6	Decorative Split	HFC-32	HFC-32	HFC-32	HFC-32	
			R-454B	R-454B	R-454B	R-454B
10	Ducted	HCC-32	R-447B	R-447B	R-447B	R-447B
			R-452B	R-452B	R-452B	R-452B
4	Split	HC-290	HC-290			
2	Window	R-444B				
3	Window	DR-3 (R-454C)				
5	Split	HFC-32				
7	Split	L-41 (R-447A)				
8	Split	R-444B				
9	Split	R-454C				
11	Ducted	R-444B				
12	Ducted	R-454C				

* Could not be completed due to 1) not fitting the timeline, and 2) the limitation of testing A3 packaged (window)

3.5. Project Monitoring

AHRTI assembled a project committee made up of AHRI members to help monitor and guide the project and set-up biweekly conference calls with OTS and the PRAHA management team. The calls, which started in November 2018, are normally held on the first and third Thursday of every month. As part of the bi-weekly update, OTS reports both on the progress as well as the technical aspects of the project and solving any possible problems that may arise

On such example is the participation of an additional refrigerant supplier in the project through the supply of information and quantities of refrigerant R-459A to test in one of the optimized and rebuilt prototypes. The problem of receiving response from the supplier was raised in one of the calls and the supplier was contacted by the PRAHA team. The supplier advised of its inability to provide R-459A timely and asked to withdraw from the project. R-459A was replaced by R-454B which has been gaining acceptance by the industry lately.

3.6. Challenges and Modifications

The implementation of this portion of the PRAHA-II project came up with some challenges:

The tests that were carried out for PRAHA-I, while sufficient for the purpose of measuring capacity and energy efficiency for the purposes of PRAHA-I, did not have enough essential data to enable a complete cycle evaluation for optimization purposes.

Some key components and specifications, such as compressors and/or compressor maps for HC-290 and heat exchangers, were not readily available to fit in the project timeline.

The scheduling mechanism of the lab for PRAHA I (fixed test window) and testing logistics was not suited for completing of the project within the budge and required timeline. Therefore equipment performance testing was carried out in-house at OTS facility; however, its lab was not equipped to test the window unit of unit 1 working with A3 flammable refrigerant HC-290 (propane) due to safety concerns and requirements. Testing Unit 1 had to be dropped. Alternatively, the optimization of window unit was carried out using modeling approach.

Overall, the analyses presented by the design assessment through modeling provided good insights on adequate component design and/or selection for proper system functioning when using novel refrigerants. The tests in activities 3-5 partially served as validation for the models developed, and as check for previous test data from PRAHA I.

3.7. Project Implementation and Findings

The full AHRTI report is an annex to this report. The summary of findings per activity are given below

3.7.1. Activity 1 – Analyzing the Design of PRAHA-I Prototypes

Activity 1 was comprised of three major tasks including: a) reception of 12 physical units at the OTS facility followed by visual inspection and parts identification; b) review of performance test reports from PRAHA I tests; and c), analysis of data and identification, for units of interest, opportunities for improvement targeting higher performance and minimal charge.

The twelve units are shown in Table 3 with the PRAHA-I test results and the new refrigerants to be used.

TABLE 3: MATRIX OF UNITS AND NEW REFRIGERANTS TO BE TESTED

Category	Unit #	Ref.	Designed Capacity Btu/h	Measured Cap. Btu/h	Voltage	Ref. (New designs)	Ref. (Tests)
Window	**1**	**L-20 (R-444B)**	**18,000**	**19,104**	**208-230/60/1**	**R-444B, R-454C, HC-290, R-457A**	**HC-290**
	2	L-20 (R-444B)	18,000	16,924	208-230/60/1		
	3	DR-3 (R-454C)	18,000	18,063	208-230/60/1		
Decorative splits	**4**	**HC-290**	**24000 (18,000)**	**19,000**	**208-230/60/1**	**HC-290**	**HC-290**
	5	HFC-32	24000 (18,000)	19,328	208-230/60/1		
	6	**HFC-32**	**24,000**	**25,456**	**208-230/60/1**	**HFC-32, R-454B**	**HFC-32, R-454B**
	7	L-41 (R-447A)	24,000	24,830	208-230/60/1		
	8	L-20 (R-444B)	24,000	22,740	208-230/60/1		
	9	R-454C	24,000	14,638	208-230/60/1		
Ducted splits	**10**	**HFC-32**	**36,000**	**35,500**	**220-240/50/1**	**R-447B, R-452B**	**R-447B, R-452B**
	11	R-444B	36,000	36,553	220-240/50/1		
	12	DR-3 (R-454C)	36,000	33,032	220-240/50/1		

Following is a summary of findings from Activity I

A. Analysis of PRAHA-I Test Results:

- **For the window units:** *Evaporator:* The inlet refrigerant temperature and pressure were not measured. The outlet pressure was estimated from suction pressure, a reasonable assumption given the short distance between the evaporator and compressor. The outlet temperature was measured so the superheat was computed. *Condenser:* The inlet refrigerant temperature and pressure were measured. The outlet pressure was not measured, but the outlet temperature was measured.
- **For the decorative splits:** *Evaporator:* The "Inlet Pressure" is the value measured at the service port at the exit of the outdoor unit, after the expansion device (capillary tubes). So, there is significant, but unmeasured pressure and saturation temperature drop between the measurement location and the actual inlet of the evaporator as abovementioned. The "Outlet Pressure" was measured at the service port before entering the outdoor unit. There was an unmeasured pressure drop in the suction line from the evaporator outlet to that measurement location. The inlet and outlet temperature measurements seem like reasonable numbers for the actual inlet and outlet. *Condenser:* The inlet pressure was not measured, the inlet temperature was measured, and the outlet pressure was only measured for Unit 4. The outlet liquid temperature was not measured, rather, the "OD Liq" temperature measurement was likely taken at the liquid service port, near the pressure

measurement. The temperature was much too low to be the actual condenser outlet, but not cold enough to be the evaporator inlet.

- **For the ducted splits**: *Evaporator:* The "Inlet Liquid" temperatures and pressures were taken before the TXV, so they were not actual measurements of the evaporator inlet condition. The outlet temperature and pressure measurements were available so the superheat could be calculated (lab used the compressor suction temperature rather than evaporator outlet temperature to compute superheat.) *Condenser:* The inlet temperature was measured, but the pressure was not. The outlet temperature and pressure were measured, so the sub-cooling was calculated. The sub-cooling computed by the lab ranged between 17 to 18°F, which doesn't correspond to the measured conditions. The calculated sub-cooling for Unit 11, however, was negative for all three tests; as such, it is possible that there was a two-phase refrigerant at the condenser outlet.

B. Hardware Improvement Assessment

This section defines a first order analysis of the effect of hardware assessment for units 1, 4, 6, and 10. A first order analysis is structural analysis that is performed without taking the unit apart or making any changes to. The analysis is made for the different components.

Unit Component Modification Potential

Table 4 shows the detailed existing components for the units of interest for modification.

TABLE 4: COMPONENTS FOR UNITS 1, 4, 6, AND 10

System	Unit 1	Unit 4	Unit 6	Unit 10
Refrigerant	**R444B**	**R290**	**R32**	**R32**
Compressor	HIGHLY SL260DG-C8EU	HIGHLY PSH356DG-C8DU3	GMCC KSG226N1UMT	Copeland ZP42K5E-PFJ-XXX
Condenser	5mm Louver TFHX	9.5mm Wavy TFHX	7mm Louver TFHX	9.5mm Louver TFHX
Expansion Device	Capillary Tube	Capillary Tube	Capillary Tube	Capillary Tube
Evaporator	9.5mm Louver TFHX	7mm Louver TFHX	7mm Slit TFHX	9.5mm Louver TFHX

- **Heat Exchangers (HX):** OTS put as an objective to improve performance while minimizing charge. One way of addressing both objectives is by reducing the tube/channel diameter since heat transfer coefficients are inversely proportional to tube diameters. Pressure drop is also inversely proportional to tube diameter so smaller tubes result in reduced size and reduced internal volume but higher pressure drop.

  A qualitative analysis using values from literature was carried out to demonstrate the relative impact of diameter over abovementioned metrics, specifically: heat transfer coefficient, compactness and overall thermal conductance (UA). The left-hand side plot in Figure 3 shows three curves inversely proportional to the diameter; a 5mm tube can achieve, in this example, 70% greater UA than a conventional 9.5mm, within the same cabinet.

These are further explored to illustrate the impact on a system level. Systems respond to UA of both condenser and evaporators, but for the purposes of this analysis, the condenser is only considered. UA represents the overall thermal conductance, which will impact the approach temperatures in the system (ΔT_{app}). If the heat of rejection is kept constant, the higher the UA, the smaller are the ΔT_{app}'s, thus allowing the condenser to operate in lower pressure levels, which will consequently increase the system performance. An example using a hypothetical HFC-32 cycle with an EER of 12 as base is shown in the right-hand side plot in Figure 3. Performance improvement is limited by the Second Law, when the approach temperatures near zero. In this illustration, the EER has the potential to increase by over 20% with better condenser design alone.

It is imperative to note that the results presented in this section are first order analysis for illustration purposes only. Further in this report it is presented in more detail a re-design framework, applied to the units of interest in this project, using the metrics outlined in this section.

Unit 1 already had a 5mm condenser, which limits the options for HX re-design. Unit 6 had a 7mm HX on both the indoor and outdoor units, which allows some room for improvement if reducing to 5mm. Lastly, both coils for Unit 10 had 9.5mm tubes, thus there is greater potential for charge reduction and performance improvement for that unit in particular.

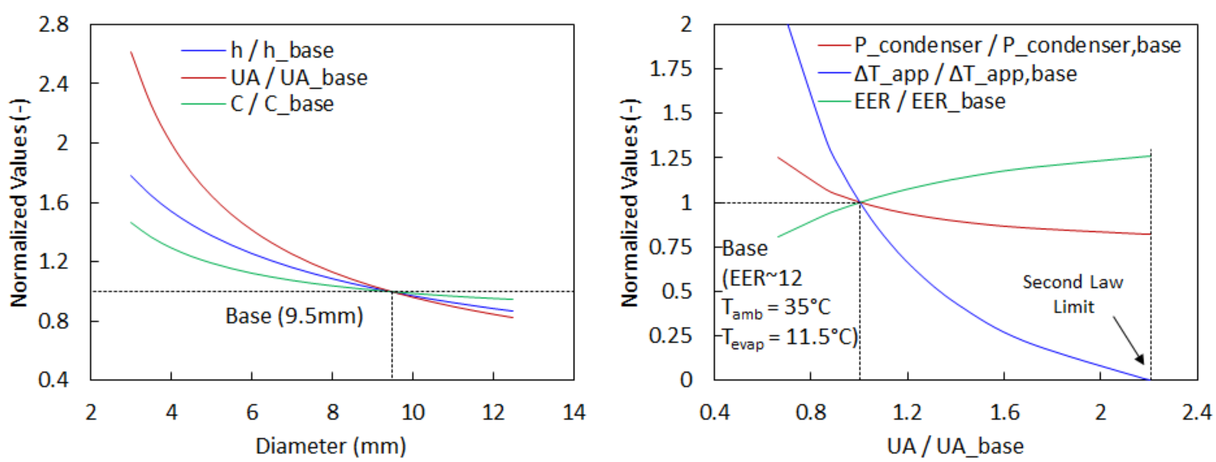


FIGURE 3: HEAT EXCHANGER FIRST ORDER ANALYSIS (FOA)

- **Compressors:** The existing units mostly use compressors sized specifically for R-410A or HCFC-22 and in some cases custom made for the particular application. This presents an opportunity for a better compressor selection when migrating to other refrigerants such as R454B or R447B on Units 6 and 10, respectively. A compressor designed for a particular refrigerant having a higher efficiency rating will result in better energy efficiency performance of the same unit.
- **Expansion Devices:** Expansion devices such as TXV's and EXV's may allow for better control and reduced losses in connecting pipes if located near the evaporator. Some units, such as 6 and 10, have a capillary tube in the outdoor unit, which forces the refrigerant to travel in two-phase

along the connecting pipes, and at lower temperatures, thus increasing pressure drop and heat gain. In some regions, expansion devices are installed in the outdoor units for noise control purposes.

- **Fans and Blowers:** Replacing the fan and blower may be necessary if newly designed HXs offer considerable change in pressure drop over the baseline since the flow rates are kept constant. The lack of test data on pressure drop forces us to rely on predicted values only.

3.7.2. Activity 2 – Design Improvements

OTS developed improved designs for some units, including use with additional refrigerants. The main goals were to maintain capacity while minimizing internal volume (refrigerant charge) and maximizing performance (COP). The exercise in optimizing the improved designs is subject to limitation in component availability from pre-established vendors. The activity involved:

- Developing a cycle simulation model for each of the baseline systems.
- Calibrating the models using the data provided in Activity 1 (relying on the performance test data for the three ambient conditions).
- For each system, evaluating whether the existing compressor and fans are the best fit, or if alternate designs would be preferred.
- Evaluating heat exchanger design options and suppliers for alternative off-the-shelf solutions. As appropriate, conduct a thorough parametric analysis study for the air-to-refrigerant heat exchangers for use with the alternative refrigerants. In addition to heat exchanger type and/or tube diameter and fin pattern, this may include revised circuitry.
- For each of the targeted design cases/refrigerants, evaluating the performance of optimum component selections and quantifying any anticipated performance gains.

Following is a summary of findings from modeling and simulation:

A. Hardware: A first order analysis in Activity 1 showed that moving towards smaller hydraulic diameter tubes can be beneficial from a charge reduction standpoint. Units 4 and 10 use conventional 9.5mm diameter tube condensers making them good candidates for condenser replacement with either a smaller tube diameter or a microchannel heat exchanger (MCHX). The compressors used on Units 1, 4 and 6 do not have available performance maps making it difficult to assess their fitness for the system. The focus of this study is on proper compressor selection and condenser re-design.

B. Refrigerant: HC-290 and HFC-32 have wider saturation regions, as can be seen from Figure 4 and Figure 5 for P/h and T/s, putting them at an advantage since they may operate with smaller superheat and sub-cooling, while benefiting from two-phase heat transfer. Their cycles may get closer to that of the ideal Carnot cycle compared to refrigerants with narrower saturation. Although this appears to be the case, this is not universally true for mixtures since they can exhibit other properties that make them suitable for certain designs.

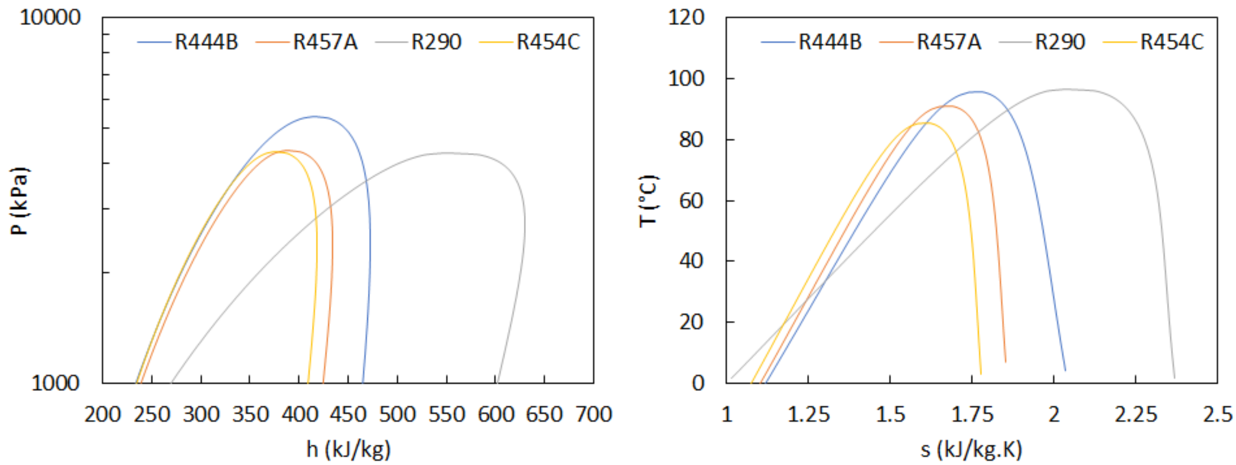


FIGURE 4: P-H AND T-S DIAGRAMS FOR HCFC-22 ALTERNATIVES

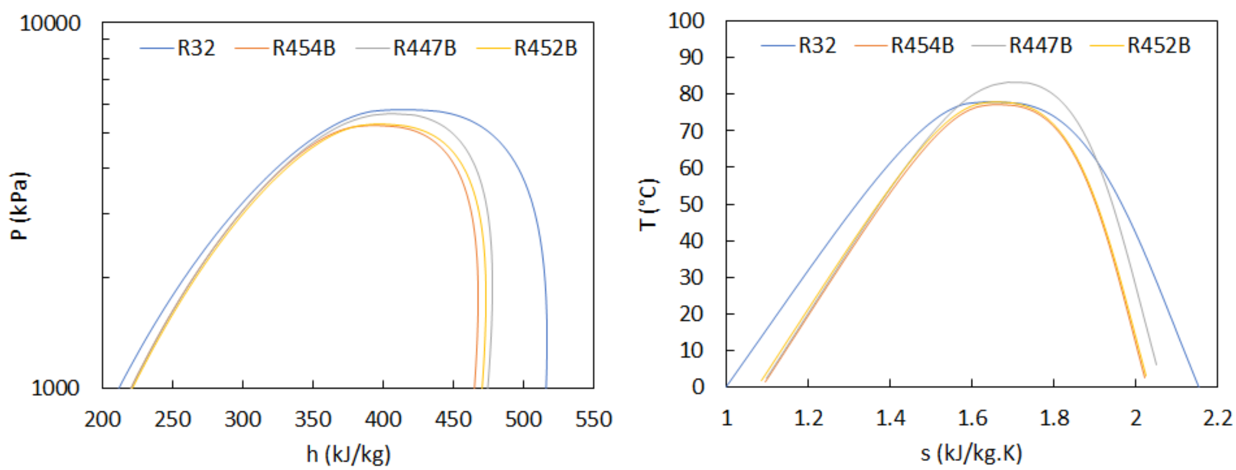


FIGURE 5: P-H AND T-S DIAGRAMS FOR R-410A ALTERNATIVES

Amongst the blends investigated for Unit 1, R-444B has the widest saturation region while also having the highest temperature glide Figure 6 .The latter is typically not beneficial, in particular for evaporators, but it may help the condenser. The glide enables the refrigerant temperature profile to get closer to the air temperature profile without crossing (Figure 6). From a thermodynamic perspective, this means R-444B can have its condensing pressure reduced further, resulting in higher theoretical COP.

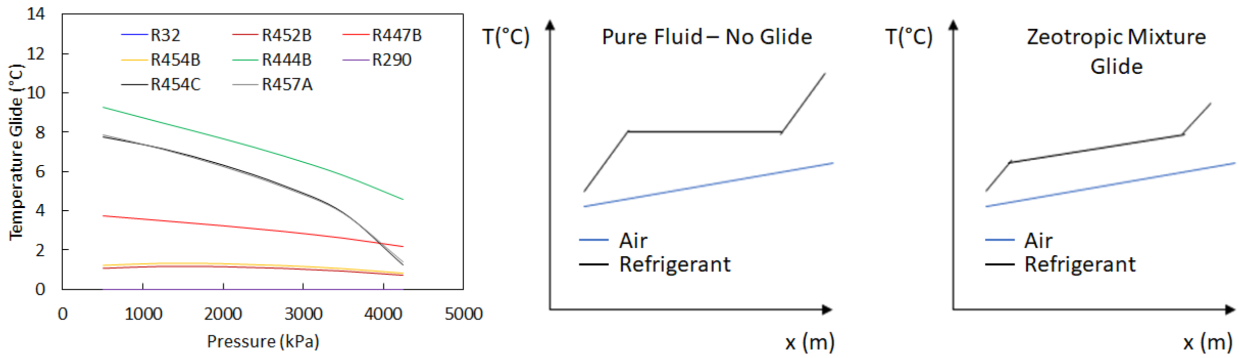


FIGURE 6: PROFILES OF REFRIGERANTS

For Units 6 and 10, the investigated blends, although having narrower saturation than the baseline R32, have similar thermophysical characteristics (Figure 4) with lower temperature glides (Figure 6Figure 7) making them more competitive from a capacity and performance perspective.

C. System Design Optimization / Modification Framework: The framework consists of a retrofit of the existing units by properly designing and selecting components that can be replaced with no modification of the cabinets. In other words, any component replaced must occupy the same envelope as the baseline component. The focus of the re-design is on:

- Compressor
- Condenser, and
- Expansion valve

The evaporator designs were not changed for two main reasons: a) some are custom-made wrap-around the blower units, such as in Unit 6, making it hard to quickly find an off-the-shelf option; and, b) the goal is to deliver the same cooling capacity while improving efficiency. For the latter, there is more room for improvement in the condenser by reducing condensing pressure, assuming the evaporator can already deliver the expected capacity.

The fans and blowers were also not considered for change, in part due to the lack of information on the performance curves from the baseline models, but also due to potential high cost and lead time for replacement with secondary impact on performance since 80-90% of the power consumed comes from the compressor.

The first step to assess the level of performance required for each component is to investigate an improved theoretical cycle, which will indicate how much COP improvement can be expected, as well as refrigerant flow rate needs and HX size (UA). To improve the performance of a vapor compression cycle, the pressure lift between evaporating and condensing pressures must be reduced. Consequently, the approach temperatures between air and refrigerant will be reduced as well (Figure 7), thus the thermal capacitance of the heat exchangers must increase. Furthermore, the closer to the saturation region, the closer the cycle reaches the ideal Carnot efficiency (Figure 8).

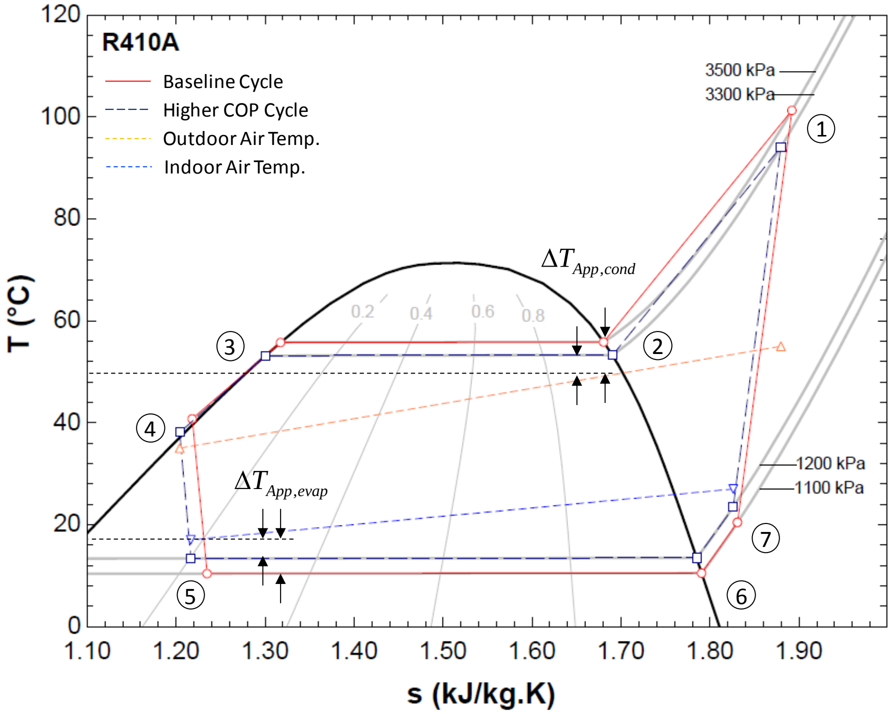


FIGURE 7: ILLUSTRATIVE T-S DIAGRAM FOR BASELINE AND IMPROVED CYCLE

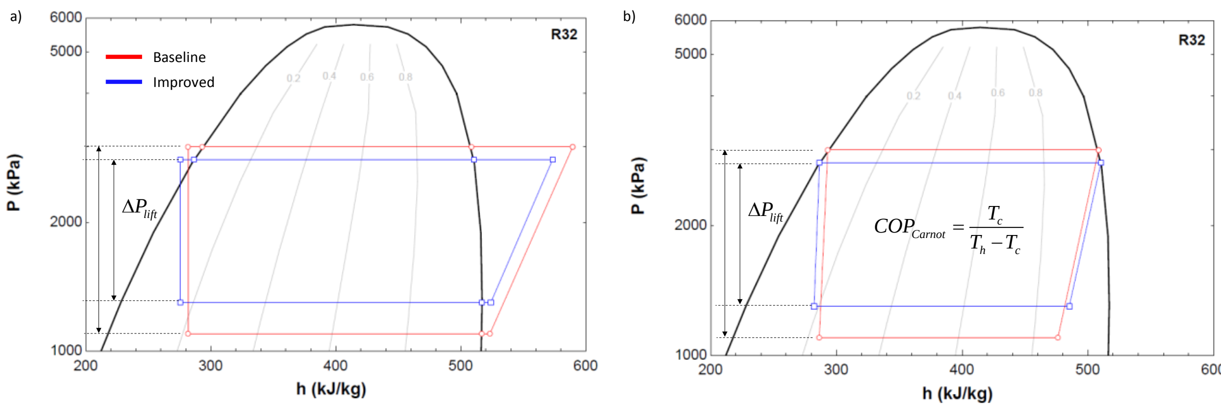


FIGURE 8: DIAGRAM ILLUSTRATING COP IMPROVEMENT A) REAL CYCLE, B) IDEAL CYCLE (CARNOT)

The system design framework is performed according to Figure 9

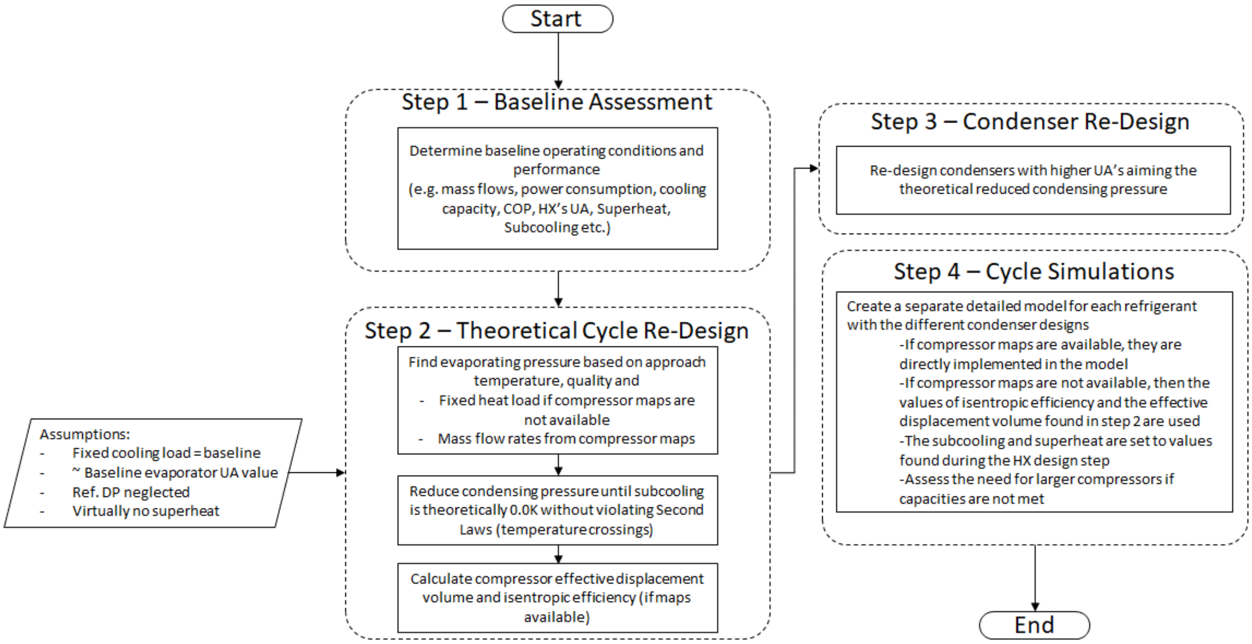


FIGURE 9: SYSTEM DESIGN FRAMEWORK

C. **Compressors**: Modeling compressors are handled in two possible ways, as suggested previously: using performance maps when available or using fixed isentropic efficiency and effective displacement volume. For the larger capacity units (6 and 10), performance maps were provided. Although these compressors were originally designed for R410A refrigerant they may operate – not necessarily optimally – with other refrigerants. Compressor manufacturers supporting this project used proprietary simulation tools, with aid from available empirical data (tests with other refrigerants), to develop theoretical maps for the various refrigerants of interest (Table 5) and made them available to OTS for modeling purposes. It is understood that the predictions are for reference only, and the compressor manufacturer does not guarantee performance for any refrigerants for which the compressors haven't been fully tested.

TABLE 5: COMPRESSOR MODELS

Model	Capacity (BTU/hr)	Frequency (Hz)	Refrigerants
ZP20K5E-PFV	24,000	60	HFC-32, R-454B, R-410A
ZP21K5E-PFV	24,000		
ZP31K6E-PFV	36,000	50/60	R-447B, R-452B, R-454B, R-410A
ZP34K6E-PFV	36,000		

For the smaller units (1 and 4), which were re-designed using HC-290 (Propane), compressor performance maps were not available. The approach for these units then was to set a target isentropic efficiency of 0.7 (baseline data suggests that the compressor efficiencies ranged from 0.55 to 0.65). The required mass flow rate is calculated based on capacity in the theoretical cycle model described above. From there, the effective displacement volume can be determined by the equation below[1]. The latter serves to determine whether a system can use the same compressors for different refrigerants.

$$V_{eff} = \eta_{vol} \cdot V_{disp} = \frac{\dot{m}_{required}}{f \cdot \rho_{suction}}$$

D. **Heat Exchangers:** The condensers design procedure takes into consideration the following:

- **Face area**: baseline face area must be preserved or at most reduced. Furthermore, the aspect ratio must also match that of the baseline so the HX can be drop-in replaced in the same cabinet.
    - o Find the number of tube rows and tube length to match as closely as possible to tube face area and aspect ratio

- **Airside pressure drop and flow rate**: the test data from reports contain only air flow rate measurements, while no information on pressure drop is provided. Additionally, the fan performance curves are also not available, which limits the ability to find the exact operating condition. The baseline models provide an estimate prediction for the pressure drop, which is used as reference.

- **Thermal performance**: this step must be iteratively conducted with the previous step, as such for each design change the air flow rate and capacity are evaluated under the new conditions found in the theoretical cycle re-design.
    - o Gradually increment the condensing pressure until attainable performance is achieved. This process is done iteratively using the theoretical cycle model, to find new expected operating conditions for evaporating pressure, superheat, sub-cooling and refrigerant flow rate.

- **HX Form**: as indicated previously, the HX design is constrained by cabinet dimensions as well as form. In the case of units 1 and 4, the condensers are flat coils placed 90° inside the cabinet (Figure 10), which makes it simpler for drop-in replacement as long as new designs have the same overall dimensions. For units 6 and 10, however, the condensers are L-shaped inside the cabinet (Figure 10). Forming coils is widely done, however, for custom coils it may be a challenge, in particular for MCHX. For this reason, the MCHX designs for units 6 and 10 are sized for a full-face area, assuming the coil can be formed, and a second design that is a single flat slab placed in longer side of the "L" shape (Figure 11).

[1] See Nomenclature at the end of this chapter

FIGURE 10. CONDENSER FORMS: UNIT 1 (LEFT), UNIT 10 (CENTER), UNIT 6 CABINET (RIGHT).

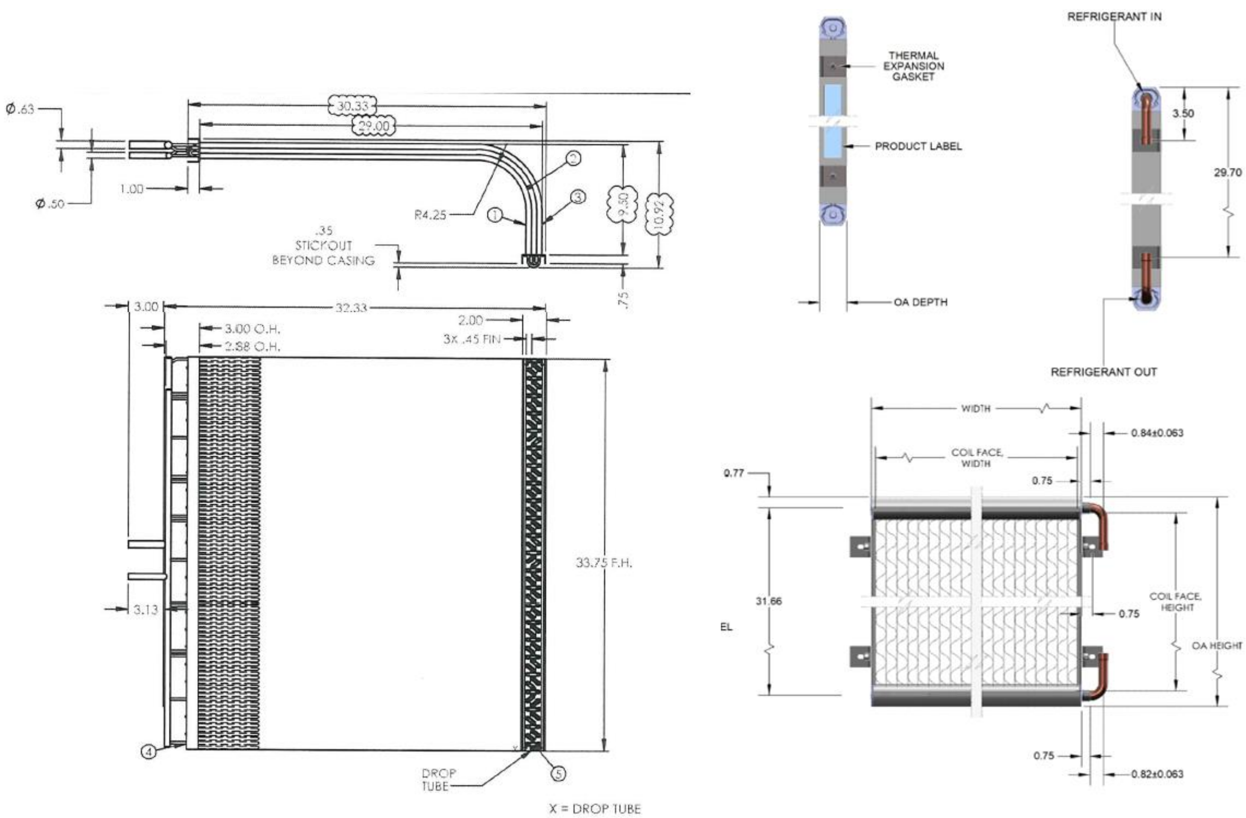


FIGURE 11. HX FORM EXAMPLES: L-SHAPE (LEFT), FLAT (RIGHT).

Summary of Results for Activity 2

Table 6 shows the summary from the design simulation activity

TABLE 6: ACTIVITY 2 RESULTS.

	General Information			Hardware					Performance	
System	Rated Capacity (@35°C)	System Configuration	Refrigerant	Compressor		Condenser		Exp Device	CC @ 46°C	EER @ 46°C
-	BTU/hr	-	-	Effective Disp. Vol. (cm³)*	Efficiency (-)	Type	Effectiveness (-)	Type	%	%
Unit 1	18000	**Baseline**	**R-444B**	**19.8**	**0.66**	**Tube-Fin (5mm Tube)**	**0.20**	**Passive**	**0.00%**	**0.00%**
		Alternate 1	HC-290	25.9	0.70	Same as Baseline	0.35	Active (EXV)	1.40%	8.20%
		Alternate 2	R-454C	24.8	0.69		0.26		4.00%	-1.30%
		Alternate 3	R-444B	19.6	0.70		0.23		4.20%	9.90%
		Alternate 4	R-457A	25.3	0.68	MCHX	0.24		2.00%	3.10%
Unit 4	24000	**Baseline**	**HC-290**	**26.4**	**0.61**	**Tube-Fin (9.5mm Tube)**	**0.24**	**Passive**	**0.00%**	**0.00%**
		Alternate 1	HC-290	26.3	0.70	Tube-Fin (5mm Tube)	0.26	Active (EXV)	1.20%	21.40%
		Alternate 2	HC-290	37.9	0.70		0.20		34.40%	-10.60%
Unit 6	24000	**Baseline**	**HFC-32**	**16.0**	**0.60**	**Tube-Fin (7mm Tube)**	**0.12**	**Passive**	**0.00%**	**0.00%**
		Alternate 1	HFC-32	16.9	0.65	Tube-Fin (5mm Tube)	0.15	Active (EXV)	3.00%	11.20%
		Alternate 2	R-454B	18.4	0.67		0.19		-1.00%	14.80%
		Alternate 3	R-452B	19.0	0.70		0.17		2.50%	13.50%
Unit 10	36000	**Baseline**	**HFC-32**	**19.6**	**0.44**	**Tube-Fin (9.5mm Tube)**	**0.13**	**Passive**	**0.00%**	**0.00%**
		Alternate 1	R-447B	22.3	0.65	Tube-Fin (5mm Tube)	0.25	Active (EXV)	5.10%	47.50%
		Alternate 2	R-452B	23.0	0.67		0.25		6.20%	60.70%
		Alternate 3	R-454B	23.3	0.67		0.25		6.20%	56.50%

** Product of displacement volume and volumetric efficiency*

The General Information describes the baseline unit with the alternate refrigerants used, while the Hardware describes the Compressor, Condenser and the Exp. (expansion) Device for each alternative.

The performance at 46°C is given as a percentage of the baseline performance for the cooling capacity (CC) and Efficiency (EER).

For unit 1 (window unit), the optimized design with the same refrigerant as the baseline can improve EER by 9.9% and using HC-290 can lead to an improvement in the EER by up to 8%.

For unit 4 (decorative split with HC-290), the baseline unit which was supposed to be a true 24,000 Btuh unit had an 18,000 Btuh (26.4 cm^3 effective displacement) compressor with a 24,000 Btuh coils. Optimizing the unit with an 18,000 Btuh compressor would lead to 21.4% improvement in EER, while if a 24,000 Btuh compressor (37.9 cm^3 effective displacement) is used, the EER drops by 10.6%.

The other decorative split (unit 6) running with HFC-32 shows an improvement in EER for all alternative refrigerants.

The unusual results for unit 10 (ducted split) showing a 50% increase in EER is due to using bigger condensers (0.25 effectiveness vs 0.13 for the baseline.

3.7.3. Activities 3, 4, and 5

A. Scope and Implementation of activities

Activity 3: Prototype Units Fabrication

Using design decisions made in Activity 2, OTS constructed two prototypes out of the three that were targeted (see section 4.6 Challenges and Changes). The two units are outlined in Table 7.

TABLE 7: PROTOTYPE UNITS FOR COMPONENT MODIFICATION AND FURTHER TESTING

Category	Unit	Refrigerant(s) for Prototype Development
Decorative Split	6	HFC-32 R-454B
Ducted Split	10	R-447B R-452B

This activity involves modifying the existing prototypes to include the new components while making additional changes, such as adding valves, to enable leak testing in Activity 5.

Activity 4: Evaluation of the Optimized Prototypes

This activity involves physically testing performance of the modified units for at least two ambient conditions:

- ❖ Measurement points include:
  - a. Refrigerant Side
    - i. Compressor suction – temperature, pressure
    - ii. Compressor discharge – temperature, pressure
    - iii. Expansion valve inlet – temperature, pressure
    - iv. Evaporator Inlet – temperature, pressure
    - v. Evaporator Outlet – temperature
  - b. Air Side
    - i. Environmental chamber ambient temperature, relative humidity
    - ii. Condenser incoming air temperature

        iii. Condenser exhaust air temperature
        iv. Evaporator incoming air temperature
        v. Evaporator exhaust air temperature
        vi. Evaporator pressure drop
        vii. Indoor air flow rate
    c. Power
        i. Compressor
        ii. Fans
        iii. Any additional controls or electrical components

- Conduct troubleshooting measures, as needed, to confirm operation prior to start of testing.
- Charging the unit was conducted at 35°C (95°F) in the outdoor unit environmental chamber. Conduct a charge optimization to assess the most appropriate refrigerant charge given the test set-up. This will include testing the unit at three different charge amounts to determine the charge that produces the best possible result (COP) at the rating condition. Conducting this step ensures appropriate charge levels and good measurement values.
- Tests repeated at the high ambient condition T3 (46°C outdoor).
- Test data analyzed and compared against the modeling predictions from Activity 2. Any system modifications that have potential to improve performance, including further adjustments to the refrigerant charge, were identified.

Activity 5: Analyzing Leaks of Alternatives

In addition to addressing the performance of the individual systems, analysis on refrigerant leakage is needed to meet Project Objective #3. Additional testing were conducted following the performance tests

Results

The detailed outcomes and test data can be found in the OTS report which is attached to this report. The following is a summary of the results:

Unit 6

Some modifications were made to Unit 6 to improve its efficiency. The baseline compressor was replaced with alternate models to account for the change in refrigerant and to improve efficiency. The compressor used with R-454B had a higher displacement volume than the one used with HFC-32. Furthermore, the capillary tubes were replaced with a manual throttling valve simulating the TXV that was installed directly at the evaporator inlet to increase the cooling capacity of the evaporator. A summary of the design modifications evaluated for Unit 6 is listed in Table 8.

Tables 9 and 10 show the performance of Unit 6 for baseline and modifications at 35°C and 46°C ambient, respectively. There is a discrepancy in the measurements from condenser outlet to expansion inlet in the baseline case, since the capillary tube (removed in the modified systems) was located in the outdoor unit. The expansion causes the refrigerant to flash in the liquid line thus compromising the readings at the expansion device. For calculation purposes, the condenser outlet enthalpy was used instead of the expansion inlet.

TABLE 8: UNIT 6 MODIFICATIONS FOR TESTING.

System	Unit 6		
	Baseline	Alternate 1	Alternate 2
Refrigerant	R32	R32	R454B
Compressor	GMCC KSG226N1UMT	Copeland ZP20K5E	Copeland ZP21K5E
Expansion Device	Capillary Tube (outdoor unit)	Manual valve[2] (indoor unit)	Manual valve (indoor unit)

Cooling capacity for the modified unit with either refrigerant was consistently lower by 6-12% than the baseline. The modified HFC-32 system reportedly showed lower mass flow rate than expected, likely the main cause for the lower-than-expected thermal performance. The R4-54B system resulted in a lower performance but was less sensitive to ambient temperature than its R32 counterpart - i.e. cooling capacity was near the same at both 35°C and 46°C, while for HFC-32 there was a ~2,000 BTU/hr reduction with the temperature increase. It is also possible that there is a mismatch between thermophysical property library and actual refrigerant properties for R454B which can happen with newer fluids. The libraries need periodic update as more test data become available.

TABLE 9: UNIT 6 - PERFORMANCE TEST SUMMARY FOR R32 BASELINE (OTS) @ 35°C.

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	HFC-32	HFC-32	R-454B	-	-
Charge	lbs.	3.83	4.27	5.02	11.5%	31.1%
Cooling Capacity	BTU/hr	25,192	23,585	21,966	-6.4%	-12.8%
Energy Balance	%	-2.28%	-4.66%	-3.06%	-	-
Compressor Power	kW	2.11	1.79	1.77	-15.1%	-16.2%
Fan Power	kW	0.32	0.33	0.33	2.2%	2.2%
Total Power	kW	2.43	2.12	2.10	-12.8%	-13.5%
EER	BTU/hr. W	10.37	11.12	10.44	7.2%	0.68%

TABLE 10: UNIT 6 - PERFORMANCE TEST SUMMARY FOR R32 BASELINE (OTS) @ 46°C.

		Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	HFC-32	HFC-32	R-454B	-	-
Charge	lbs.	3.83	4.27	5.02	11.5%	31.1%
Cooling Capacity	BTU/hr	23,390	21,450	21,821	-8.3%	-6.7%
Energy Balance	%	-1.78%	-4.42%	-7.61%	-	-
Compressor Power	kW	2.71	2.32	2.25	-14.2%	-16.6%
Fan Power	kW	0.40	0.42	0.42	5.3%	5.3%
Total Power	kW	3.10	2.74	2.67	-11.7%	-13.8%
EER	BTU/hr. W	7.55	7.84	8.17	3.8%	8.2%

[2] A manual valve was used to mimic a TXV or EXV; recommended as component modification in these systems.

Unit 10

Applying what was learned in the initial modifications to Unit 6, modifications to Unit 10 were limited to include the compressor and expansion device only. Unlike Unit 6, however, the re-test of the baseline system was not successful; refer Appendix D of the OTS report for additional information. However since Unit 6 baseline re-test showed good reproducibility from original data, it is assumed that the Unit 10 original baseline will act similarly.   A summary of the design modifications evaluated for Unit 10 is listed in Table 11. The detailed test data is presented in Appendix E of the OTS report.

TABLE 11: UNIT 10 MODIFICATION FOR TETSING

System	Unit 10		
	Baseline	Alternate 1	Alternate 2
Refrigerant	R32	R447B	R452B
Compressor	Copeland ZP42K6E	Copeland ZP34K5E	Copeland ZP31K5E
Expansion Device	Orifice	Manual Valve	Manual Valve

At 35°C the modified units exhibited almost 20% less cooling capacity with 10% less power consumption, resulting in up to 11% less EER (Table 12). These results were not unexpected since the modified units were re-designed using the 46°C temperature, when the baseline system's performance showed a great degradation of performance. At 46°C condition, the tests confirmed exhibited 2-5% greater cooling capacity with up to 12% less power consumption compared to the baseline, which was equivalent to 13-17% greater system performance.

In Activity 2 the compressor power consumptions were underestimated, as well as the total fan power consumption, leaving the impression the overall performance improvement would considerably be greater than the observed. The cooling capacity, on the other hand, was predicted with less than 2% deviation from test data, validating at least the models created.

TABLE 12: UNIT 10 - PERFORMANCE TEST SUMMARY AT 35°C.

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	HFC-32	R-447B	R-452B	-	-
Charge	lbs.	5.625	6.625	6.625	17.78%	17.78%
Cooling Capacity	BTU/hr	35,543	32,195	28,128	-9.42%	-20.86%
Energy Balance	%	---	7.52%	-3.29%	-	-
Compressor Power	kW	-	2.67	2.4	-	-
Fan Power	kW	-	0.95	0.98	-	-
Total Power	kW	3.761	3.62	3.38	-3.75%	-10.13%
EER	BTU/hr. W	9.451	8.894	8.322	-5.89%	-11.94%

TABLE 13 : UNIT 10 -PERFORMANCE TEST SUMMARY AT 46°C

		Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	**-**	**HFC-32**	**R-447B**	**R-452B**	**-**	**-**
Charge	lbs.	5.625	6.625	6.625	17.78%	17.78%
Cooling Capacity	BTU/hr	29,633	31,073	30,292	4.86%	2.22%
Energy Balance	%	---	4.21%	1.21%	-	-
Compressor Power	kW	---	3.18	2.93	-	-
Fan Power	kW	---	0.95	0.97	-	-
Total Power	kW	4.466	4.13	3.9	-7.52%	-12.67%
EER	BTU/hr. W	6.64	7.52	7.76	13.33%	16.95%

Leak Tests

In the interest of time the leak tests were conducted only on Unit 10 for R447B. The choice of refrigerant was based on temperature glide, where R447B exhibits the highest glide amongst the refrigerants evaluated between Unit 6 and Unit 10 (refer to Figure 6). The leak tests were conducted to closely represent field operation. The procedure applied include the following steps:

1- Run unit until steady-state is achieved (repeat 46°C performance test), monitoring capacity and sub-cooling
2- Gradually remove refrigerant from vapor line until capacity is reduced to approximately 50%, if possible
3- Store and weigh removed refrigerant
4- Re-charge with new refrigerant until same sub-cooling is achieved
5- Compare cooling capacities; if more than 5% deviation is observed, repeat steps 1-4, however in step 2, reduce capacity to 25% only
6- Repeat steps 1-5 for the liquid line

The comparison herein presented refers to a leakage of approximately 30% of charge, while reducing capacity in approximately 50% based on airside only. The leak tests showed less than 2% deviation in cooling capacity after re-charge from both vapor and liquid lines (Table 14). Since the capacity deviation was less than 5%, no further testing for 25% capacity reduction was conducted. The results suggest little impact due to fractionation.

Table 14: Unit 10 – R447B Leak Test Summary Results.

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R-447B**	**R-447B**	**R-447B**	**R-447B**	**R-447B**
Charge	lbs.	6.625	4.27	6.625	4.23	6.77
Cooling Capacity	BTU/hr	31,073	14,216	30,865	15,171	30,587
Energy Balance	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Compressor Power	kW	3.18	2.93	3.18	2.94	*
Fan Power	kW	0.95	0.98	0.98	0.98	0.98
Total Power	kW	4.13	3.90	4.16	3.92	*
EER	BTU/hr. W	7.52	3.64	7.42	3.87	*

*Compressor power consumption was not properly recorded for this test; the error was identified after the fact and the team was unable to retrieve that information. While that compromises the assessment of the overall system performance, the deviations are expected to be marginal. The leak test on liquid line suggest minimal impact on power consumption after re-charge, while cooling capacity was reportedly fully recovered after recharge on both leak tests.

3.8. Conclusion and Recommendations from the Optimization Element

The original scope and schedule were modified during the project as new findings and challenges surfaced. The data analysis and processing from the tests conducted in the PRAHA-I project showed that more testing parameters and instrumentation would have been needed to support the optimization and/or redesign process within the scope of PRAHA-II since PRAHA-I was designed to conduct testing and comparison of cooling capacity vs. EER for the prototypes against the baseline units from same manufacturers. This affected the evaluation of the units' performance and consequently in building the baseline models.

The Conclusion from **Activity 1** is that for systems operating in considerably higher temperatures (greater than 46°C), the resultant impact on performance must be considered since performance will degrade compared to operating under more temperate conditions. Furthermore, the discharge temperature should be considered when selecting alternative refrigerants.

The key components for performance improvement identified were the compressor, condenser and expansion device.

- At higher temperatures, the saturation temperatures and refrigerant density at the compressor suction port can be very different than that from the rated conditions. Larger displacement volumes and efficiency curves optimized for higher pressure lifts might be required. Therefore, the proper selection of the compressor is paramount.

- A better performance condenser will reduce the approach temperature between refrigerant and air, reducing discharge pressure.

At high ambient conditions, the system is forced to operate in higher pressure lift than at rated conditions, but still requires a certain refrigerant mass flow rate. Passive devices such as capillary tubes and orifices may not be able to provide enough expansion to allow the system to operate in higher temperature conditions. An active expansion device such as Electronic expansive valve (EXV) can adequately control operating conditions and maintain design superheat.

The analyses presented in **Activity 2** (design evaluation through modeling) provided good insights on adequate component design and/or selection for proper system functioning when using alternative refrigerants. The tests in activities 3-5 partially served as validation for the models developed, and as check for previous test data from PRAHA I. The key conclusions and recommendations are:

I. HC-290 and HFC32 have wider saturation regions allowing the system to operate with smaller superheat and sub-cooling, while benefiting from two-phase heat transfer.
II. Refrigerants with high temperature glide may require new heat exchanger (HX) designs, namely condensers. The original designs proved to be sufficiently effective to allow for most systems to operate with the different refrigerants; however, better designs would allow for higher system efficiency and potentially less charge. HX designs are severely constrained by allowed envelope dimensions. A complete system re-design would provide an opportunity for designing HX's with even higher efficiency.
III. The results of this analysis suggest that for an effective use of alternate low-GWP refrigerant, a proper compressor selection must be done. Higher isentropic efficiencies are desired for higher temperatures, but most importantly, the displacement volume requirements can vary from one refrigerant to another.
IV. It is also imperative that having an active expansion device (preferably an EXV) to not only allow for more controlled superheat, but also to enable the unit to run with different refrigerants with very different thermophysical properties.

For **Activities 3, 4, and 5**

I. Unit 6 re-tested baseline exhibited similar performance to that found in PRAHA I testing. It should be stressed that the baseline unit by design had its capillary tube located in the outdoor unit. This would cause liquid refrigerant leaving the outdoor unit to flash. The refrigerant enthalpy at the condenser outlet state was used to calculate the refrigerant-side capacity assuming an isenthalpic expansion without heat loss in connecting pipe. This is different from the modified systems of which the capillary tube was removed, and a manual expansion valve was placed at the inlet of the indoor unit. For modified systems, the enthalpy at the expansion valve inlet was used to calculate the refrigerant-side capacity.
II. The Unit 6 modified systems had lower performance than expected from the Activity 2 models. The R32 system configuration exhibited more than 10% less flow rate than anticipated due to performance maps over prediction, which corresponded to 10% lower capacity. The R454B configuration exhibited a deviation of 5% between model and test due also in part to a 3% flow rate over prediction in the model.
III. Unit 10, on the other hand, exhibited an excellent agreement to the models with less than 2% deviation in cooling capacity.

IV. Unit 10 exhibited a considerable reduction in power consumption at the high ambient test condition (46°C) as compared to the original test data. This also indicates the importance of proper compressor selection.

V. The higher-than-expected power consumption in the Unit 10 baseline tests is also evidenced by the fact that even with zeotropic mixtures (R-447B and R-452B), Unit 10 had higher cooling capacity and efficiency than the baseline for the 46°C test condition, as projected in activity 2.

VI. Because of the differences in saturation curves from the Activity 2 analysis, HFC-32 tends to result in systems with higher efficiency and less charge when no modifications to the hardware are made. The results showed however, that making appropriate component selection, such as compressors with larger displacement volumes for the other refrigerants, cooling capacities and overall performance were of the same order of magnitude.

VII. Refrigerant fractionation as evidenced by the leak tests, does not appear to be a great concern since less than 2% in cooling capacity was observed after the system's re-charge.

VIII. The model validation adds confidence in the numerical simulation findings and recommendations provided in activity 2.

The **recommendations** for future development are:

- Establish a baseline system by conducting comprehensive testing including measurements and metrics not typically performed in energy certification tests.
- Replacing refrigerants is viable and can be competitive to presently used refrigerants but doing so requires proper component design and selection; compressor and expansion device particularly. Drop-in replacement without hardware change is never recommended.
- It is recommended to always perform numerical simulations, and to conduct at least some level of "soft" optimization analyses that will provide information for an educated system re-design / retrofit at much lower costs than gradual trial-and-error changes.
- Always test the modified systems in the same test setup as the baseline, with the same instrumentation.

Nomenclature

COP	Coefficient of Performance	-
D_o	Tube Outer Diameter	mm
f	Frequency	Hz
FPI	Fins per Inch	1/in
h	Enthalpy	kJ/kg
h_t	Tube Height	mm
HX	Heat Exchanger	-
$\dot{m}$	Mass Flow Rate	kg/s
MCHX	Microchannel Heat Exchanger	-
P	Pressure	kPa
P_l	Tube Longitudinal Pitch	mm
P_t	Tube Transverse Pitch	mm
s	Entropy	kJ/kg.K
T	Temperature	°C
TFHX	Tube-Fin Heat Exchanger	-

UA	Thermal Conductance	kW/K
V	Volume	m^3
w_t	Tube Width	mm
η_{vol}	Volumetric Efficiency	-
ρ	Density	kg/m^3

4. Risk Assessment

This component includes designing, developing and examining a risk assessment model suitable for the use pattern and operating conditions at high ambient conditions and in particular for the Gulf Cooperation Council (GCC) region. The plan was to coordinate with local institutes and experts in HAT countries to build a special risk assessment model that suits the countries' local needs and operating conditions. This process was to be conducted through the following elements:

I. Developing comprehensive terms of reference for building the local risk assessment model;
II. Analyzing the needs of local technical and research institutes to implement the risk assessment model including the technical capacities of personnel and laboratories;
III. Examining the risk assessment model and validating its applicability at levels of manufacturing, installations, operation and servicing.

Each of the above elements was to be led by a local research institute in consultation and cooperation with international associations partnering in this project. This chapter explains what was achieved given the large scope of this component of PRAHA-II.

4.1. Background on Risk Assessment

The concept of risk assessment in RACHP applications is fairly new as it was introduced with the advent of flammable refrigerants. A brief background is presented in this section to explain the concept and the different terms.

4.1.1. Flammability Definition and Classes

Flammability

For a fire to happen there needs to be three elements: a rapid leak of the flammable gas, a concentration higher than the lower flammability level, and a source of ignition as shown in figure below. Figure 12 shows the probability of ignition as the resultant of these three elements. Lower Flammability Limit (LFL), usually expressed in volume per cent, is the lower end of the concentration range over which a flammable gas can be ignited at a given temperature and pressure.

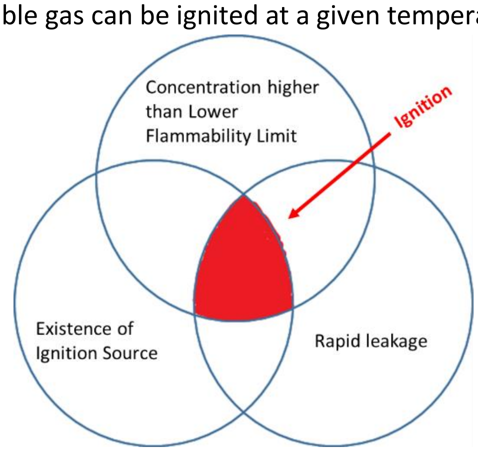


FIGURE 12: FACTORS AND PROBABILITY OF IGNITION

Probability = [rapid Leakage] x [High Concentration] x [Ignition Source]

This report does not aim to cover all aspects of flammability such as the ignition source energy and speed of propagation etc.

Flammability Classification for Refrigerants: Table 15 shows the classes of flammability as defined in ISO 847 and ASHRAE 34.

TABLE 15: FLAMMABILITY CLASSIFICATION FOR REFRIGERANTS

Class	
1	No flame propagation when tested at 60°C and 101.3 kPa
2	Flame propagation and LFL > 0.1 kg/m3 and HOC < 19,000 kJ/kg
2L	Same as 2 except Burning Velocity < 10 cm/s
3	Flame propagation and LFL <= 0.1 kg/m3 and HOC >= 19,000 kJ/kg

Refer to Annex II for a discussion on safety and standards.

4.1.2. Concept of Risk Assessment

The concept behind risk assessment is to define what is an acceptable risk given the conditions for ignition in a particular location. To begin with, a definition of risk is agreed upon and a matrix of probability vs. severity is built. For this purpose, this report adopts the work done by JRAIA in Japan.

Definition of Risk

Risk is a combination of the probability of concurrence of harm and the severity of that harm. Tolerable risk is the level of risk that is accepted in a given context based on the current acceptable values by a community. Residual risk is the risk remaining after reduction measures have been implemented. Safety is freedom from risk which is not tolerable.

The risk levels depend on the severity of injury, the amount of damage to the environment, the frequency at which people are exposed to the danger and the duration of exposure.

Tolerable risk is determined by the search for an optimal balance between the ideal absolute safety and the demands to be met by a product. The factors influencing risk are the practicality and means to reduce risk, the benefit to users, cost effectiveness, and social conventions.

The concept of tolerable vs. unacceptable risk was introduced based on the probability of harm and the severity of harm as per Figure 13.

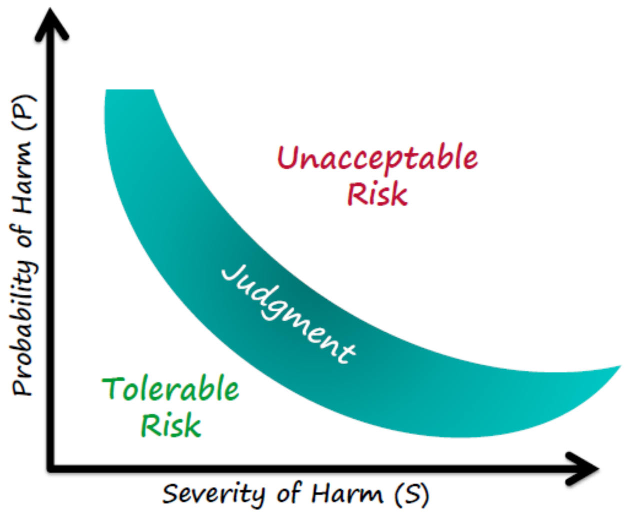


FIGURE 13: TOLERABLE VS. ACCEPTABLE RISK (SOURCE: UL)

The sources of risk start with manufacturing all the way to the end of life of the refrigerant and the equipment. It includes transport and storage, installation and service, operation, as well as removal and dismantling.

4.1.3. Approach of a Risk Assessment Model

The following is part of the process to build a model:

- An outline of the methodology and the components that are the basis for the risk assessment model;
- A model of what data can be collected;
- Information on the regulatory regime and the enforcement mechanisms;
- International standards play a role in the next step of risk assessment in the form of recommendations for local standards; however, the intention is to build a model, not convert it into regulation. Rigorous regulations as those adopted in other regions must be adapted to HAT countries.
- Stakeholders: governments and local research institutions, industry and private sector, and UN Environment & UNIDO;

To determine the outline of the risk assessment model, PRAHA organized a roundtable meeting in cooperation with The Japanese Refrigeration and Air Conditioning Industry Association (JRAIA), and the Air Conditioning, Heating, and Refrigeration Institute (AHRI) as international partners.

The roundtable briefly reviewed the research and testing projects on lower-GWP alternatives for HAT countries as well as the research projects conducted in the United States on A2L refrigerants such as ASHRAE and AHRTI research on flammable refrigerants. Underwriters Laboratory (UL) presented the work that is being done on safety standards and KISR presented a glimpse of their research projects. The industry was also represented in the proceedings and presented their own research and R&D on flammable refrigerants.

A review of the adoptability of flammable refrigerants globally shows the four regions where refrigerants are accepted to varying degrees. Work still needs to be done on HAT regions.

4.1.4. Outline of a Risk Assessment Model

A special expert meeting was held in Cairo in August 2018 focused on the first step of building a risk assessment model through collecting local data and assumptions needed for drafting the model. The meeting aimed to discuss, review and comment on the data collection methodology designed. The meeting was attended by selected experts from the air-conditioning servicing and firefighting sectors, including participation of two members from the Montreal Protocol Refrigeration Technical Options Committee and members of the Halons Technical Options Committee, as well as research institutes' experts, servicing sector expert and National Ozone Officers from Egypt and Kuwait.

JRAIA experts joined the meeting through web-conferencing during the two days. The meeting built clarity and better understanding about the model suggested by JRIAA and included the following:

- Quick Overview of PRAHA-II and First Roundtable Meeting
- JRAIA Risk Assessment Model (Via Web-Meeting) - Brief Introduction to Risk Assessment Concept - Risk Scenarios for installation, use and service of split A/Cs - Explanation of field data/assumptions needed for building the model
- Discussion on Risk Assessment Datasheet and Compilation of Enquiries and Clarification needed from JRAIA - JRAIA Risk Assessment Model - Risk Scenarios for installation, use and service of split A/Cs - Field data/assumptions needed for building the model - Work plan for Data Collection, Review and Validation

The process that will be used is outlined in Figure 14.

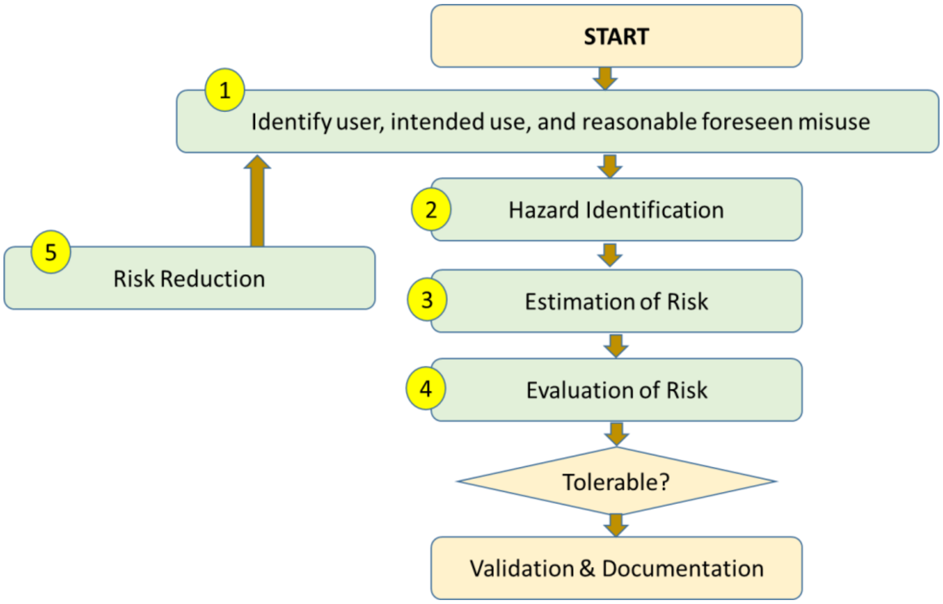


FIGURE 14: PROCEDURE OF RISK EVALUATION ACCORDING TO ISO/IEC 51 (SOURCE: JRAIA)

The experts also discussed the application for the model for which data and information which will be collected. Several applications were suggested with size and use of the room and the sources of ignition. One application will be chosen.
An example of the data tables to be filled before the workshop is shown in **Annex I**.

For more info about the Cairo meeting, please refer to:
https://www.unenvironment.org/ozonaction/news/editorial/un-environment-and-unido-help-countries-high-ambient-temperatures-assess-risk

4.1.5. Global Risk Assessment Efforts

The purpose of this section is not to present a comprehensive background on all the work that has been done globally, but to review those efforts that were presented or shared during the different PRAHA-II events. The PRAHA team is aware of risk assessment efforts done in Columbia and India, among others, some done with the help of implementing or bilateral agencies. Similarly, Chinese associations and industry built their own local risk assessment for the use of A3 refrigerants in unitary air-conditioning applications.

The following is a brief review of research projects that were reviewed both at the International Workshop on Risk Assessment for HAT in Kuwait in Oct 2017 and the Flammable Refrigerant Research and Planning Conference in Chicago in Oct 2018:

Note: AHRTI is the research arm of AHRI in the United States, ASHRAE is the Association of engineers and NFPA is the National Fire Protection Association:

- AHRTI-9007 to conduct refrigerant leak and ignition testing and investigate the control limits and safety factors proposed for IEC 603325-2-40 for air conditioners and 60223-2-89 for refrigeration;
- AHRTI-9009 refrigerant leak detector long-term reliability assessment, to conduct a thorough review of sensor technologies that can detect A2L refrigerants;
- AHRTI-9008 investigation of hot surface ignition temperatures for A2L refrigerants in order to establish a standard;
- ASHRAE-1806 to determine the severity of ignition events using computer modeling;
- ASHRAE-1808 to determine leak rates through mechanical joints;
- NFPA evaluation of fire hazard of A3 refrigerants

AS an example of the work done on A3 refrigerants, the project "Benchmarking Risk by Whole Room Scale Leaks and Ignitions Testing of A3 Refrigerants" conducted by AHRTI conducted leak and ignition testing for HC-290 (propane) under whole room scale conditions to develop data and insight into the risks associated with the use of Class A3 refrigerants. This included parametric testing to investigate how key variables (refrigerant charge amount, release rate and height etc.) influence the 'ignition event' under whole room scale scenarios. It involved releasing liquid HC-290 refrigerant into spaces with a variety of viable ignition sources present. The testing scenario simulated a Packaged Terminal Air Conditioner (PTAC) and a mini-split air conditioner (AC) in a typical motel room plus a single door reach-in cooler and a three-door reach-in cooler in a convenience store. The testing scenario was according to the existing requirements or proposed requirements in the IEC Standards 60335-2-40 (for air-conditioning products) and IEC 60335-2-89 (for commercial refrigeration products), and their equivalent North American version published by Underwriters Laboratory (UL).

UL in the US has done work in developing requirements for flammable refrigerants applicable to both air conditioning and refrigeration equipment, as well as the requirements for testing and evaluation of flammable refrigerants including A2L refrigerants. As a result of the work, Standards were published for air conditioners recommending three times the Lower Flammability Limit (3xLFL) under UL 484. For refrigeration, Standard UL 250 for household refrigerators published a 57 gram limit, while UL 60335-2-24 published a 150 gram limit for commercial refrigerators. The transitioning to IEC standards 60335-2-40; 60335-2-24; and 60335-2-89 is now complete.

JRAIA developed a comprehensive risk assessment model for A2L refrigerants. The JRAIA model was used by the PRAHA-II team in the risk assessment work and studied in detail in this chapter. PRAHA-II collaborated with JRAIA to build a model that suits the HAT countries usage and servicing practices.

Initially, it was hoped to cover models for both A3 and A2L. UN Environment and UNIDO were planning to build another parallel model for HAT countries addressing flammable (A3) refrigerants in cooperation with China, given China's expertise and knowledge about hydrocarbon refrigerants, HC-290 in particular. The work which was planned to be with the Chinese association CHEAA.

4.2. Process of a Risk Assessment Model

The following is a step-by-step outline of a Risk Assessment model based on the workshop that was held in japan in April 2019. Experts from Kuwait and Egypt were invited along with the representative of the national Ozone unit of Kuwait to a two and a half days of workshop and lab visit in Tokyo. The agenda covered a reintroduction of the risk assessment model of Japan with focus on minis-splits as well as the introduction of Japan's experience in data collections methodology. The rest of the workshop was dedicated to the study of a risk scenario prepared by the PRAHA team.

A Step-by-step approach to the case study by the PRAHA team is outlined below:

I. **Selection of equipment type and application**: From residential to refrigeration as per figure below identified by JRAIA. The work on VRF and refrigeration assessment by JRAIA is completed. The PRAHA-II team chose residential air conditioning as it is the most used type in number of units and where the risk might be greatest. The team also identified servicing of the indoor unit as the most relevant for the model.

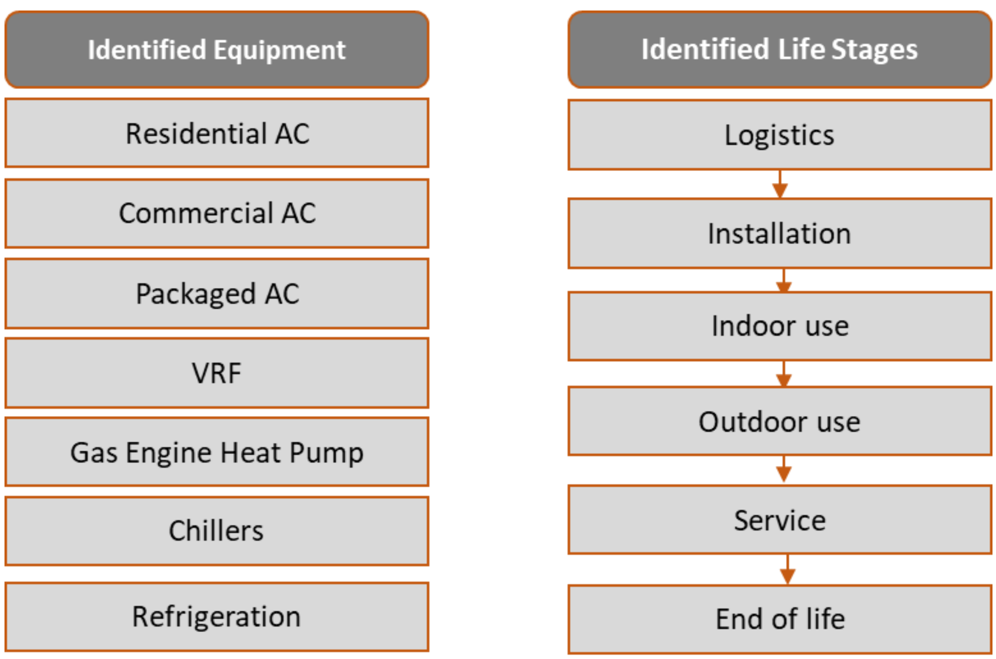


FIGURE 15: SELECTION OF EQUIPMENT AND LIFE STAGE FOR THE RISK ASSESSMENT MODEL

II. **Identify Acceptable and tolerable risk:** Tolerable risk depends on the number of units in the market of the product identified. Tolerable risk depends on the frequency and severity of the accident.

JRAIA defines risk in terms of probability and frequency vs. severity. A low risk is where the probability of an accident is lower and the severity is least. An extreme risk is where the probability is high and the severity is also high.

Table 16 shows the frequency of accidents vs. severity. Frequent accidents leading to catastrophic events are the least acceptable; while improbable of incredible (as in incredibly low frequency) with the least severity are socially acceptable.

TABLE 16 RISK MATRIX - FREQUENCY VS. SEVERITY (SOURCE JRAIA)

	None	**Negligible** (slight injury)	**Marginal** (need for outpatient treatment)	**Critical** (serious injury or need to be hospitalized)	**Catastrophic** (death)
Frequent	C	B3	A1	A2	A3
Probable	C	B2	B3	A1	A2
Occasional	C	B1	B2	B3	A1
Remote	C	C	B1	B2	B3
Improbable	C	C	C	B1	B2
Incredible	C	C	C	C	C
A = Unacceptable risk levels: 1=least, 3= highest		B= Risk levels should be reduced 1= least, 3= highest		C= Socially acceptable risk levels	

III. Analyze Product Cycle

It is necessary to classify the air conditioners into groups and assess the individual risk of each group. If the classification is very narrow, the risk assessment becomes complicated, and data common to different groups cannot be collected because the risk assessment needs to be performed on an individual basis.

The most important considerations for HAT relate primarily to the installation and servicing issue and technicians' skill levels. The temperature has no direct effect on the risk, it is the practice that matters. The question of whether to build a model from scratch or adopt an international model is moot since there is a need to know the status of doing things in the countries that built similar models in order to plug into the locally built model, i.e. level of service, frequency of service, types of installation etc. The team decided to build a model from scratch.

The life cycle range for assessment is shown in Figure 16. Each stage has to be assessed separately and added together to get to the total risk.

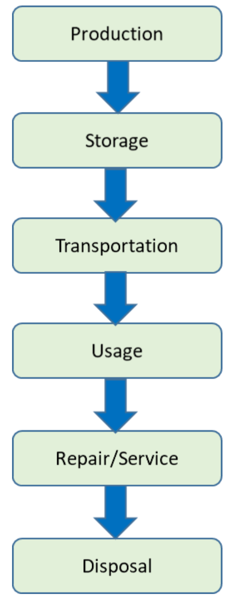


FIGURE 16: LIFE CYCLE RANGE FOR ASSESSMENT

The determination of tolerable risk depends on the population of products in the country. The example from Japan is in Table 17:

TABLE 17: DETERMINATION OF TOLERABLE RISK LEVELS

Product/System	Unit Population	Tolerable risk Usage stage	Tolerable risk Service stage
Residential AC	1×10^{8}	1×10^{-10}	1×10^{-9}
Commercial AC	7.8×10^{6}	1.3×10^{-9}	1.3×10^{-8}
VRF	1×10^{7}	1×10^{-9}	1×10^{-8}
Chillers	1.34×10^{5}	7.5×10^{-7}	7.5×10^{-7}
Condensing units	1.46×10^{5}	6.9×10^{-8}	6.9×10^{-7}

The PRAHA team used the JRAIA approach to set the tolerable risk for residential units at the following levels:
For the usage stage = 1 / 100 x unit population
For the service stage = 1 / 10 x unit population

And the risk map becomes as in Figure 17:

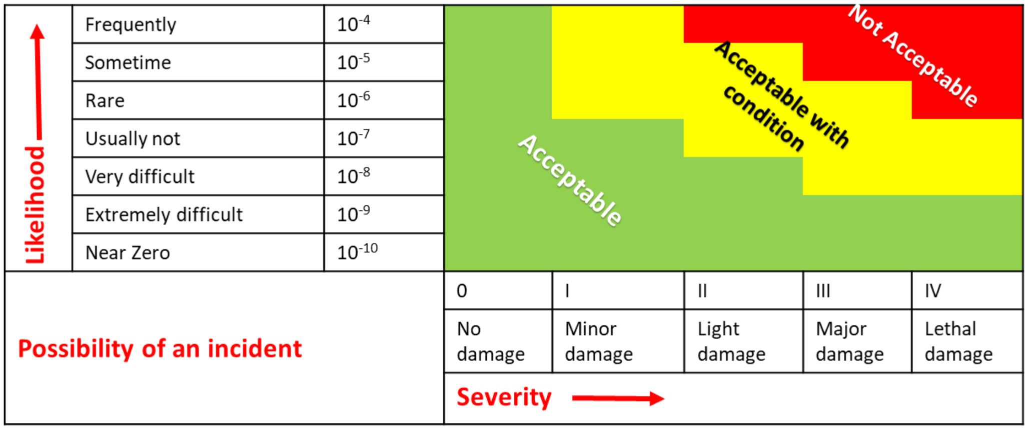


FIGURE 17: RISK MAP

IV. Risk Scenarios

A critical stage of the risk assessment is to identify those scenarios in which an ignition source is present in conjunction with a flammable concentration of leaked refrigerant. To better understand these scenarios, one must consider the various triggering events which could cause refrigerant to be released, the location of the release, and the specific type of person that might be present (*i.e.*, a worker, repair person or customer) at the time of the release. It is important to note that, during normal operations, the refrigerant will be contained within the system, and thus there is no risk of adverse events associated with these refrigerants during regular use. However, if refrigerant leaks from the equipment and is not dispersed prior to accumulating to a flammable concentration and a sufficient energy source is present, refrigerant ignition could occur (AHRTI 8009)

The first step in a risk analysis is to select a risk assessment method. There are three known methods used: Event Tree Analysis (ETA), and Failure Modes and Effects Analysis (FMEA), and Fault Tree Analysis (FTA). ETA is based on binary logic, in which an event either has or has not happened or a component has or has not failed. FMEA is a structured approach to discovering potential failures that may exist within the design of a product or process. Failure modes are the ways in which a process can fail. Effects are the ways that these failures can lead to harmful outcomes for the user. The goal of FTA is to provide an order of magnitude estimate of the likelihood that the outcome in question will occur (US NRC, 1981).

The team chose the fault tree analysis in line with JRAIA. Refer to item VII for FTA description.

The risk assessment of flammable refrigerants considers two individual phenomena: the presence of an ignition source and the generation of a flammable volume. The risk scenarios that were considered were:

A. Refrigerant leak during maintenance work on the indoor unit during brazing and due to pipe breakage by corrosion with an ignition source caused by live wire, static electricity, or electric tool such as screw drivers;

B. Refrigerant leak during brazing of outdoor unit with leakage caused by prior maintenance work or during maintenance work and an ignition source from the brazing torch;

C. Refrigerant leakage during normal home use caused by pipe breakage through corrosion, external pressure or natural causes such as earthquakes with an ignition source of an open flame, electric spark or static electricity.

V. Select Risk Analysis Sources

The input into the model is taken from data tables for the type of application and usage of the equipment that are being studied. Source for input into the volume of the flammable cloud can be taken from research done for the type of gas. Data for source and time of ignition can sometimes be available from the fire department.

VI. Data Collection

Data collection takes into consideration the following:

a) Select the stages of the life cycle of the air conditioners. Choose the manner of classification of manufacturing, transportation, use, service, and disposal of an air conditioner into separate stages for evaluation. The evaluation of the manufacturing stages of each product is normally the responsibility of the manufacturer;

b) Investigate the conditions of installation of the selected air conditioner to determine the conditions to be evaluated during the risk assessment;

c) Determine the severity of the hazard focusing on the damage caused by flammability;

d) Set tolerance levels. Set socially acceptable probability of harm for the air conditioner;

e) Investigate refrigerant leakage rate, speed, and amount based on surveys conducted with air conditioning service companies. The initial leakage location and leakage concentration should also be determined;

f) Determine flammable time volume through CFD or calculations. For the conditions set as per point (b), the flammable time volume can be calculated by CFD simulation based on the leakage amount, speed, and concentration of the refrigerant as per point (e).

g) Consider ignition sources. Distinguish the ignition properties depending on whether the ignition source is a spark (for example, electrical contacts, lighter, and/or static electricity), or an open flame (for example, candles, matches, and/or combustion equipment).

VII. Fault Tree Analysis (FTA)

It utilizes a "top-down" approach, starting with the undesired effect as the top event of a tree of logic. Fault trees (FTs) consist of various event boxes, which reflect the probability or frequency of key events leading up to a system failure. The event boxes are linked by connectors (gates), which describe how the contributing events may combine to produce the system failure. Events may be combined in different ways: in cases where a series of events must all occur to produce an outcome (e.g., ignition source and sufficient oxygen to support combustion), the probabilities or frequencies of the individual contributing events are multiplied via an "AND" gate; in cases where only one of a series of events is needed to produce an outcome (e.g., a strong spark, open flame, or a hot surface all possibly leading to refrigerant ignition), the probabilities are usually added via an "OR" gate. (AHRTI 8009, 2015).

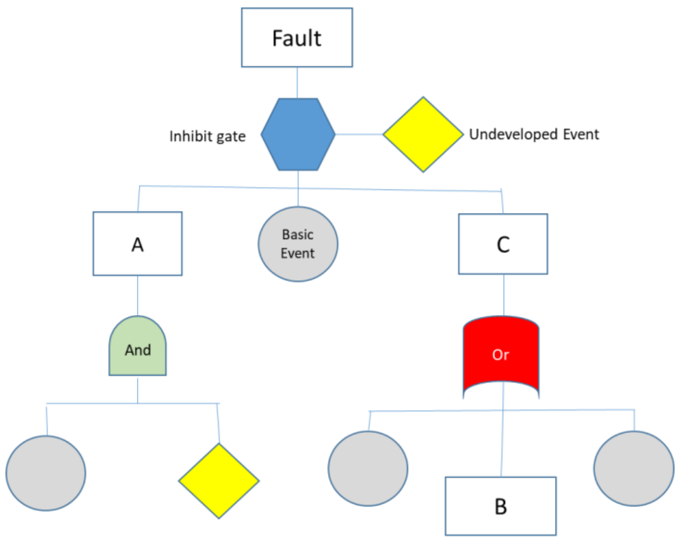


FIGURE 18: FAULT TREE ANALYSIS (FTA) MODEL

In the case of flammability, the probability of leakage is combined with ("and" gate) the possibility that the length of time that flammable cloud exits covered area would lead to ignition in case of the existence of an ignition source (another "and" gate).

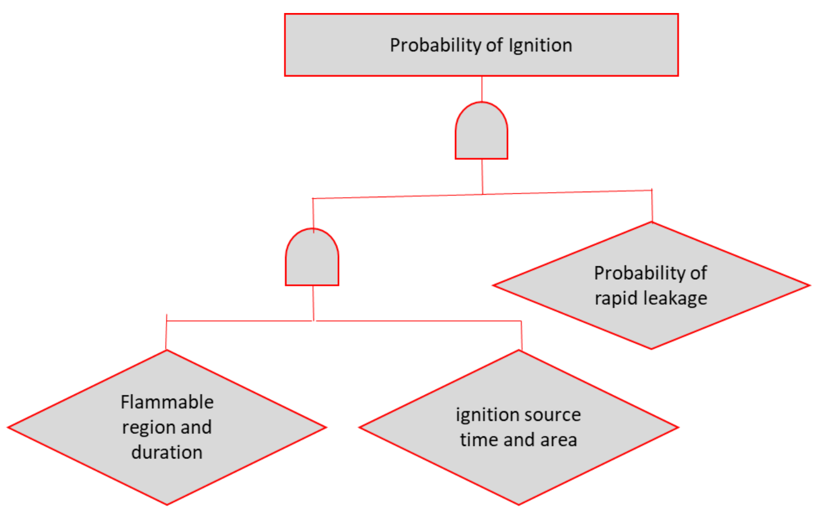


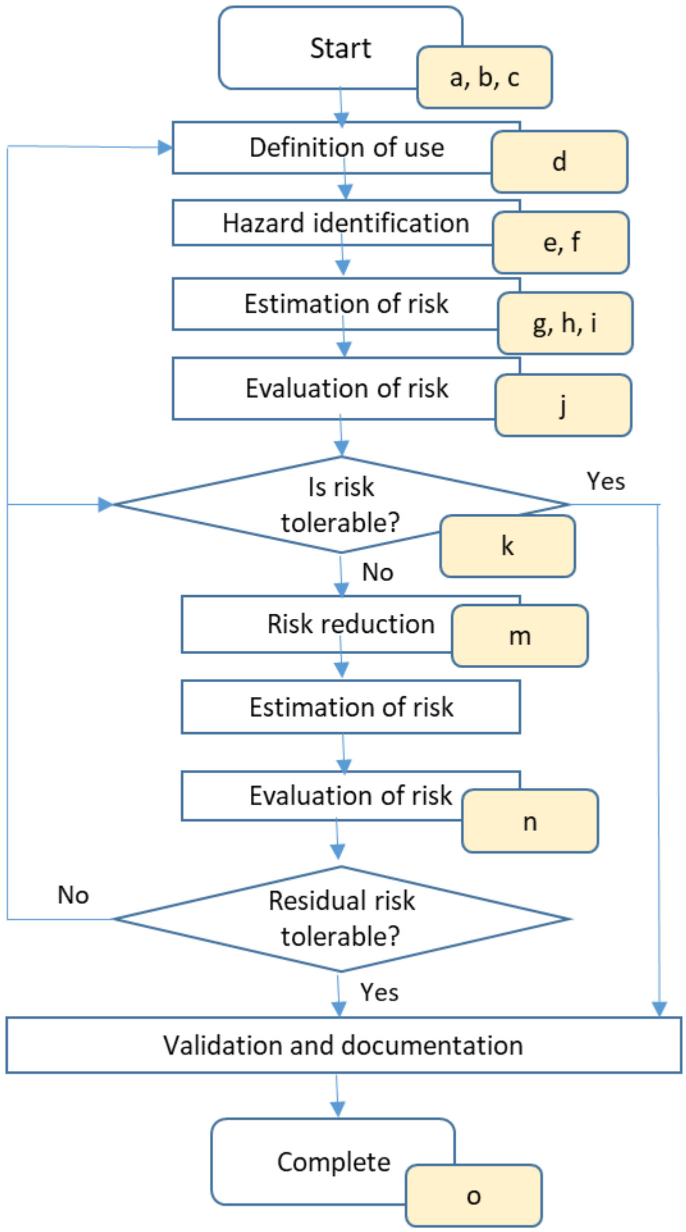
FIGURE 19: PROBABILITY OF IGNITION FTA

In the development of FTA for flammability, the presence of the flammable region and the ignition source correspond to independent trees. Then, their probabilities are multiplied in the final step to calculate the accident probability.

When the contents are reviewed, the risk is evaluated against the risk map in item III above and the calculated accident probability is compared to the acceptable probability in the risk map. The risk tolerance propriety is then determined.

VIII. Suggest Measure to Mitigate Intolerable Risk

When the tolerance from the risk evaluation in the steps above is satisfactory, the risk assessment ends. If the risk exceeds the tolerance, countermeasures to reduce the risk should be taken. These countermeasures include the implementation of regulations and other measures like introducing safety procedures in order to reduce the risk of accidents. In some instances, it might be necessary to revise laws and regulations in order to ensure that they cover the accepted probability. The reiterative process, which is explained in Figure 20, is as follows:



a) Select risk assessment method
b) Select product
c) Select stages of the product life, i.e. usage or service etc.
d) Investigate installation circumstances
e) Determine severity of hazard
f) Set tolerance levels
g) Investigate refrigerant leak rate, speed and amount
h) Determine flammable time volume
i) Consider ignition sources
j) Develop FTA
k) Compare against tolerance
l) Evaluate risk against tolerance
m) Reduce risk with countermeasures
n) Redevelop FTA
o) Confirm and publish

FIGURE 20: FTA REITERATIVE PROCESS

IX. Recommend Standards and Codes

Once the countermeasures have been introduced, the FTA factors are reviewed and these countermeasures are added in the appropriate position of the tree. A new calculation can then be made and repeated until the calculations confirm the accepted tolerance according to the risk map. The results can then be released to the public and standards and codes can be drawn.

4.3. Example of a Risk Assessment Model

The team chose a case study of an office space in a government building during the usage phase when the equipment is running and during the repair/service stage. The target product is a 5.3 kW split system using an A2L refrigerant. The team selected the Fault Tree Analysis method which is described under item VII below. The target product and the indoor and outdoor conditions plus the service case are shown in the tables below.

At the workshop in Tokyo in April 2019, the PRAHA team worked with the JRAIA experts to do two case studies using the information provided by the PRAHA team. The two case studies are:

- During usage of an air conditioner in a government office. The sources of ignition are extreme including charcoal and lighter used for incense burning, an aroma candle, as well as cigarettes and lighters as smoking is still allowed.
- During the repair stage during brazing with sources of ignition including the brazing burner, a cigarette and a lighter.

Table 18 lists the equipment as well as the indoor and outdoor conditions

TABLE 18: INFORMATION FOR THE RISK ASSESSMENT MODEL USED BY PRAHA TEAM

Target Product	Value
Model number	CS-PC36JKF
Type(cooling / HP)	HP
Capacity(kW)	10.5
Refrigerant type	A2L
Refrigerant amount(kg)	2.7
Alternative refrigerant type	HFC-32, R-454B

Indoor Condition during usage of target product		Value
Room size (m^2)	max	25
	min	16
Height of installation(m)		2.1
Ceiling height(m)		2.8
Ventilation	yes/no	YES
	Ventilation amount (m^3/hr.)	80
The area of the gap under the door (m^2)		0.02
other openings, if any (m^2)		0

Outdoor Condition during usage of target product		Value
Size of the place enclosed with walls , or fences etc.(m^2)	max	8
	min	4

Condition during repair of target product	value
Average size of outdoor spaces for repairs (m^3)	20
Percentage of single outdoor unit installations(A%）	50
Percentage of the installations of multiple outdoor units (B%）	50
Average working hours per repair (outdoor unit) (hr.)	1
Average working hours per repair (indoor unit)(hr.)	0.5
Wind condition (wind velocity） (m/s)	1 TO 3
Windless condition percentage (%)	10

(Windless condition; 0.1m/s or less. the windless rate in one year.)

Notes:

- No alternative refrigerant is available from the manufacturer for this product;
- Ventilation amount was calculated based on 1.5 air changes per hour;
- Gap under door was based on the door width is 1.00 m, gap with floor is 2 cm;
- The outdoor unit was assumed to be installed on a roof open area.

The methodology is to calculate the probability of ignition due to a space factor and a time factor.

Space Factor

The space factor takes into consideration the space volume, the volume of the flammable cloud, and the volume of the source of ignition. The volume of the flammable cloud depends on the leakage rate and other considerations such as pressure. The volume of the source of ignition can be very small as in the case of a spark, or sizeable as in the case of an open flame.

Time Factor

The time factor takes into consideration the number of occurrences of the ignition source and the duration of each occurrence.

Terminology

The following terminology will be used in the calculation example:

T_{Ref} = Time of application: 24 hours for usage or duration of maintenance for service
T_S = Time of Ignition Source
T_F = Time of Flammable Cloud
V_{FT} = Flammable Volume Time Integration
V_{SOI} = Volume of source of Ignition
$V_{F\ Cloud}$ = Volume of Flammable Cloud
V_{Ref} = Volume of space or room
$P_{A,\ B\ or\ C}$ = Probability of ignition for the different sources of ignition (A), (B), or (C)
P_R = Refrigerant Leak Probability

Equations

The Volume of Flammable Cloud is the Flammable Volume Time Integration divided by the Time of Flammable Cloud

$\mathbf{V_{F\ Cloud} = V_{FT} / T_F}$

The probability of ignition is the sum of the space and time factors for each source of ignition.

The probability of time is calculated as the sum of the time of the flammable cloud plus time of source of ignition divided by the time of reference (usage or service time).

$\mathbf{P_T = (T_F + T_S) / T_{Ref}}$

The Probability for Space is similarly calculated as the sum of the volume of source of ignition plus the volume of the flammable cloud divided by the reference volume which is the volume of the room or space where service is done.

$\mathbf{P_S = (V_{F\ Cloud} + V_{SOI}) / V_{Ref}}$

The probability for one source of ignition (A), referred to as "Event" is the multiple of the Time probability and the Space probability:

$\mathbf{P_A = P_T \times P_S}$

The probability for all events is sum of the probabilities for all sources of ignition. The three sources identified in the example i.e. charcoal, cigarette and candle are herein called A, B, and C

$\mathbf{P_{Events} = P_A + P_B + P_C}$

$\mathbf{P_R}$ = Leak Frequency x Number of Occurrence in a 24 hour period

The Total probability is the multiple of the probability of each event by the Refrigerant Leak probability

$\mathbf{P_{Total} = P_{Events} \times P_R}$

4.3.1. Simulation of Time Factor and Space factor During Usage Stage

The data in Table 19 was provided by the PRAHA-II team for the workshop.

TABLE 19: DATA FOR THE CALCULATION OF RISK FOR USAGE STAGE

Event	Ignition source	No. of Occurrence	Duration per day	T_S = Time of Source
A	Charcoal + lighter	2	1 hour	I hr/2
B	Cigarette+ lighter	2	0.2 hour	0.2 hr/2
C	Aroma candle	4	3 hours	3 hr/4

Flammable volume Time Integration:

- T_F = 18 minutes/60 minutes = 18/60 hour Time of the flammable cloud. The time is derived from lab data for the type of refrigerant
- Ts is show in table 19
- $V_{F\ Cloud}$ = 6.4 x 10^{-2} m^3 min/ 18 minutes: Volume of the flammable cloud for indoor unit is derived from simulation data for the class of refrigerant and type of application.
- V_{SOI} is negligible.
- T_{Ref} = 24 hours: Time of application is 24 hours since usage is throughout the day
- V_{Ref} = 25 m^2 floor area x 2.1 m height of the indoor unit.
- $1x10^{-3}$ = Leak frequency per year taken from a study for Japan as data is not available from the countries under study.

Figure 21 shows the FTA calculation for the usage stage.

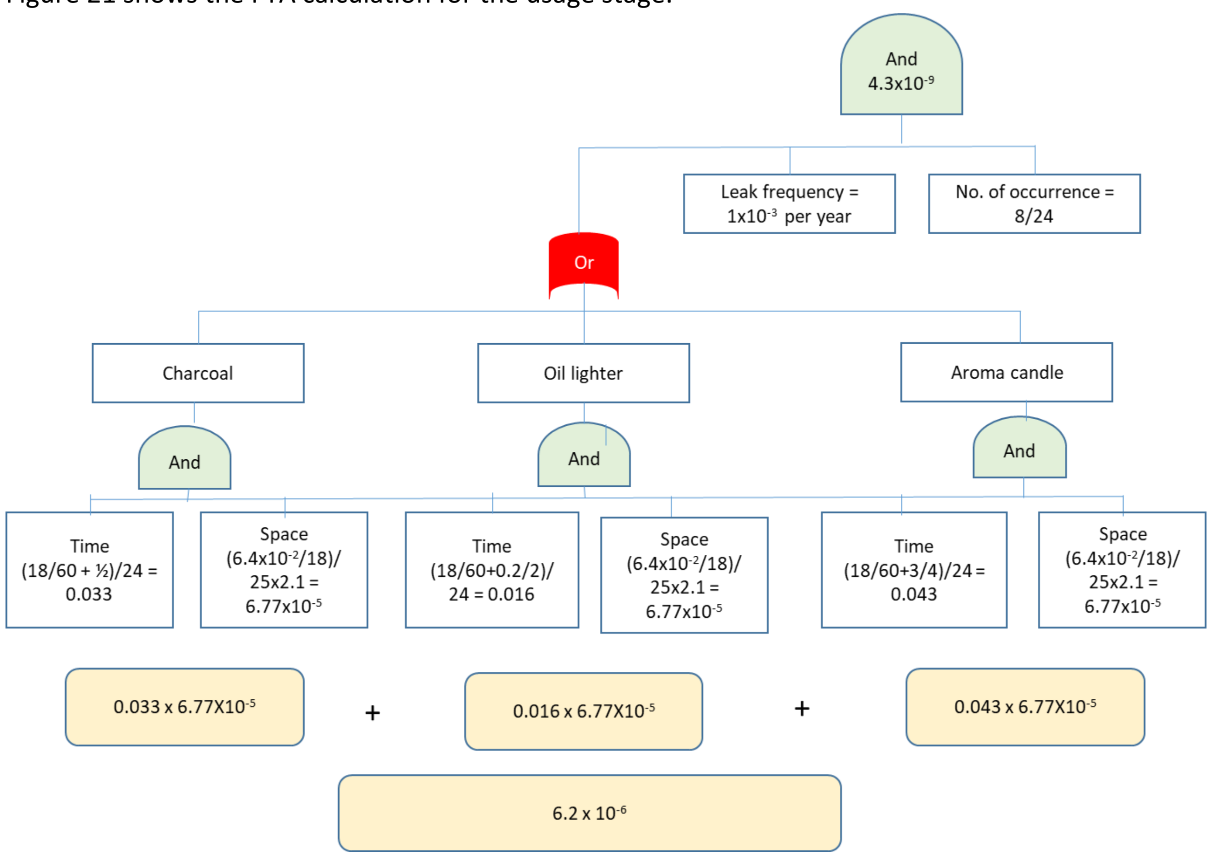


FIGURE 21: FTA FOR USAGE STAGE

For each event, i.e. charcoal, oil lighter, and aroma candle the probability of time and space are calculated according to the equations given above, for example:

- For charcoal the time factor is the sum of the time of the flammable cloud and the time of the ignition source divided by the usage time which is 24 hours. The probability equation is $(T_F + T_S)/T_{Ref.}$ T_F is 18/60 derived from data, Ts = ½ from table 19 and T_{Ref} is 24 hours.
- The space factor for charcoal is $(V_{F\ Cloud} + V_{SOI})/V_{Ref.}$ $V_{F\ Cloud}$ is $6.4x10^{-2}$ /18 while V_{SOI} is negligible. $V_{Ref.}$ is the volume up to the height of the unit = 25x2.1

- The addition of the three ignition sources gives a probability of $6.2x10^{-6}$ which is P_{Events}
- $P_{R} = 1x10^{-3} x (8/24) = 7x10^{-4}$
- The Total probability is P Events x PR = $(6.2x10^{-6}) x (7x10^{-4}) = 4.3x10^{-9}$ shown in the top "And". This puts the probability in the "Extremely Difficult" area of Figure 17: Risk Map.

4.3.2. Simulation of Time Factor and Space factor During Servicing Stage

TABLE 20: DATA FOR CALCULATION OF RISK FOR SERVICE STAGE

Event	Ignition source	No. of Occurrence	Duration per day	T_S = Time of Source
A	Burner	2	2 minutes	4/2
B	Cigarette	2	3 minutes	6/2
C	Lighter	2	10 seconds	0.167/2

Flammable Volume Time Integration

$V_{F\ Cloud} = 6.3 \times 10^4\ m^3$ sec/3600 sec Volume of the flammable cloud for outdoor unit is derived from simulation data for the class of refrigerant and type of application.

V_{SOI} is negligible

T_{Ref} = 60 minutes (I hour)

$V_{Ref} = 20\ m^2$ space x 3.5 m height. This is the volume of service space for the outdoor unit.

Ts is shown in table 20

T_F is 60 minutes is the time of the flammable cloud

T_{Ref} is the time of service which is 60 minutes

The FTA for servicing stage is shown in Figure 22.

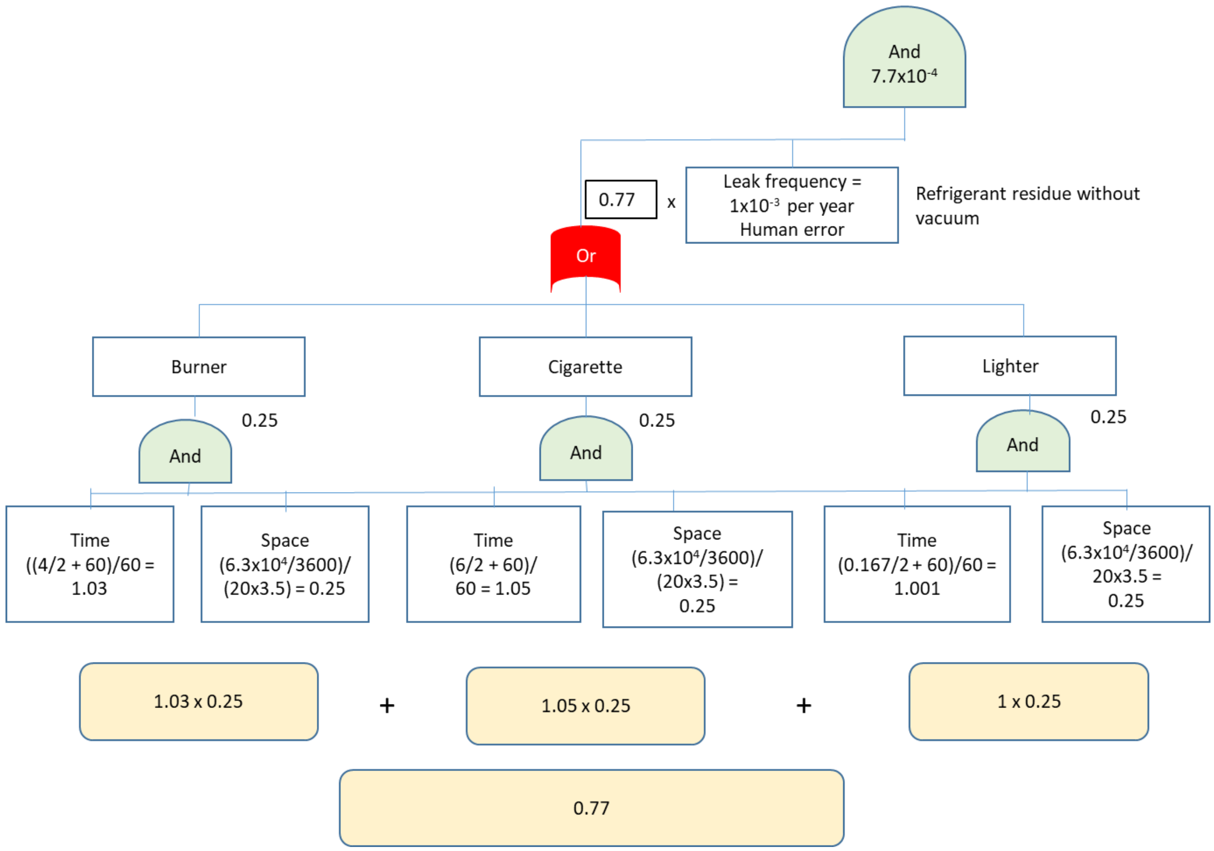


Figure 22: FTA for servicing stage

The calculations are similar to the usage stage example given above.
The Total probability is $0.77x\ 1x10^{-3} = 7.7x10^{-4}$ which is shown in the top "And". This puts it in the "Frequent" from the Risk Map of table 17 and mitigation measures should be taken. One evident measure is to ban smoking in the service area!

4.4. Conclusions and Recommendations from the Risk Assessment Element

The above two FTA were created in collaboration with HAT countries and Japan. The purpose of this FTA was to simulate a risk scenario in HAT region with unique climate, product-usage, lifestyle and culture which differs from Japan's case. The exercise has shown the need for a reliable data for the HAT region on leaks, practices etc.

Building a risk assessment model for the HAT countries that suits the climate and the service practices of the local technicians helps the HAT countries, as well as setting the foot for all A5 countries, in understanding the risk associated with flammable refrigerants and adopting the needed regulations and training programs especially in relation to the logistics of lower-GWP based technologies i.e. installation, transportation, storage, servicing and decommissioning.

The recommendation is for HAT countries to continue the risk assessment based on actual situations, and reduce the risk by implementing various measures that are verified by FTA. It is also important to minimize ignition probability by implementing various measures that are verified by FTA. In addition, the risk assessments of other stages matching cultural and lifestyle aspects should be studied.

References for chapter 4

AHRTI 8009, 2015. Risk Assessment of Refrigeration Systems Using A2L Flammable Refrigerants. April 2015

JSRAE, 2017. Risk Assessment of Mildly Flammable Refrigerants. Final Report 2016. March 2017

US Nuclear Regulatory Commission (US NRC). 1981. "Fault Tree Handbook." NUREG-0492. 209p. January.

5. Overall Conclusions and Recommendations

The outcomes of PRAHA-II components can draw several concluding remarks in relation to the main objectives of the project which can be summarized as follows:

In relation to support the process advancing the promotion and deployment of lower-GWP alternatives:

I. A tailored Risk Assessment is essential, not only for HAT countries, in better understanding safety implications associated with deploying alternative refrigerants, either A2L or A3, considering the specifics of different types of equipment and life stages.
II. Efforts in building risk assessment models should be exerted towards analyzing risks in the logistics side of the supply-chain i.e. Installation, In-door use, outdoor use, servicing and end of life (decommission); understanding the design and manufacturing risk assessment are covered by relevant international standards which should more or less apply to most countries.
III. The concept of risk assessment is quite similar worldwide, including methodologies in calculating and analyzing severity and frequency of risks. However, criteria for acceptable tolerance levels may differ depending on local considerations. Measures to mitigate risks would depend on type of exiting/operational standards and/or codes in each country noting
IV. Few Article 5 countries and some of the non-Article-5 countries have built similar models. Learning from the pioneers in risk assessment models through partnership and cooperation will leapfrog the technical difficulties and provide a quick access to building the model.
V. PRAHA-II was the first step in is providing the impetus for this leapfrogging. Similarly, Building the risk assessment model with the involvement of local research institutes and organizations will add depth and reach for those institutes and involve the HAT countries in the global research efforts on new alternatives as well as build countries' ownership.
VI. Building a risk assessment model for the HAT countries that suits the climate and the service practices of the local technicians will help the HAT countries will set the foot of A5 countries, not only HAT, in understanding and establishing local risk assessment models hence adopting the needed regulations and training programs especially in relation to the logistics of lower-GWP based technologies i.e. installation, transportation, storage, servicing and decommissioning.

In relation to building capacities of local industry to better design with lower-GWP alternatives:

VII. The optimization work on the prototypes of PRAHA-I is helping the OEMs who built the original prototypes get the best support in their R&D efforts. The activities of that element substantiated by result of testing of the optimized units confirm that enhanced design and the use of the proper components can lead to better performance and energy efficiency.

VIII. The optimization element of PRAHA-II also pointed out that components, especially compressors for the new refrigerants, are still not widely available. These and other limitations have to be dealt in order to help manufacturers make an informed decision on the way forward.

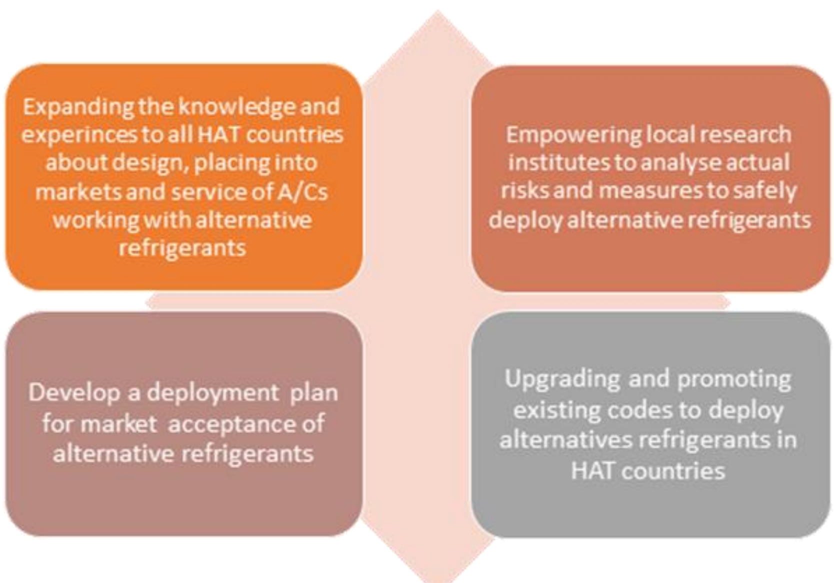
IX. PRAHA capacity building activities have helped the PRAHA stakeholders in acquiring added knowledge about working with alternative lower-GWP refrigerants that are flammable. The study tours have exposed stakeholders to the latest in technology for both A2L and A3 refrigerants at global technology centers. The capacity building activities helped many manufacturers in HAT countries in building or engaging in other research projects.

In relation to maintaining sustainable technical platform to support PRAHA process and sharing knowledge about up-to-date technological developments amongst HAT countries:

X. The capacity building efforts have turned PRAHA into a global process that can be extended to all 35 HAT counties and not only the Gulf and Middle East countries that were engaged with PRAHA-I.

XI. PRAHA-II events continued to attract global and regional participation in terms of government authorities, technology providers, manufacturers, and international/regional institutes. PRAHA presentations and knowledge sharing at networks of ozone officers and international conferences have become a fixture for exchanging experiences and knowledge about HAT technological related aspects. PRAHA-II has helped to spread the awareness of HAT challenges in optimization and risk assessment as well as opportunities.

Key take-home messages from PRAHA-II conclusions and recommendations can be illustrated as below.



Annex I – Examples of Risk Assessment Model Data Tables filled

A. Target Product

	value
model number	
type(cooling / HP)	
capacity(kW)	
refrigerant type	
refrigerant amount(kg)	
alternative refrigerant type	R32?

B-1. Indoor condition during usage of target product

		value
room size (m^2)	max	
	min	
height of installation(m)		
ceiling height(m)		
ventilation	yes/no	
	Ventilation (m^3/hr.)	
gap under door area (m^2)		
other openings, if any (m^2)		

B-2. Outdoor condition during usage of target product

		value
the size of the place enclosed with walls ,or fences etc.(m2)	max	
	min	

(ex. the internal area of a balcony)

C. Condition during repair of target product

	value
the average size of outdoor spaces for repairs (m3)	
the percentage of single outdoor unit installations (A%)	
the percentage of the installations of multiple outdoor units (B%)	
the average working hours per repair (outdoor unit) (hr.)	
the average working hours per repair (indoor unit) (hr.)	
wind condition (wind velocity) (m/s)	
windless condition (percentage %)	
(Windless condition; 0.1m/s or less. the windless rate in one year.)	

(note1)A+B=100% (note 2) multiple outdoor units installed with a considerable amount of spaces between them is included in the single installation category.

Praha-II List of Possible Ignition Source and estimation of ignition occurrence in Kuwait's case

(during usage - indoor)

Type of Ignition source	Ignition Source		Estimate of ignition occurrence / day: Occurrence (times/day)	Estimate of ignition occurrence / day: Duration (hours/day)
Ignition source caused within flammable region (triggered by the ignition source)	open flame	cigarette		
	Electric spark (human conduct)	oil lighter		
		ignition switch of heater		
		connect / disconnect of electric plug		
		on/off relay within electrical equipment		
		relay operation of electrical equipment		
		brush motor		
	Electric spark (excluding human conduct)	malfunction of equipment		
		slip on / off the clothes		
	Human conduct	slip on / off the clothes		
open flame (triggered by flammable region)	open flame	candle		
		heater		
		stove burner		
		catch fire		
	High temperature surface	Electric heater		

Annex II - Safety

Overview of RACHP safety standards (Source: *TEAP report Volume 4: Decision XXX/5 on Cost and Availability of Low-GWP Technologies/Equipment that Maintain/Enhance Energy Efficiency*)

The requirements and implications of various international and regional safety standards covering RACHP sectors are detailed in report TEAP TF XXVIII/4.[3] This includes a table of relevant standards and the applicable various sub-sectors (Table 2-1). An extract of that table is provided below (Table I). Throughout the report there are discussions on what the upper charge limits are.

Table I: Scope of selected RACHP safety standards that include flammable refrigerants

Sector	Vertical (Product Standards)		Horizontal (Group Standards)
	IEC 60335-2-40	IEC 60335-2-89	ISO 5149-1,-2,-3,-4
Commercial refrigeration		×	×
Air-to-air air conditioners & heat pumps	×		×

Table II attempts to summarise the upper charge limits, where values have been separated into two categories.

- "with limited measures" means only with elimination of potential ignition sources
- "With additional measures" refers to situations where additional protective measures have to be applied, such as imposing a minimum room size, additional ventilation, etc.

It is not straight-forwards to summarise the "with additional measures" charge limits as they often depend upon the choice of several measures, installation conditions and so on. The exercise should be carried out on a case-by-case basis.

Table II: Maximum charge size limits for flammable refrigerants according to RACHP safety standards

	With limited measures			With additional measures		
	A3	A2	A2L	A3	A2	A2L
IEC 60335-2-89	0.15 kg	0.15 kg	0.15 kg	n/a	n/a	n/a
IEC 60335-2-40	0.15 kg	0.5 kg	1.8 kg	0.3 kg/1.0 kg	3.4 kg	8.0 kg/78 kg
ISO 5149	0.15 kg	0.5 kg	1.8 kg	1.5 kg/2.5 kg/ unlimited	3.4 kg/ unlimited	60 kg/ unlimited

All of these standards are in various stages of revision including with special attention to application of flammable refrigerants. Again, a summary of these may be found in the TEAP TF XXVIII/4 report.

Overview of safe refrigerant handling

In terms of refrigerant safe handling training, the situation differs widely amongst countries, due to the variety of national legislation. The IIR has published an information note on qualification and competence of technicians,[4] which offers an overview of schemes available in many countries.

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[3] TEAP TASK FORCE Decision XXVIII/4 Report: on safety standards relevant for low-GWP alternatives

[4] http://www.iifiir.org/userfiles/file/publications/notes/NoteTech_28_EN.pdf

Some international and regional standard touch on the topic. An international standard is under preparation, ISO 22712 - Refrigerating systems and heat pumps — Competence of personnel (currently in the form EN 13113), which addresses the required competence of technicians for all refrigerant types and tasks. More specifically, IEC 60335-2-40 includes an Annex (DD) covering requirements for operation, service and installation manuals of appliances using flammable refrigerants, which is essentially a compilation of procedures. Another annex (HH) addresses "Competence of service personnel". Whilst neither IEC 60335-2-89 nor ISO 5149 contains any such material, EN 378-4 does have a short annex on competence of persons working with flammables.

Most countries tend to operate training programmes that are either national or private schemes. There are also a number of regional training programmes in existence, such as the "Real Alternatives" scheme, which covers most of the European countries.[5] In North America there are two such schemes: North America Training Excellence (NATE) for HVAC[6] and AHAM-Home Appliance[7]. China operates a national training scheme for flammables as does JRAIA in Japan.

The entire topic is rather disparate, but it is expected that the global approach will become more harmonised as introduction of flammable refrigerants become more prevalent.

[5] https://www.realalternatives.eu/learning-platform
[6] https://www.natex.org/site/1/Homehttp://
[7] www.aham.org/AHAM/Safety/Safe_Servicing_of_Cold_Appliances/AHAM/Safety/Safe_Servicing_of_Cold_Appliances.aspx?hkey=23d1344d-f8b0-410a-9e21-8181048b2b82

ANNEX-III: AHRTI Final Report

Promoting Alternative Refrigerants in High-Ambient Countries Phase (PRAHA-II):

Optimization Study on PRAHA I Equipment

September 2019

AHRTI Air-Conditioning, Heating and Refrigeration Technology Institute

Final Report

AHRTI Report No. 9011

Promoting Alternative Refrigerants in High-Ambient Countries Phase II (PRAHA-II): Optimization Study on PRAHA I Equipment

Final Report

September 2019

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DISCLAIMER

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1. Executive Summary

Over the past several years through the Promoting low- Global Warming Potential (GWP) Refrigerants for Air-Conditioning Sectors in High-Ambient Temperature Countries (PRAHA-I) project, 18 different prototypes have been developed and compared to respective baselines to support the assessment of alternative lower-GWP refrigerants for air-conditioning applications. Since the work originally started in 2012, researchers have identified gaps in the performance and operation of the PRAHA-1 prototypes. These gaps include the need to redesign and optimize prototype air-conditioning units, evaluate new alternative refrigerants, and improve component selection. As such, a new project, *Advancing the Designs of PRAHA-I for Meeting or Exceeding the Baseline Designs Performance*, conducted by Optimized Thermal Systems, Inc. (OTS) is herein presented.

The objectives of this project include the following:

1) Evaluate the design limitation of the PRAHA-I prototypes;
2) Optimize and physically evaluate selected prototypes with new refrigerants not evaluated during PRAHA-I; and,
3) Assess potential refrigerant fractionation impact due to leakage.

The project was organized into six activities for which a summary of the results, conclusions and recommendations are presented below:

1) Activity 1: Analyzing the Design of PRAHA-I Prototypes
    a. Certification laboratories, such as the one used for testing the units in PRAHA I, provide limited information for the purposes of product design and development. For future reference it is recommended that for research-oriented efforts such as this one, the units undergo a more rigorous testing process along with full characterization of the system and its individual components operating conditions and performance.
    b. In applications of high ambient temperatures, it is expected that performance will degrade as compared to operating under more temperate conditions and the resultant impact on performance must be considered. The key components for performance improvement identified herein were the compressor, condenser and expansion device.
        i. At higher temperatures, the saturation temperatures and refrigerant density at compressor's suction port can be very different than that from the rated conditions. Larger displacement volumes and efficiency curves optimized for higher pressure lifts might be required. Therefore, the proper selection of the compressor is paramount.
        ii. A better performance condenser will reduce the approach temperature between refrigerant and air, helping the compressor not to discharge refrigerant at very high pressure and temperatures, which degrade performance.
    c. At high ambient conditions, the system is forced to operate in higher pressure lift than at rated conditions, but still requires a certain refrigerant mass flow rate. Passive devices such as capillary tubes and orifices may not be able to provide enough expansion to allow the system to operate in higher temperature conditions. An active expansion device such as EXV's can adequately control operating conditions and maintain stable superheat.

2) Activity 2: Design Improvements (Summary results in Table 1)
    a. R290 and R32 have wider saturation regions allowing the system to operate with smaller superheat and subcooling, while benefiting from two-phase heat transfer. Their cycles

may get closer to that of the ideal Carnot cycle compared to refrigerants with narrower saturation.

b. Refrigerants with high temperature glide may require new heat exchanger (HX) designs, namely condensers. The original designs proved to be sufficiently effective to allow for most systems to operate with the different refrigerants, however, better designs would allow for higher system efficiency and potentially less charge. HX designs are severely constrained by allowed envelope dimensions. A complete system re-design would provide an opportunity for designing HX's with even higher efficiency.

c. The results of this analysis suggest that for an effective refrigerant replacement, a proper compressor selection must be accompanied with it. Higher isentropic efficiencies are desired for higher temperatures, but most importantly, the displacement volume requirements can vary considerably from one refrigerant to another.

d. It is also imperative that having an active expansion device (preferably an Electronic Expansion valve (EXV)) to not only allow for more controlled superheat, but also to enable the unit to run with different refrigerants with very different thermophysical properties.

Table 1: Activity 2 Summary Modeling Results.

General Information			Hardware				Performance	
System	**Rated Capacity (@35°C)**	**System Configuration**	**Compressor**	**Condenser**	**Expansion Device**	**Ref.**	**Cooling Capacity (@46°C)**	**EER (@46°C)**
-	BTU/hr	-	Efficiency (-)	Type	Type	-	BTU/hr	BTU/hr.W
Unit 1	18000	**Baseline**	**0.66**	**Tube-Fin (5mm Tube)**	**Passive**	**R444B**	**17403**	**7.4**
		Alternate 1	0.7	Same as Baseline	Active (EXV)	R290	17639	8.01
		Alternate 2	0.69			R454C	18104	7.31
		Alternate 3	0.7			R444B	18140	8.14
		Alternate 4	0.68	MCHX		R457A	17749	7.63
Unit 4	24000	**Baseline**	**0.61**	**Tube-Fin (9.5mm Tube)**	**Passive**	**R290**	**17940**	**7.52**
		Alternate 1	0.7	Tube-Fin (5mm Tube)	Active (EXV)	R290	18147	9.12
		Alternate 2	0.7			R290	24120	6.72
Unit 6	24000	**Baseline**	**0.6**	**Tube-Fin (7mm Tube)**	**Passive**	**R32**	**23115**	**8.46**
		Alternate 1	0.65	Tube-Fin (5mm Tube)	Active (EXV)	R32	23798	9.41
		Alternate 2	0.67			R454B	22894	9.71
		Alternate 3	0.7			R452B	23702	9.6
Unit 10	36000	**Baseline**	**0.44**	**Tube-Fin (9.5mm Tube)**	**Passive**	**R32**	**29005**	**6.39**
		Alternate 1	0.65	Tube-Fin (5mm Tube)	Active (EXV)	R447B	30478	9.43
		Alternate 2	0.67			R452B	30796	10.27
		Alternate 3	0.67			R454B	30809	10

3) Activities 3-5: Prototype Modification and Testing (Summary results in Table 2)

a. Unit 6 re-tested baseline exhibited similar performance to that found in PRAHA I testing. It should be stressed that the baseline unit by design had its capillary tube located in the outdoor unit. This would cause liquid refrigerant leaving the outdoor unit to flash. The refrigerant enthalpy at the condenser outlet state was used to calculate the refrigerant-side capacity assuming an isentalphic expansion without heat loss in connecting pipe. This is different from the modified systems of which the capillary tube was removed, and a manual expansion valve was placed at the inlet of the indoor unit. For modified systems, the enthalpy at the expansion valve inlet was used to calculate the refrigerant-side capacity.

b. Unit 10 exhibited a considerable reduction in power consumption at the high ambient test condition (46°C) as compared to the original test data. This supports the hypothesis of low compressor efficiency during PRAHA I tests, which also indicates the importance of proper compressor selection.
c. The above is also evidenced by the fact that even with R447B and R452B (zeotropic mixtures), Unit 10 had higher cooling capacity and efficiency than the baseline for the 46°C test condition, as projected in activity 2. The tests at 35°C, however, did not have the same trend.
d. The impact of refrigerant replacement was not very clear, in part due to the hardware change along with it. But because of the differences in saturation curves from the Activity 2 analysis, R32 tends to result in systems with higher efficiency and less charge. The zeotropic mixtures consistently required compressors with larger displacement volumes and even higher mass flow rates for cooling capacities of the same magnitude.
e. Refrigerant fractionation as evidenced by the leak tests, does not appear to a great concern since less than 2% in cooling capacity was observed after the system's re-charge.
f. The Unit 6 modified systems had lower performance than expected from the Activity 2 models. The R32 system configuration exhibited around 10% less flow rate than anticipated, which corresponded to 10% lower capacity. The R454B configuration exhibited a deviation of 5% between model and test due also in part to a 3% flow rate over prediction in the model. Unit 10, on the other hand, exhibited an excellent agreement to the models with less than 2% deviation in cooling capacity.
g. The model's validation adds confidence in the numerical simulation findings and recommendations provided in activity 2.

Table 2: Tests Summary Results.

Syst.	Test	Refrigerant	Charge	35°C			46°C		
				Cooling Capacity	Total Power	EER	Cooling Capacity	Total Power	EER
			lb	BTU/hr	kW	BTU/hr.W	BTU/hr	kW	BTU/hr.W
Unit 6	Perfor mance	R32 (Baseline)	3.83	25192	2.43	10.4	23390	3.10	7.54
		R32 (Alternate 1)	4.27	23585	2.12	11.1	21450	2.74	7.84
		R454B (Alternate 2)	5.02	21966	2.10	10.4	21821	2.67	8.17
Unit 10	Perfor mance	R32 (Baseline)*	5.63	34517	3.76	9.18	29005	3.84	7.55
		R447B (Alternate 1)	6.63	32195	3.62	8.88	31073	3.90	7.96
		R452B (Alternate 2)	6.63	28128	3.38	8.33	30292	3.90	7.76
	Liquid Line	Low Charge	4.23	N/A			14216	3.90	3.64
		Re-Charged	6.63				30865	4.16	7.42
	Vapor Line	Low Charge	4.27				15171	3.92	3.87
		Re-Charged	6.77				30587	-	-

Original baseline values from PRAHA

4) Conclusions: This report presented a comprehensive set of activities with the objectives of advancing the PRAHA program. The original scope and schedule were modified during the project as new findings and challenges surfaced. The tests that were carried out for PRAHA-I, while sufficient for the purpose of measuring capacity and energy efficiency for the purposes of PRAHA-I, did not have enough essential data to enable a complete cycle evaluation for optimization purposes. This is primarily due to using standard test rig on systems with critical hardware configuration differences. The analyses presented in Activity 2 (design assessment through modeling) provided good insights on adequate component design and/or selection for proper system functioning when using novel refrigerants. The tests in activities 3-5 partially served as validation for the models developed, and as check for previous test data from PRAHA I. The final recommendations for future development are listed as follows:
    a. Establish a baseline system by conducting comprehensive testing including measurements and metrics not typically performed in energy certification tests. Furthermore, testing systems with different configurations require custom test rigs as such to adequately measure working fluid's states to avoid mischaracterization of the operating conditions and performance. Such approach is considerably more labor-intensive which should be factored in the scope in future developments.
    b. Using alternate low-GWP refrigerants is viable and can be competitive to commonly used pure refrigerants but doing so requires proper component design and selection; compressor and expansion device particularly. Drop-in replacement without hardware change is never recommended as evidenced by the change requirements in Activity 2 and performance tests in the subsequent activities.
    c. It is recommended to always perform numerical simulations, and to conduct at least some level of "soft" optimization analyses that will provide information for an educated system re-design / retrofit at much lower costs than gradual trial-and-error changes.
    d. Always test the modified systems with the same instrumentation as the baseline, however mindful of the modifications as such to properly place sensors to obtain adequate readings as suggested in item a above.

2. Introduction

Over the past several years through the Promoting low- Global Warming Potential (GWP) Refrigerants for Air-Conditioning Sectors in High-Ambient Temperature Countries (PRAHA-I) project, 18 different prototypes have been developed and compared to respective baselines to support the assessment of alternative lower-GWP refrigerants for air-conditioning applications. Since the work originally started in 2012, researchers have identified gaps in the performance and operation of the PRAHA-1 prototypes. These gaps include the need to redesign and optimize prototype air-conditioning units, evaluate new alternative refrigerants, and improve component selection. As such, a new project, *Advancing the Designs of PRAHA-I for Meeting or Exceeding the Baseline Designs Performance*, is desired.

The objectives of this project include the following:

4) Evaluate the design limitation of the PRAHA-I prototypes;
5) Optimize and physically evaluate selected prototypes with new refrigerants not evaluated during PRAHA-I; and,
6) Characterize leaks.

The project is divided into six activities namely:

- **Activity 1 – Analyzing the Design of PRAHA-I Prototypes**: evaluate systems performance from selected units tested in PRAHA-I, and assess potential design improvements
- **Activity 2 – Design Improvement**: improve design of specific units targeting higher efficiencies while using alternate low-GWP refrigerants
- **Activity 3 - Prototype Units Fabrication**: modify the a sub-set of the units according to modifications proposed in Activity 2
- **Activity 4 - Evaluation of the Optimized Prototypes**: conduct performance tests on modified units at standard and high ambient temperature conditions (35°C and 46°C)
- **Activity 5 - Analyzing Leaks of Alternatives**: simulate refrigerant leakage and evaluate possible impact of zeotropic mixtures fractionation on performance
- **Activity 6 - Reporting and Data Management**: simulation and test data processing, preparing progress and final reports

3. Activity 1 - Analyzing the Design of PRAHA-I Prototypes

Activity 1 was comprised of three major tasks including: reception of 12 physical units at the OTS facility followed by visual inspection and parts identification; review of performance test reports from PRAHA I tests; and lastly, analyze data and identify, for units of interest, opportunity for improvement targeting higher performance and minimal charge. OTS has completed this activity and an executive summary of the findings are presented herein.

3.1. Physical Units

All 12 units of interest to this project (Table 3) were received on November 8th, 2018. Visual inspection indicated no evident signs of damage. Relevant information to the project such as compressor model, heat exchanger (HX) geometry and circuiting, as well as expansion device were also received.

Table 3: Unit Specifications Summary.

Category	Unit #	Ref.	Designed Capacity Btu/h	Measured Cap. Btu/h	Voltage	Ref. (New designs)	Ref. (Tests)
Window	**1**	**L-20 (R-444B)**	**18,000**	**19,104**	**208-230/60/1**	**L-20, R454C, R290, R457A**	**R290**
	2	L-20 (R-444B)	18,000	16,924	208-230/60/1		
	3	DR-3 (R-454C)	18,000	18,063	208-230/60/1		
Decorative splits	**4**	**R-290**	**24000 (18,000)**	**19,000**	**208-230/60/1**	**R-290**	**R-290**
	5	R-32	24000 (18,000)	19,328	208-230/60/1		
	6	**R-32**	**24,000**	**25,456**	**208-230/60/1**	**R32, R459A**	**R32, R459A**
	7	L-41 (R-447A)	24,000	24,830	208-230/60/1		
	8	L-20 (R-444B)	24,000	22,740	208-230/60/1		
	9	DR-3	24,000	14,638	208-230/60/1		
Ducted splits	**10**	**R-32**	**36,000**	**35,500**	**220-240/50/1**	**R447B, R452B**	**R447B, R452B**
	11	L-20	36,000	36,553	220-240/50/1		
	12	DR-3 (R-454C)	36,000	33,032	220-240/50/1		

3.2. PRAHA-I Performance Reports Assessment

OTS received a complete package of files containing the performance reports for all units tested in PRAHA I. The tests conducted in PRAHA I were meant to assess high-level performance of these units focusing on a large control volume where only total energy in and out was evaluated. As such, these tests were not comprehensive in terms of measurements for cycle analysis required in PRAHA II. Refrigerant side measurements, in most cases, were very limited (few pressure and temperature measurements and no flow rates); thus, it is not possible to fully characterize the cycle and perform energy balances between air and refrigerant sides of the system. Common issues found in the reports include:

- Tag mislabeling and / or mismatching sensor location and tag
- No independent outdoor capacity reported – typically reported the same as indoor capacity
- Missing energy balance checks
- Missing measurement on either airside pressure drop and temperature or fan power
- Inconsistent reported measurements with thermophysical properties for units tested with L-20
- Systematic inconsistency in reported superheat and subcooling
- Missing measurements on refrigerant side at evaporator inlet
- Missing temperature and/or pressure measurements on refrigerant side
- Missing refrigerant mass flow measurements

A summary of the original PRAHA-1 data and results of the data reduction are provided under separate documentation.

3.3. Hardware Improvement Assessment

3.3.1. Heat Exchanger (HX) First Order Analysis (FOA)

This section outlines a FOA for the HXs of Units 1, 4, 6 and 10 to identify improvement potential. The project's objective, as stated above, is to improve performance while minimizing charge. One way of addressing both objectives is by reducing tube / channel diameter. Heat transfer coefficients are inversely proportional to surface hydraulic diameters, however, so is pressure drop. Smaller tubes result in more compact (C = surface area / footprint volume), with reduced internal volume, HXs.

A qualitative analysis using values from literature was carried out to demonstrate the relative impact of diameter over abovementioned metrics, specifically: heat transfer coefficient, compactness and overall thermal conductance (UA). The left-hand side plot in Figure 1 show three curves inversely proportional to the diameter; a 5mm tube can achieve, in this example, 70% greater UA than a conventional 9.5mm, within the same footprint volume (or cabinet).

These are further explored to illustrate the impact on a system level. Systems respond to UA of both condenser and evaporators, but for the purposes of this analysis, condenser only is considered. The UA represents the overall thermal conductance, which will impact the approach temperatures in the system (ΔT_{app}). If the heat rejection is kept constant, the higher the UA, the smaller are the ΔT_{app}'s, thus allowing the condenser to operate in lower pressure levels, which will consequently increase the system performance. An example using a hypothetical R32 cycle with an EER of 12 as base is shown in the right-hand side plot in Figure 1. Performance improvement is limited by the Second Law, when the approach temperatures near zero; however, in this illustration, the EER has potential to increase in over 20% with better condenser design alone.

It is imperative to note that the results presented in this section are for **illustration purposes only**. Further in this report it is presented in more detail a re-design framework, applied to the units of interest in this project, using the metrics outlined in this section.
Unit 1 already had a 5mm condenser, which limits the options for HX re-design. Unit 6 had a 7mm HX on both the indoor and outdoor units, which allows some room for improvement if reducing to 5mm. Lastly, both coils for Unit 10 had 9.5mm tubes, thus there is greater potential for charge reduction and performance improvement for that unit in particular.

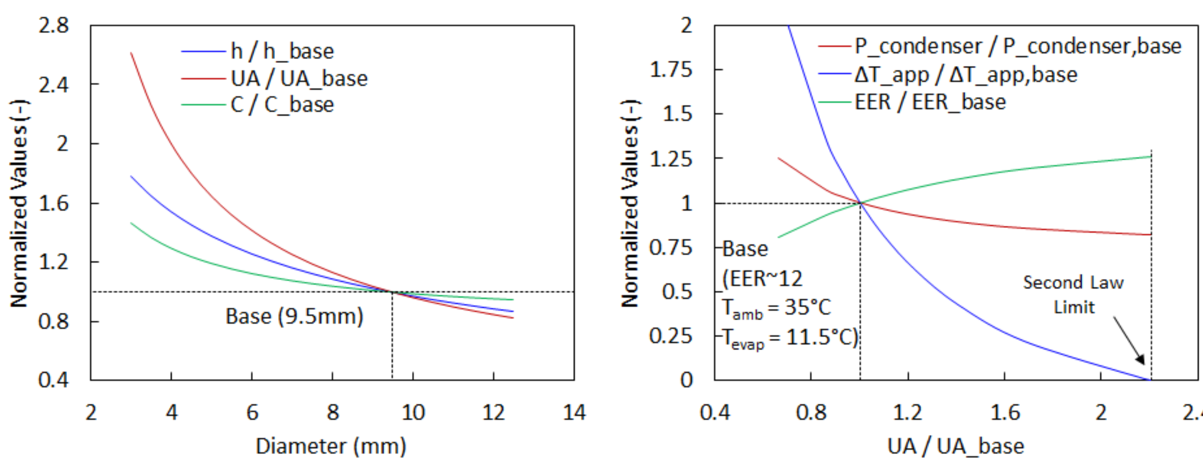

Figure 1. Heat Exchangers FOA.

3.3.2. Compressors

The existing units mostly use compressors sized specifically for R410A or R22 and in some cases custom made for this effort. There is, however, opportunity for a better compressor selection when migrating from R32 to R454B or R447B on Units 6 and 10, respectively.

3.3.3. Expansion Devices

Expansion devices such as TXV's and EXV's may allow for better control and reduced losses in connecting pipes if located near the evaporator. Some units, such as 6 and 10, have a capillary tube in the outdoor unit, which forces the refrigerant to travel in two-phase along the connecting pipes, and at lower temperatures, thus increasing pressure drop and heat gain.

3.3.4. Fan and Blower

Replacing the fan and blower may be necessary if newly designed HXs offer considerable change in pressure drop over the baseline since the flow rates are kept constant. The lack of test data on pressure drop forces us to rely on predicted values only. These will be considered for replacement as a last priority.

3.3.5. Units Component Modification Potential

Table 4 shows the detailed existing components for the units of interest for modification.

Table 4: Units 1, 4, 6 and 10 Components.

System	Unit 1	Unit 4	Unit 6	Unit 10
Refrigerant	**R444B**	**R290**	**R32**	**R32**
Compressor	HIGHLY SL260DG-C8EU	HIGHLY PSH356DG-C8DU3	GMCC KSG226N1UMT	Copeland ZP42K5E-PFJ-XXX
Condenser	5mm Louver TFHX	9.5mm Wavy TFHX	7mm Louver TFHX	9.5mm Louver TFHX
Expansion Device	Capillary Tube	Capillary Tube	Capillary Tube	Capillary Tube
Evaporator	9.5mm Louver TFHX	7mm Louver TFHX	7mm Slit TFHX	9.5mm Louver TFHX

3.4. Conclusions and Recommendations

The first part of this activity regarded data analysis and processing from the original tests conducted in the original PRAHA-I project, which was designed to conduct testing and comparison of cooling capacity vs. EER for the prototypes against the baseline units from same manufacturers. Since limited certification tests were required then, more testing parameters would have been needed to support the optimization and/or redesign process within the scope of PRAHA-II. The second part pertained assessing potential hardware modifications that could result in higher performance and less charge, with the intent of replacing the original refrigerants with alternative, low-GWP ones. The key conclusions and recommendations are:

1- Certification laboratories, such as the one used for testing the units in PRAHA I, provide limited information for the purposes of product design and development. For future reference it is recommended that for research-oriented efforts such as this one, the units undergo a more rigorous testing process along with full characterization of the system and its individual components operating conditions and performance.

2- In applications of high ambient temperatures, it is expected that performance will degrade as compared to operating under more temperate conditions and the resultant impact on performance must be considered. The key components for performance improvement identified herein were the compressor, condenser and expansion device.

   a. At higher temperatures, the saturation temperatures and refrigerant density at compressor's suction port can be very different than that from the rated conditions. Larger displacement volumes and efficiency curves optimized for higher pressure lifts might be required. Therefore, the proper selection of the compressor is paramount.
   b. A better performance condenser will reduce the approach temperature between refrigerant and air, helping the compressor not to discharge refrigerant at very high pressure and temperatures, which degrade performance.

3- At high ambient conditions, the system is forced to operate in higher pressure lift than at rated conditions, but still requires a certain refrigerant mass flow rate. Passive devices such as capillary tubes and orifices may not be able to provide enough expansion to allow the system to operate in higher temperature conditions. An active expansion device such as EXV's can adequately control operating conditions and maintain stable superheat.

4. Activity 2 - Design Improvements

The details of modeling and simulation results are provided in a separate document submitted in conjunction with this one, while in this section only the summarized performance results are presented.

4.1. Hardware

A general design improvement assessment was presented in the report for Activity 1, focusing on the units of interest to this study. A first order analysis on the HX's showed that moving towards smaller hydraulic diameter tubes can be beneficial from a material savings and charge reduction standpoint. Units 4 and 10 use conventional 9.5mm diameter tube condensers (Table 4), making them good candidates for condenser replacement with either a smaller tube diameter or a microchannel heat exchanger (MCHX). The compressors used on Units 1, 4 and 6 do not have available performance maps making it difficult to assess their fitness for the system. The focus of this study is on proper compressor selection and condenser re-design.

4.2. Refrigerant

R32 and R290 have wide saturation regions (Figure 2 and Figure 3) putting them at an advantage since they may operate with smaller superheat and subcooling, while benefiting from two-phase heat transfer. Their cycles may get closer to that of the ideal Carnot cycle compared to refrigerants with narrower saturation.

Amongst the blends investigated for Unit 1, R444B has the widest saturation region while also having the highest temperature glide (Figure 4). The latter is typically not beneficial, in particular for evaporators, but it may help the condenser. The glide enables the refrigerant temperature profile to get closer to the air temperature profile without crossing (Figure 4). From a thermodynamic perspective, this means R444B can have its condensing pressure reduced further, resulting in higher theoretical COP.

For Units 6 and 10, the investigated blends, although having narrower saturation than the baseline R32, have similar thermophysical characteristics (Figure 3) with lower temperature glides (Figure 4) making them more competitive from a capacity and performance perspective.

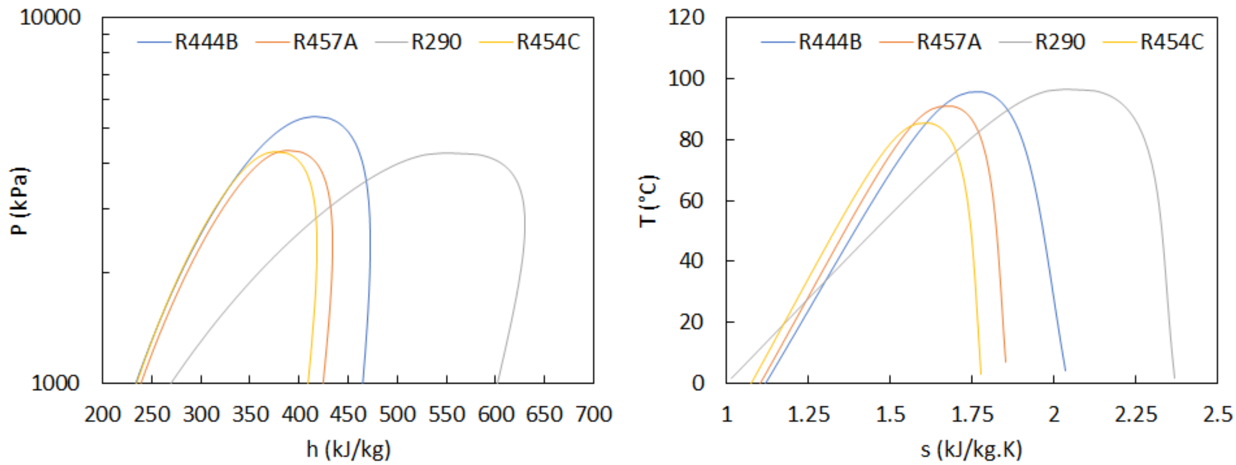

Figure 2. Refrigerants Investigated for Units 1 and 4.

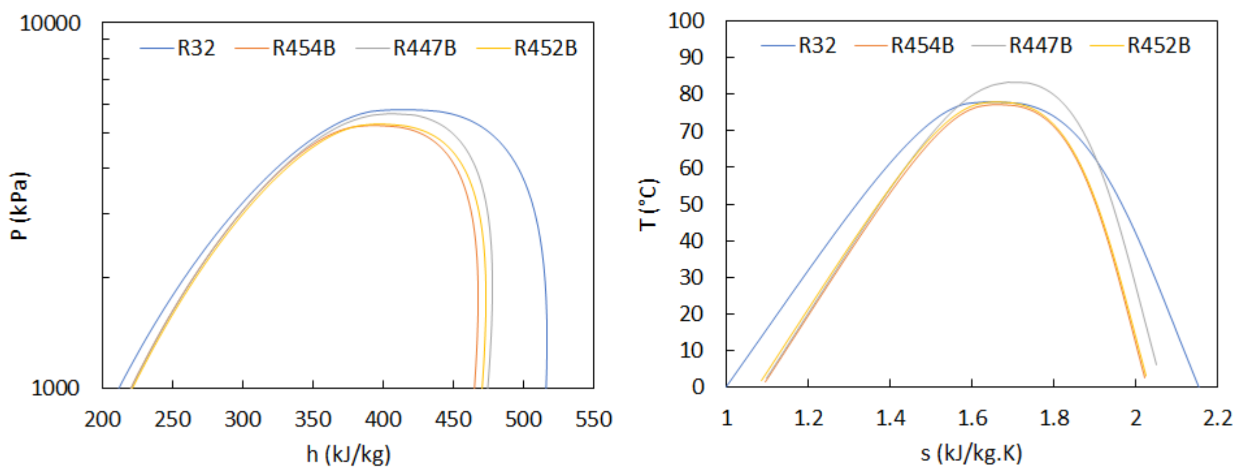

Figure 3. Refrigerants Investigated for Units 6 and 10.

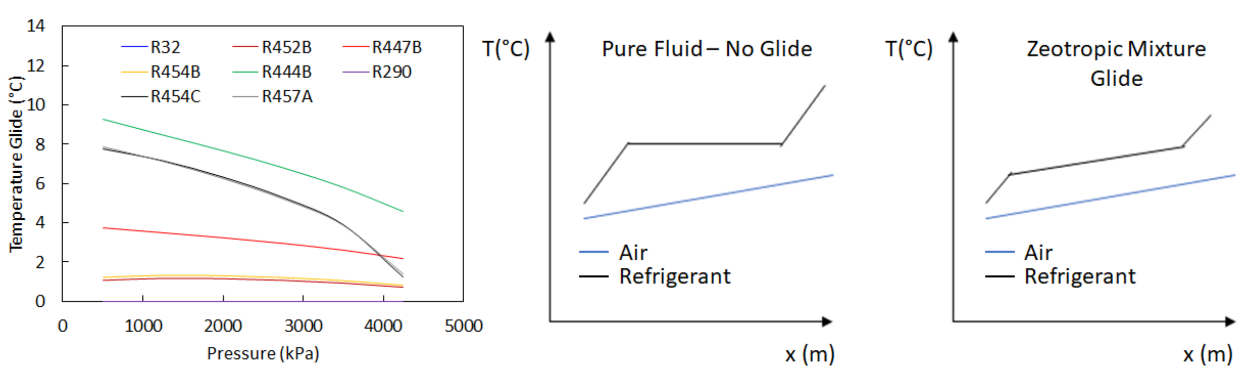

Figure 4. Refrigerant Temperature Glides.

4.3. System Design Modification Framework

The systems' re-design herein presented ultimately consists of a retrofit of the existing units by properly designing and selecting components that can be replaced as drop-ins, with minimal or no modification of the packaging (cabinets). In other words, any component replaced must occupy the same envelope as the baseline component. The focus of the re-design is on:

- Compressor
- Condenser, and
- Expansion valve

The evaporator designs were not changed for two main reasons: a) some are custom-made wrap-around the blower units, such as in Unit 6, making it harder to quickly find an off-the-shelf option; and, b) the goal is to deliver the same cooling capacity while improving efficiency. For the latter, there's more room for improvement in the condenser by reducing condensing pressure, assuming the evaporator can already deliver the expected capacity.

The fans and blowers were also not considered for change, in part due to the lack of information on the performance curves from the baseline models, but also due to potential high cost and lead time for replacement with secondary impact on performance since 80-90% of the power consumed comes from the compressor.

The first step to assess the level of performance required for each component is to investigate an improved theoretical cycle, which will indicate how much COP improvement can be expected, as well as refrigerant flow rate needs and HX size (UA). To improve the performance of a vapor compression cycle, the pressure lift between evaporating and condensing pressures must be reduced. Consequently, the approach temperatures between air and refrigerant will be reduced as well (Figure 5), thus the thermal capacitance of the heat exchangers must increase. Furthermore, the closer to the saturation region, the closer the cycle reaches the ideal Carnot efficiency (Figure 6).

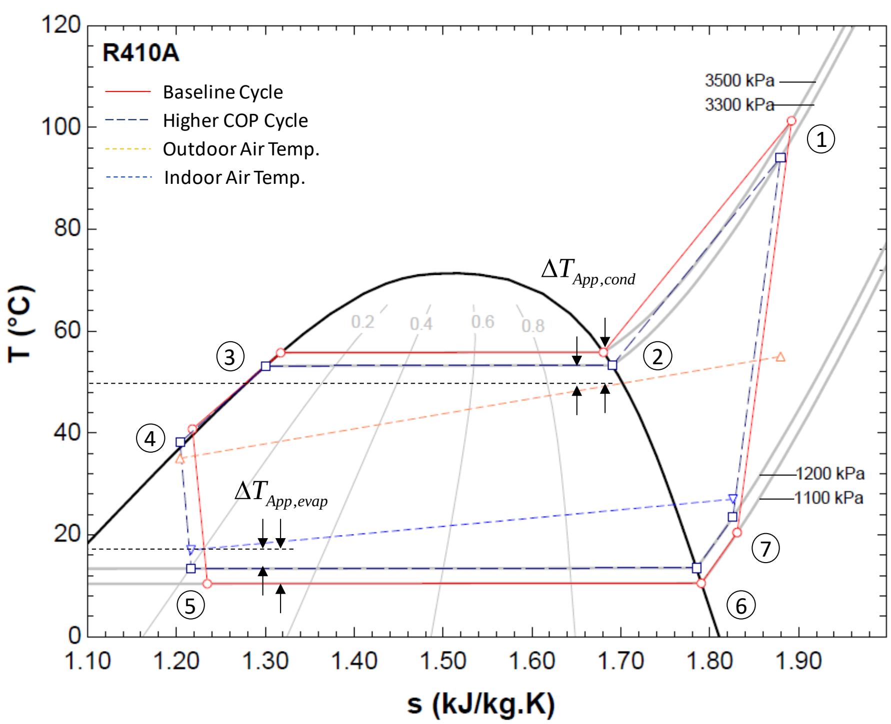

Figure 5. Illustrative T-s diagram for baseline and improved cycles.

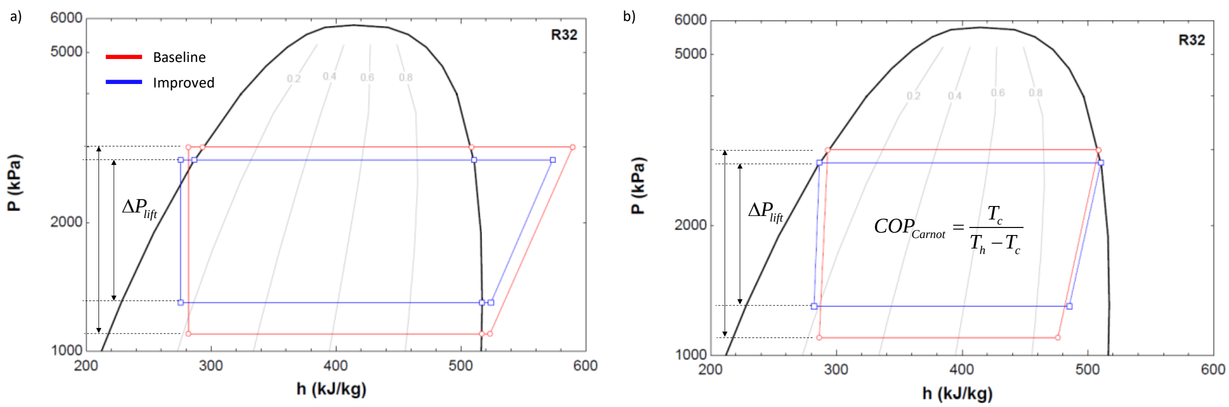

Figure 6. P-h Diagrams Illustrating COP Improvement: a) Real Cycle; b) Ideal Cycle (Carnot).

The system design framework is performed according to Figure 7.

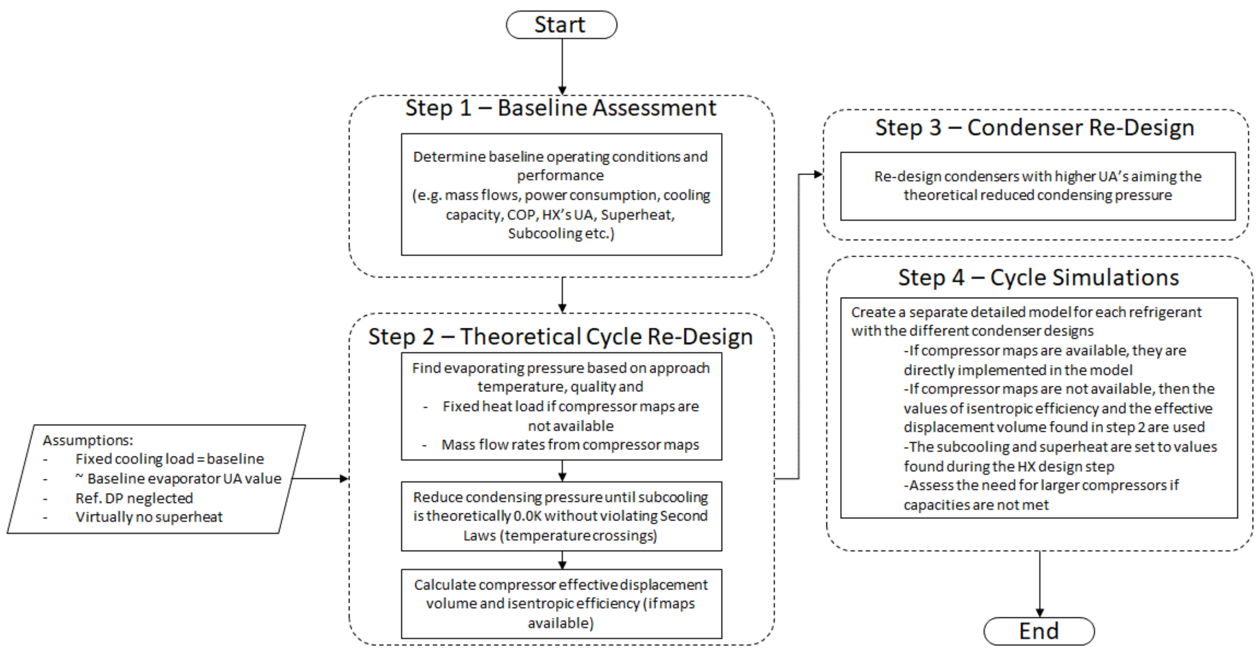

Figure 7. System Re-Design Framework,

4.3.1. Compressors

Modeling compressors are handled in two possible ways, as suggested previously: using performance maps when available or using fixed isentropic efficiency and effective displacement volume. For the larger capacity units (6 and 10), performance maps were provided. Although these compressors were originally designed for R410A refrigerant they may operate – not necessarily optimally – with other refrigerants. Compressor manufacturers supporting this project used proprietary simulation tools, with aid from available empirical data (tests with other refrigerants), to develop theoretical maps for the various refrigerants of interest (Table 5) and made them available to OTS for modeling purposes. It is understood that the predictions are for reference only, and the compressor manufacturer does not guarantee performance for any refrigerants for which the compressors haven't been fully tested.

Table 5: Compressor Models.

Model	Capacity (BTU/hr)	Frequency (Hz)	Refrigerants
ZP20K5E-PFV	24,000	60	R32, R459A, R454B, R410A
ZP21K5E-PFV	24,000		
ZP31K6E-PFV	36,000	50/60	R447B, R452B, R454B, R410A
ZP34K6E-PFV	36,000		

For the smaller units (1 and 4), which were re-designed using R290 (Propane), compressor performance maps were not available. The approach for these units then was to set a target isentropic efficiency of 0.7 (baseline data suggests that the compressor efficiencies ranged from 0.55 to 0.65). The required mass flow rate is calculated based on capacity in the theoretical cycle model described above. From there, the effective displacement volume can be determined (eq. (1))[1]. The latter serves to determine whether a system can use the same compressors for different refrigerants.

$$V_{eff} = \eta_{vol} \cdot V_{disp} = \frac{\dot{m}_{required}}{f \cdot \rho_{suction}} \qquad (1)$$

4.3.2. HX Design and Selection

The condensers design procedure takes into consideration the following:

- **Face area**: baseline face area must be preserved or at most reduced. Furthermore, the aspect ratio must also match that of the baseline so the HX can be drop-in replaced in the same cabinet.
    - Find the number of tube rows and tube length to match as closely as possible to tube face area and aspect ratio

- **Airside pressure drop and flow rate**: the test data from reports contain only air flow rate measurements, while no information on pressure drop is provided. Additionally, the fan performance curves are also not available, which limits the ability to find the exact operating condition. The baseline models provide an estimate prediction for the pressure drop, which is used as reference.

- **Thermal performance**: this step must be iteratively conducted with the previous step, as such for each design change the air flow rate and capacity are evaluated under the new conditions found in the theoretical cycle re-design.
    - Gradually increment the condensing pressure until attainable performance is achieved. This process is done iteratively using the theoretical cycle model, to find new expected operating conditions for evaporating pressure, superheat, subcooling and refrigerant flow rate.

- **HX Form**: as indicated previously, the HX design is constrained by cabinet dimensions as well as form. In the case of units 1 and 4, the condensers are flat coils placed 90° inside the cabinet (Figure 8), which makes it simpler for drop-in replacement as long as new designs have the same overall dimensions. For units 6 and 10, however, the condensers are L-shaped inside the cabinet (Figure 8). Forming coils is widely done, however, for custom coils it may be a challenge, in particular for MCHX. For this reason, the MCHX designs for units 6 and 10 are sized for a full-face area, assuming the coil can be formed, and a second design that is a single flat slab placed in longer side of the "L" shape(Figure 9).

[1] Variable definitions in the Nomenclature list after final conclusions section in this document.

- **HX Name Tag Convention:** for practical purposes, the HX's will be tagged according to the following W XX YY Z
  - **W:** B = Baseline or N = New Design
  - **XX:** TF **=** Tube-Fin or MC = Microchannel
  - **YY:** D# = Tube Diameter or Height
  - **Z:** R = Reduced Face Area
  - **Example:** New Tube Fin Design with 5.0mm diameter with same face area as the baseline → NTFD5

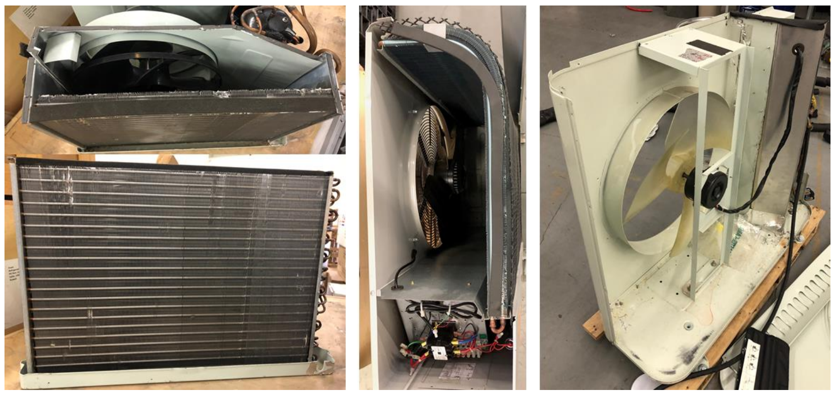

Figure 8. Condenser Forms: Unit 1 (left), Unit 10 (center), Unit 6 Cabinet (right).

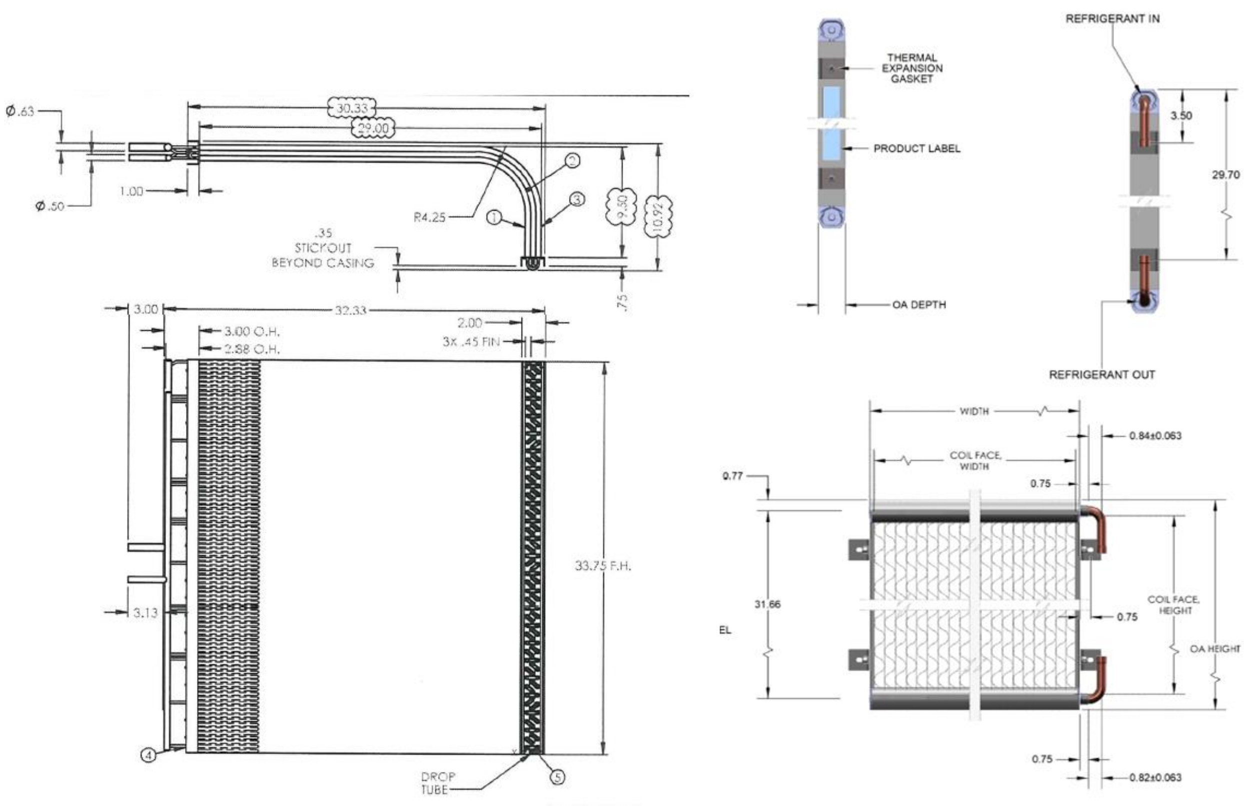

Figure 9. HX Form Examples: L-shape (left), Flat (right).

4.3.3. System Design

In the final step, the modified systems are evaluated holistically through system level modeling and simulation using an in-house Steady-State vapor compression cycle software that has the capability to integrate with the HX and compressor models (performance maps, generic etc.). For each modified system and each refrigerant, a system model was created.

4.4. Modified Systems Results Summary

The final results of Activity 2 are summarized in Table 6. For more detailed results in the framework steps refer to APPENDIX A .

4.5. Conclusions and Recommendations

This section presents a systematic approach based on first order analysis providing educated guidance towards the direction of more efficient systems with fewer simulations and minimal changes to the systems. The study includes a wide variety of refrigerants as well as condenser designs and compressor model options. Given the challenges with original test data the baseline models serve as a numerical reference only. The findings are strictly valid to comparisons against the baseline models and OTS does not guarantee that results would be reflected in actual systems as herein reported. The key conclusions and recommendations are:

1- R290 and R32 have wider saturation regions allowing the system to operate with smaller superheat and subcooling, while benefiting from two-phase heat transfer.

2- Refrigerants with high temperature glide may require new heat exchanger (HX) designs, namely condensers. The original designs proved to be sufficiently effective to allow for most systems to operate with the different refrigerants, however, better designs would allow for higher system efficiency and potentially less charge. HX designs are severely constrained by allowed envelope dimensions. A complete system re-design would provide an opportunity for designing HX's with even higher efficiency.

3- The results of this analysis suggest that for an effective use of alternate low-GWP refrigerant, a proper compressor selection must be accompanied with it. Higher isentropic efficiencies are desired for higher temperatures, but most importantly, the displacement volume requirements can vary considerably from one refrigerant to another.

4- It is also imperative that having an active expansion device (preferably an EXV) to not only allow for more controlled superheat, but also to enable the unit to run with different refrigerants with very different thermophysical properties.

Table 6: Activity 2 Results.

General Information			Hardware					Ref.	Performance			
System	Rated Capacity (@35°C)	System Configuration	Compressor		Condenser		Expansion Device		Cooling Capacity (@46°C)		EER (@46°C)	
-	BTU/hr	-	Effective Disp. Vol. (cm³)*	Efficiency (-)	Type	Effectiveness (-)	Type	-	BTU/hr	%	BTU/hr. W	%
Unit 1	18000	**Baseline**	**19.8**	**0.66**	**Tube-Fin (5mm Tube)**	**0.20**	**Passive**	**R444B**	**17403**	**0.00%**	**7.4**	**0.00%**
		Alternate 1	25.9	0.70	Same as Baseline	0.35	Active (EXV)	R290	17639	1.40%	8.01	8.20%
		Alternate 2	24.8	0.69		0.26		R454C	18104	4.00%	7.31	-1.30%
		Alternate 3	19.6	0.70		0.23		R444B	18140	4.20%	8.14	9.90%
		Alternate 4	25.3	0.68	MCHX	0.24		R457A	17749	2.00%	7.63	3.10%
Unit 4	24000	**Baseline**	**26.4**	**0.61**	**Tube-Fin (9.5mm Tube)**	**0.24**	**Passive**	**R290**	**17940**	**0.00%**	**7.52**	**0.00%**
		Alternate 1	26.3	0.70	Tube-Fin (5mm Tube)	0.26	Active (EXV)	R290	18147	1.20%	9.12	21.40%
		Alternate 2	37.9	0.70		0.20		R290	24120	34.40%	6.72	-10.60%
Unit 6	24000	**Baseline**	**16.0**	**0.60**	**Tube-Fin (7mm Tube)**	**0.12**	**Passive**	**R32**	**23115**	**0.00%**	**8.46**	**0.00%**
		Alternate 1	16.9	0.65	Tube-Fin (5mm Tube)	0.15	Active (EXV)	R32	23798	3.00%	9.41	11.20%
		Alternate 2	18.4	0.67		0.19		R454B	22894	-1.00%	9.71	14.80%
		Alternate 3	19.0	0.70		0.17		R452B	23702	2.50%	9.6	13.50%
Unit 10	36000	**Baseline**	**19.6**	**0.44**	**Tube-Fin (9.5mm Tube)**	**0.13**	**Passive**	**R32**	**29005**	**0.00%**	**6.39**	**0.00%**
		Alternate 1	22.3	0.65	Tube-Fin (5mm Tube)	0.25	Active (EXV)	R447B	30478	5.10%	9.43	47.50%
		Alternate 2	23.0	0.67		0.25		R452B	30796	6.20%	10.27	60.70%
		Alternate 3	23.3	0.67		0.25		R454B	30809	6.20%	10	56.50%

** Product of displacement volume and volumetric efficiency*

5. Activities 3, 4 & 5 - Prototype Units Fabrication, Evaluation of the Optimized Prototypes and Analyzing Leaks of Alternatives

Activities 3-5 officially began in April 2019 when the first round of tests on modified Unit 6 were carried out. Initial tests resulting in unsuccessful outcomes leading OTS to change the system modifications and the scope. Additional information found in APPENDIX B . The detailed test data and charge optimization for Units 6 and 10 are presented in APPENDIX C through APPENDIX E . Comparisons between Activity 2 model validations and experimental data are presented in APPENDIX F .

5.1. Unit 6

Some modifications were made to Unit 6 to improve its efficiency. The baseline compressor was replaced with alternate models to account for the change in refrigerant and to improve efficiency. The compressor used with R454B had a higher displacement volume than the one used with R32. Furthermore, the capillary tubes were replaced with a manual TXV that was installed directly at the evaporator inlet to increase the cooling capacity of the evaporator. A summary of the design modifications evaluated for Unit 6 is listed in Table 7, while Table 8 and Table 9 show the performance of Unit 6 for baseline and modifications at 35°C and 46°C ambient, respectively. The baseline system performed similar, within 2%, to reported performance in PRAHA I. There is a discrepancy in the measurements from condenser outlet to expansion inlet in the baseline case, since the capillary tube (removed in the modified systems) was located in the outdoor unit The expansion causes the refrigerant to flash in the liquid line thus compromising the readings at the expansion device. For calculation purposes, the condenser outlet enthalpy was used instead of the expansion inlet.

Table 7: Unit 6 Modifications for Testing.

System	Unit 6		
	Baseline	Alternate 1	Alternate 2
Refrigerant	R32	R32	R454B
Compressor	GMCC KSG226N1UMT	Copeland ZP20K5E	Copeland ZP21K5E
Expansion Device	Capillary Tube (Outdoor unit)	Manual Valve (Indoor Unit)[2]	Manual Valve (Indoor Unit)[2]

Cooling capacity for the modified unit with either refrigerant was consistently lower by 6-12% than the baseline. The modified R32 system reportedly showed lower mass flow rate than expected, likely the main cause for the lower-than-expected thermal performance. The R454B system resulted in a poorer performance but was less sensitive to ambient temperature than its R32 counterpart - i.e. cooling capacity was near the same at both 35°C and 46°C, while for R32 there was a ~2,000BTU/hr reduction with the temperature increase. It is also possible that there is a mismatch between thermophysical property library and actual refrigerant properties for R454B which can happen with newer fluids. The libraries need periodic update as more test data become available.

[2] A manual valve was used to mimic a TXV or EXV recommended as component modification in these systems configurations.

Table 8: Unit 6 - Performance Test Summary for R32 Baseline (OTS) @ 35°C.

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	**R32**	**R32**	**R454B**	-	-
Charge	lb	3.83	4.27	5.02	11.5%	31.1%
Cooling Capacity	BTU/hr	25192	23585	21966	-6.4%	-12.8%
Energy Balance	%	-2.28%	-4.66%	-3.06%	-	-
Compressor Power	kW	2.11	1.79	1.77	-15.1%	-16.2%
Fan Power	kW	0.32	0.33	0.33	2.2%	4.2%
Total Power	kW	2.43	2.12	2.10	-12.8%	-13.5%
EER	BTU/hr.W	10.37	11.12	10.44	7.2%	0.68%

Table 9: Unit 6 - Performance Test Summary for R32 Baseline (OTS) @ 46°C.

		Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	**R32**	**R32**	**R454B**	-	-
Charge	lb	3.83	4.27	5.02	11.5%	31.1%
Cooling Capacity	BTU/hr	23390	21450	21821	-8.3%	-6.7%
Energy Balance	%	-1.78%	-4.42%	-7.61%	-	-
Compressor Power	kW	2.71	2.32	2.25	-14.2%	-16.6%
Fan Power	kW	0.40	0.42	0.42	5.3%	5.3%
Total Power	kW	3.10	2.74	2.67	-11.7%	-13.8%
EER	BTU/hr.W	7.55	7.84	8.17	3.8%	8.2%

5.2. Unit 10

Applying what was learned in the initial modifications to Unit 6, modifications to Unit 10 were limited to include the compressor and expansion device only. Unlike Unit 6, however, the re-test of the baseline system was not successful; refer to APPENDIX D for additional information. However since Unit 6 baseline re-test showed good reproducibility from original data, it is assumed that the Unit 10 original baseline is appropriate for comparison against the modified system configurations. A summary of the design modifications evaluated for Unit 10 is listed in Table 10. The detailed test data is presented in APPENDIX E .

At 35°C the modified units exhibited almost 20% less cooling capacity with 10% less power consumption, resulting in up to 11% less EER (Table 11). These results were not unexpected since the modified units were re-designed using the 46°C temperature, when the baseline system's performance showed a great degradation of performance. At 46°C condition, the tests exhibited 2-5% greater cooling capacity with up to 12% less power consumption compared to the baseline, which was equivalent to 13-17% greater system performance.

In Activity 2 the compressor power consumptions were underestimated, as well as the total fan power consumption, leaving the impression the overall performance improvement would considerably be greater than the observed. The cooling capacity, on the other hand, was predicted with less than 2% deviation from test data, validating at least the models created.

Table 10: Unit 10 Modifications for Testing.

System	Unit 10		
	Baseline	Alternate 1	Alternate 2
Refrigerant	R32	R447B	R452B
Compressor	Copeland ZP42K6E	Copeland ZP34K5E	Copeland ZP31K5E
Expansion Device	Orifice	Manual Valve	Manual Valve

Table 11: Unit 10 - Performance Test Summary for R32 Baseline @ 35°C.

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	**-**	**R32**	**447B**	**452B**	**-**	**-**
Charge	lb	5.625	6.625	6.625	17.78%	17.78%
Cooling Capacity	BTU/hr	35543	32195	28128	-9.42%	-20.86%
Energy Balance	%	---	7.52%	-3.29%	-	-
Compressor Power	kW	-	2.67	2.4	-	-
Fan Power	kW	-	0.95	0.98	-	-
Total Power	kW	3.761	3.62	3.38	-3.75%	-10.13%
EER	BTU/hr.W	9.451	8.894	8.322	-5.89%	-11.94%

Table 12: Unit 10 - Performance Test Summary for R32 Baseline @ 46°C.

		Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	**-**	**R32**	**447B**	**452B**	**-**	**-**
Charge	lb	5.625	6.625	6.625	17.78%	17.78%
Cooling Capacity	BTU/hr	29633	31073	30292	4.86%	2.22%
Energy Balance	%	---	4.21%	1.21%	-	-
Compressor Power	kW	---	3.18	2.93	-	-
Fan Power	kW	---	0.95	0.97	-	-
Total Power	kW	4.466	4.13	3.9	-7.52%	-12.67%
EER	BTU/hr.W	6.64	7.52	7.76	13.33%	16.95%

5.3. Leak Tests

In the interest of time the leak tests were conducted only on Unit 10 for R447B. The choice of refrigerant was based on temperature glide, where R447B exhibits the highest glide amongst the refrigerants evaluated between Unit 6 and Unit 10 (refer to Figure 4). The leak tests were conducted to closely represent field operation. The procedure applied includes the following steps:

1- Run unit until steady-state is achieved (repeat 46°C performance test), monitoring capacity and subcooling
2- Gradually remove refrigerant from vapor line until capacity is reduced to approximately 50%, if possible
3- Store and weigh removed refrigerant
4- Re-charge with new refrigerant until same subcooling is achieved
5- Compare cooling capacities; if more than 5% deviation is observed, repeat steps 1-4, however in step 2, reduce capacity to 25% only
6- Repeat steps 1-5 for the liquid line

The comparison herein presented refers to a leakage of approximately 30% of charge, while reducing capacity by approximately 50% based on airside only. The leak tests showed less than 2% deviation in cooling capacity after re-charge from both vapor and liquid lines (Table 13). Since the capacity deviation was less than 5%, no further testing for 25% capacity reduction was conducted. The results suggest little impact due to fractionation.

Table 13: Unit 10 – R447B Leak Test Summary Results.

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	-	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Charge	lb	6.625	4.27	6.625	4.23	6.77
Cooling Capacity	BTU/hr	31073	14216	30865	15171	30587
Energy Balance	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Compressor Power	kW	3.18	2.93	3.18	2.94	-[3]
Fan Power	kW	0.95	0.98	0.98	0.98	0.98
Total Power	kW	4.13	3.90	4.16	3.92	-[3]
EER	BTU/hr.W	7.52	3.64	7.42	3.87	-[3]

5.4. Conclusions and Recommendations

This section presented the performance tests conducted on units 6 and 10. The key conclusions and recommendations are:

1- Unit 6 re-tested baseline exhibited similar performance to that found in PRAHA I testing. It should be stressed that the baseline unit by design had its capillary tube located in the outdoor unit. This would cause liquid refrigerant leaving the outdoor unit to flash. The refrigerant enthalpy at the condenser outlet state was used to calculate the refrigerant-side capacity assuming an isentalphic expansion without heat loss in connecting pipe. This is different from the modified systems of which the capillary tube was removed, and a manual expansion valve was placed at the inlet of the indoor unit. For modified systems, the enthalpy at the expansion valve inlet was used to calculate the refrigerant-side capacity.

2- Unit 10 exhibited a considerable reduction in power consumption at the high ambient test condition (46°C) as compared to the original test data. This also indicates the importance of proper compressor selection.

3- The higher-than-expected power consumption in the Unit 10 baseline tests is also evidenced by the fact that even with zeotropic mixtures (R447B and R452B), Unit 10 had higher cooling capacity and efficiency than the baseline for the 46°C test condition, as projected in activity 2.

4- Because of the differences in saturation curves from the Activity 2 analysis, R32 tends to result in systems with higher efficiency and less charge when no modifications to the hardware are made. The results showed however, that making appropriate component selection, such as compressors with larger displacement volumes and higher mass flow rates for the zeotropic mixtures, cooling capacities and overall performance were of the same order of magnitude.

5- Refrigerant fractionation as evidenced by the leak tests, does not appear to be a great concern since less than 2% deviation in cooling capacity was observed after the system's re-charge.

6- The Unit 6 modified systems had lower performance than expected from the Activity 2 models. The R32 system configuration exhibited more than 10% less flow rate than anticipated due to performance

[3] Compressor power consumption was not properly recorded for this test; the error was identified after the fact and the team was unable to retrieve that information. While that compromises the assessment of the overall system performance, the deviations are expected to be marginal. The leak test on liquid line suggest minimal impact on power consumption after re-charge, while cooling capacity was reportedly fully recovered after recharge on both leak tests.

maps overprediction, which corresponded to 10% lower capacity. The R454B configuration exhibited a deviation of 5% between model and test due also in part to a 3% flow rate over prediction in the model. Unit 10, on the other hand, exhibited an excellent agreement to the models with less than 2% deviation in cooling capacity.

7- The model's validation adds confidence in the numerical simulation findings and recommendations provided in activity 2.

6. Conclusions

This report presents a comprehensive set of activities with the objectives of advancing the PRAHA program. The original scope and schedule were modified during the project as new findings and challenges surfaced. The tests that were carried out for PRAHA-I, while sufficient for the purpose of measuring capacity and energy efficiency for the purposes of PRAHA-I, did not have enough essential data to enable a complete cycle evaluation for optimization purposes. This is primarily due to using standard test rig on systems with critical hardware configuration differences. The analyses presented in Activity 2 (design assessment through modeling) provided good insights on adequate component design and/or selection for proper system functioning, when using novel refrigerants.

The final recommendations for future development are listed as follows:

1- Establish a baseline system by conducting comprehensive testing including measurements and metrics not typically performed in energy certification tests. Furthermore, testing systems with different configurations require custom test rigs as such to adequately measure working fluid's states to avoid mischaracterization of the operating conditions and performance. Such approach is considerably more labor-intensive which should be factored in the scope in future developments.

2- Using alternate low-GWP refrigerants is viable and can be competitive to presently used refrigerants but doing so requires proper component design and selection; compressor and expansion device particularly. Drop-in replacement without hardware change is never recommended as evidenced by the change requirements in Activity 2 and performance tests in the subsequent activities.

3- It is recommended to always perform numerical simulations, and to conduct at least some level of "soft" optimization analyses that will provide information for an educated system re-design / retrofit at much lower costs than gradual trial-and-error changes.

4- Always test the modified systems with the same instrumentation as the baseline, however mindful of the modifications as such to properly place sensors to obtain adequate readings as suggested in item 1 above.

Nomenclature

COP	Coefficient of Performance	-
D_o	Tube Outer Diameter	mm
f	Frequency	Hz
FPI	Fins per Inch	1/in
h	Enthalpy	kJ/kg
h_t	Tube Height	mm
HX	Heat Exchanger	-
$\dot{m}$	Mass Flow Rate	kg/s
MCHX	Microchannel Heat Exchanger	-
P	Pressure	kPa
P_l	Tube Longitudinal Pitch	mm
P_t	Tube Transverse Pitch	mm
s	Entropy	kJ/kg.K
T	Temperature	°C
TFHX	Tube-Fin Heat Exchanger	-
UA	Thermal Conductance	kW/K
V	Volume	m^3
w_t	Tube Width	mm
η_{vol}	Volumetric Efficiency	-
ρ	Density	kg/m^3

APPENDIX A - Activity 2 Design Framework Results

Table 14: Unit 1 – Theoretical Cycle Re-Design Summary.

System		*Baseline*	*Alternative 1*	*Alternative 2*	*Alternative 3*	*Alternative 4*
Case	-	Simulation	Target			
Refrigerant	**-**	**R444B**	**R290**	**R454C**	**R444B**	**R457A**
Condenser	-	BTFD5	-	-	-	-
Compressor	-	SL260DG-C8EU	-	-	-	-
Cooling Capacity	BTU/hr	17403	17477	17477	17477	17477
Compressor Power	kW	1.92	1.49	1.49	1.33	1.43
Fan Power	kW	0.43	0.43	0.43	0.43	0.43
Total Power	kW	2.35	1.92	1.93	1.76	1.86
COP	-	2.17	2.66	2.66	2.91	2.75
COP Gain	-	1.00	1.23	1.23	1.34	1.27

Table 15: Unit 1 – HX Analysis Summary

Condenser		**R444B**		**R290**		**R454C**		**R457A**	
Inputs		***BTFD5***	***NMCD2***	***BTFD5***	***NMCD2***	***BTFD5***	***NMCD2***	***BTFD5***	***NMCD2***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37	16.37	16.37	16.37	16.37
Air Flowrate	m^3/s	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Refrigerant Pressure	kPa	2875.0	2875.0	2170.7	2170.7	2436.4	2436.4	2183.9	2183.9
Saturation Temperature at Inlet	°C	61	61	61	61	61	61	61	61
Refrigerant Temperature	°C	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
Mass Flow Rate	kg/s	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03
Outputs									
Heat Load	W	7512.9	7441.2	8232.4	8016.6	6168.0	6040.0	6592.0	6429.0
Air Dry-Bulb Temperature	°C	58.6	58.2	59.7	59.6	56.3	56.3	57.0	56.9
Refrigerant Temperature	°C	46.7	48.1	50.3	53.8	47.2	49.5	48.0	51.1
LMTD	°C	12	15	19	23	14	18	16	21
UA	W/K	635.57	482.84	439.36	350.35	451.67	327.93	424.35	313.48
NTU	-	1.04	0.79	0.72	0.57	0.74	0.53	0.69	0.51
Effectiveness	-	0.1915	0.1896	0.2098	0.2043	0.1572	0.1539	0.1680	0.1638
Refrigerant Pressure Drop	kPa	78.2	1.4	85.0	1.7	79.3	1.4	87.2	1.7
Airside DP	Pa	75.1	75.5	75.1	75.5	75.1	75.5	75.1	75.5
Air Heat Transfer Coefficient (Average)	$W/m^2.K$	130.0	148.3	130.0	148.3	130.0	148.3	130.0	148.3
Refrigerant Heat Transfer Coefficient (Average)	$W/m^2.K$	3341.0	1721.0	4113.0	2033.0	3040.0	1382.0	3423.0	1601.0
Subcooling	°C	13.20	13.14	8.96	7.35	6.77	5.93	5.34	4.05
Charge	kg	0.3822	0.1143	0.1079	0.0352	0.3097	0.094	0.2522	0.0764

Table 16: Unit 1 – Compressor Performance Summary.

Compressor		Baseline				
Refrigerant	-	**R444B**	**R290**	**R454C**	**R444B**	**R457A**
Isentropic efficiency	-	0.66	0.70	0.69	0.70	0.68
Power	kW	1.9175	1.7682	2.0449	1.7966	1.8932
Pressure Lift	kPa	2284.8	1556.0	2087.7	1902.2	1904.9
Effective Displacement Volume	cm^3	19.80	25.87	24.80	19.64	25.35
Rotation Speed	RPM	3600	3600	3600	3600	3600

Table 17: Unit 1 – Expected Modified System Performances.

System		***Baseline***				
Case	-	**Simulation**	**Expected**			
Refrigerant	**-**	**R444B**	**R290**	**R454C**	**R444B**	**R457A**
Condenser	-	BTFD5	BTFD5	BTFD5	BTFD5	NMCD2
Compressor	-	SL260DG-C8EU	-	-	-	-
Cooling Capacity	BTU/hr	17403	17639	18104	18140	17749
Compressor Power	kW	1.92	1.77	2.04	1.80	1.89
Fan Power	kW	0.43	0.43	0.43	0.43	0.43
Total Power	kW	2.35	2.20	2.48	2.23	2.33
COP	-	2.17	2.35	2.14	2.38	2.24
COP Gain	-	1.00	1.08	0.99	1.10	1.03

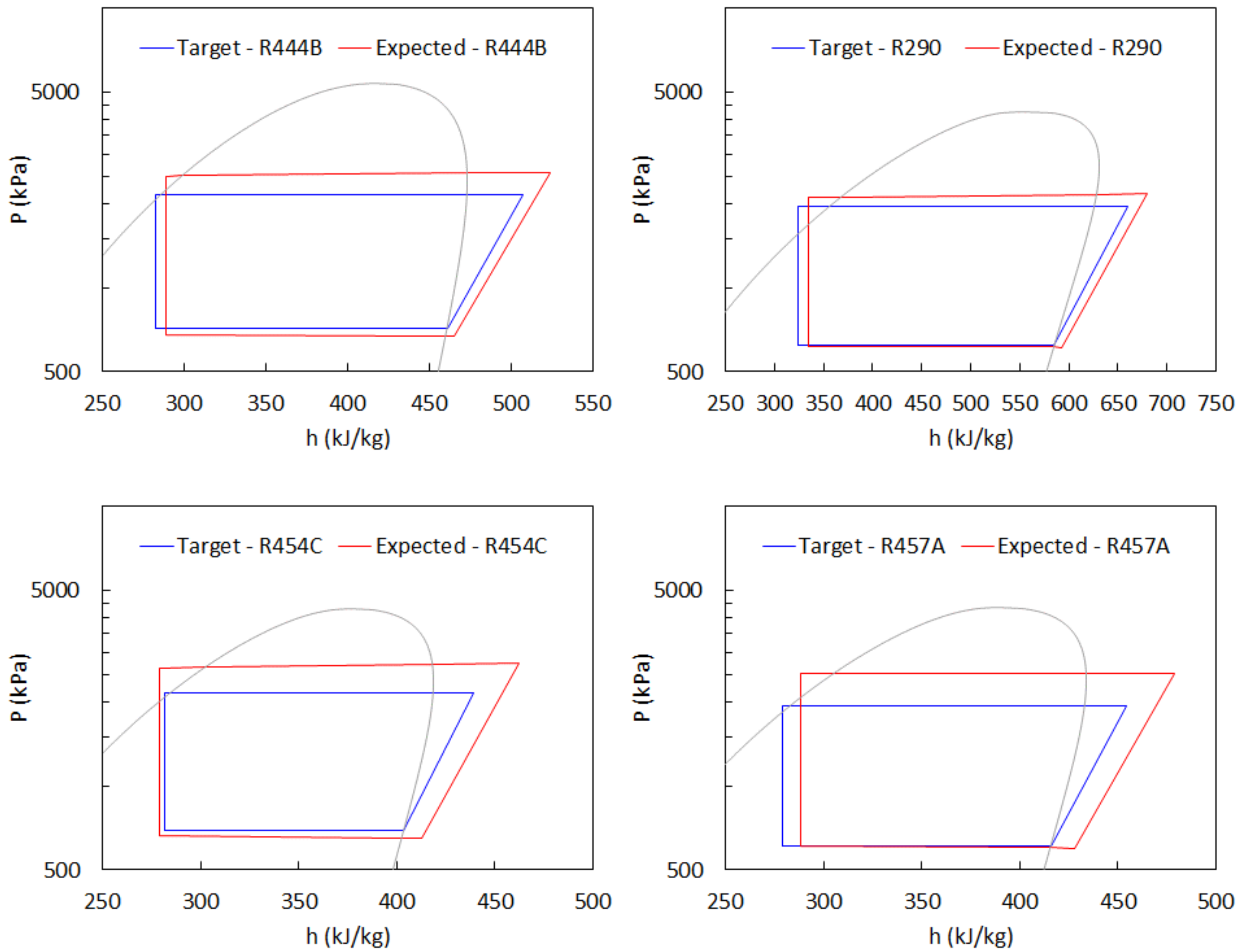

Figure 10. Unit 1 – Modified Systems P-h Diagrams.

Table 18: Unit 4 – Theoretical Cycle Re-Design Summary.

System		*Baseline*	*Alternative 1*	*Alternative 2*
			Target	
Refrigerant	-	**R290**	**R290**	**R290**
Condenser	-	BTFD9	-	-
Compressor	-	PSH356DG-C8DU4	-	-
Cooling Capacity	BTU/hr	17940	17940	23920
Compressor Power	kW	2.11	1.40	3.23
Fan Power	kW	0.28	0.28	0.28
Total Power	kW	2.39	1.68	3.51
COP	-	2.20	3.14	2.00
COP Gain	-	1.00	1.42	0.91

Table 19: Unit 4 – HX Analysis Summary.

Condenser		**R290 - 18kBTU**		**R290 - 24kBTU**	
Inputs		***BTFD9***	***NTFD5***	***BTFD9***	***NTFD5***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m^3/s	0.81	0.76	0.81	0.76
Refrigerant Pressure	kPa	2875	2875	2875	2875
Saturation Temperature at Inlet	°C	75.5	75.5	75.5	75.5

Condenser		R290 - 18kBTU		R290 - 24kBTU	
Inputs		***BTFD9***	***NTFD5***	***BTFD9***	***NTFD5***
Refrigerant Temperature	°C	110	110	110	110
Mass Flow Rate	kg/s	0.02	0.02	0.03	0.03
Outputs					
Heat Load	W	8139	8148	12080	12190
Air Dry-Bulb Temperature	°C	55.0	56.1	59.5	61.2
Refrigerant Temperature	°C	46.2	46.0	47.7	46.4
LMTD	°C	9.6	7.4	14.3	10.0
UA	W/K	848	1097	846	1216
NTU	-	0.97	1.34	0.97	1.48
Effectiveness	-	0.15	0.16	0.22	0.23
Refrigerant Pressure Drop	kPa	4.2	13.4	11.0	35.2
Airside DP	Pa	16.0	15.9	16.0	15.9
Air Heat Transfer Coefficient (Average)	W/m².K	82.9	100.7	82.9	100.7
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	1535.2	1493.7	2382.4	2505.6
Subcooling	°C	29.2	29.2	27.6	28.4
Charge in Tubes	kg	0.90	0.46	0.76	0.39

Table 20: Unit 4 – Compressor Performance Summary.

Compressor		**Baseline**	**18kBTU/Hr**		**24kBTU/Hr**	
Refrigerant	**-**	**R290**	**R290**	**R290**	**R290**	**R290**
Isentropic efficiency	-	0.61	0.70	0.70	0.70	0.70
Power	kW	2.1067	1.7364	1.7093	3.3152	3.31
Pressure Lift	kPa	1457.6	1556.3	1513.7	2947.1	2937.4
Effective Displacement Volume	cm³	26.394	26.309	26.309	37.866	37.866
Rotation Speed	RPM	3600	3600	3600	3600	3600

Table 21: Unit 4 – Expected Modified System Performances.

System		***Baseline***	***Alternative 1***		***Alternative 2***	
			Expected			
Refrigerant	**-**	**R290**	**R290**	**R290**	**R290**	**R290**
Condenser	-	BTFD9	BTFD9	NTFD5	BTFD9	NTFD5
Compressor	-	PSH356DG-C8DU4	-	-	-	-
Cooling Capacity	BTU/hr	17940	17991	18147	24045	24120
Compressor Power	kW	2.11	1.74	1.71	3.32	3.31
Fan Power	kW	0.28	0.28	0.28	0.28	0.28
Total Power	kW	2.39	2.02	1.99	3.60	3.59
COP	-	2.20	2.61	2.67	1.96	1.97
COP Gain	-	1.00	1.19	1.21	0.89	0.89

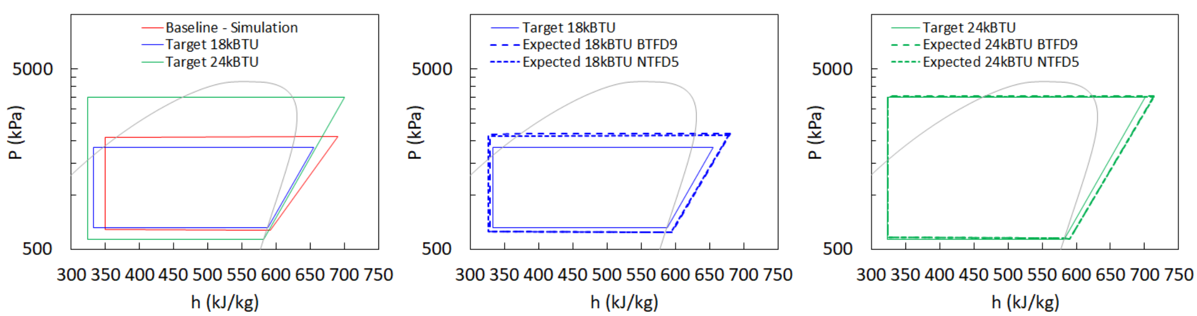

Figure 11. Unit 4 – Modified Systems P-h Diagrams.

Table 22: Unit 6 – Theoretical Cycle Re-Design Summary.

System			*Alternate 1*	*Alternate 2*	*Alternate 3*
		Simulation	**Target**		
Refrigerant	**-**	**R32**	**R32**	**R454B**	**R452B**
Condenser	-	BTFD9	-	-	-
Compressor	-	GMCC KSG226N1UMT	ZP20K5E	ZP21K5E	-
Cooling Capacity	BTU/hr	23115	23114	23114	23115
Compressor Power	kW	2.73	2.37	2.29	2.04
Fan Power	kW	8.46	9.75	10.10	11.31
Total Power	kW	2.73	2.37	2.29	2.04
COP	-	2.48	2.86	2.96	3.32
COP Gain	-	1.00	1.15	1.19	1.34

Table 23: Unit 6 – HX Analysis for R32

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3562	3562	3562	3562
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	9159	9416	9332	9113
Air Dry-Bulb Temperature	°C	53.63	55.35	54.27	55.24
Refrigerant Temperature	°C	49.78	46.15	47.40	50.47
LMTD	°C	19.94	9.46	15.13	20.57
UA	W/K	459.40	995.12	616.75	443.09
NTU	-	0.39	0.97	0.52	0.43
Refrigerant Pressure Drop	kPa	100.98	26.10	3.06	4.70
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	5543.00	2624.00	2353.00	2978.00
Subcooling	°C	4.48	9.04	8.10	5.07
Charge	kg	0.39	0.71	0.17	0.11

Table 24: Unit 6 – HX Analysis for R452B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3247	3247	3247	3247
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	7876	7964	7936	7866
Air Dry-Bulb Temperature	°C	52.52	53.94	53.06	53.99
Refrigerant Temperature	°C	47.41	46.05	46.53	47.61
LMTD	°C	15.49	8.09	12.37	15.72
UA	W/K	508.37	984.95	641.46	500.33
NTU	-	0.43	0.96	0.55	0.49
Refrigerant Pressure Drop	kPa	71.90	21.03	2.60	3.70
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	4252.00	2077.00	2103.00	2112.00
Subcooling	°C	6.14	8.20	7.99	6.89
Charge	kg	0.55	0.90	0.21	0.15

Table 25: Unit 6 – HX Analysis for R447B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3025	3025	3025	3025
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	7607	8241	8157	7914
Air Dry-Bulb Temperature	°C	52.41	54.19	53.25	54.04
Refrigerant Temperature	°C	50.00	46.24	47.63	51.40
LMTD	°C	20.58	10.45	15.92	22.14
UA	W/K	369.65	788.34	512.32	357.47
NTU	-	0.31	0.77	0.44	0.35
Refrigerant Pressure Drop	kPa	185.90	27.30	3.18	4.90
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	5396.00	2439.00	2397.00	3281.00
Subcooling	°C	0.00	6.05	5.17	1.22
Charge	kg	0.33	0.70	0.16	0.11

Table 26: Unit 6 – HX Analysis for R454B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3204	3204	3204	3204
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	7993	8094	8060	7976
Air Dry-Bulb Temperature	°C	52.61	54.06	53.16	54.10
Refrigerant Temperature	°C	47.59	46.06	46.61	47.91
LMTD	°C	15.95	8.28	12.72	16.40
UA	W/K	501.09	977.17	633.67	486.37
NTU	-	0.43	0.96	0.54	0.48
Refrigerant Pressure Drop	kPa	74.70	22.02	2.70	4.10
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	4445.93	2140.00	2008.00	2201.00
Subcooling	°C	5.75	8.03	7.75	6.43
Charge	kg	0.51	0.87	0.20	0.14

Table 27: Unit 6 – Compressor Performance Summary.

		Baseline	***Alternate 1***	***Alternate 2***	***Alternate 3***
Refrigerant		***R32***	***R32***	***R454B***	***R452B***
Isentropic Efficiency	-	0.60	0.64	0.66	0.70
Volumetric Efficiency	-	-	0.87	0.90	-
Displacement Volume	cm³	-	19.34	20.31	-
Frequency	Hz	60	60	60	60
Effective Displacement	cm³	16.0	16.8	18.3	19.0
Compressor Power	kW	2.4	2.3	2.3	2.1

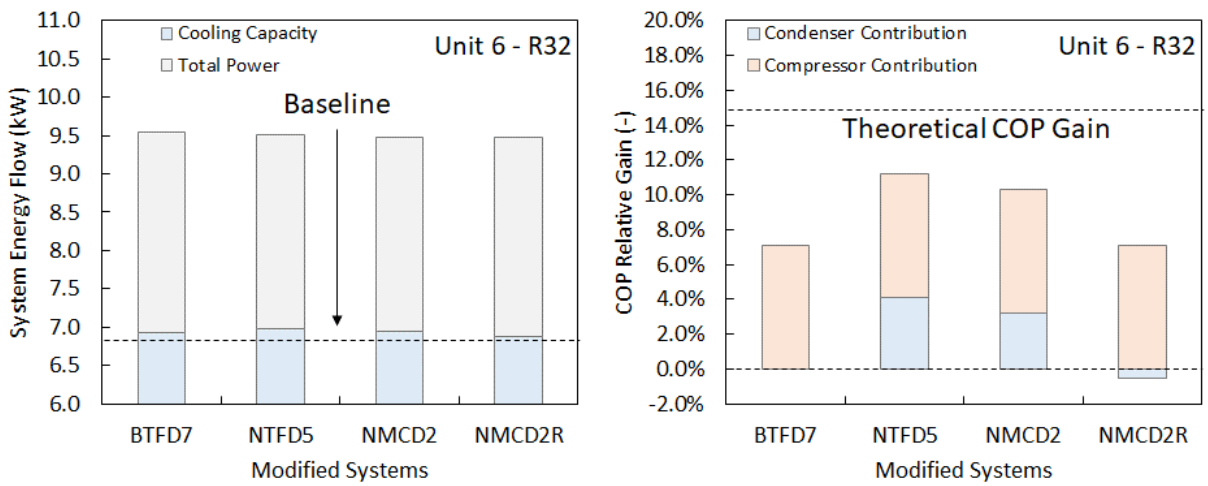

Figure 12. Unit 6 – System Level Analysis: Performance Results for R32.

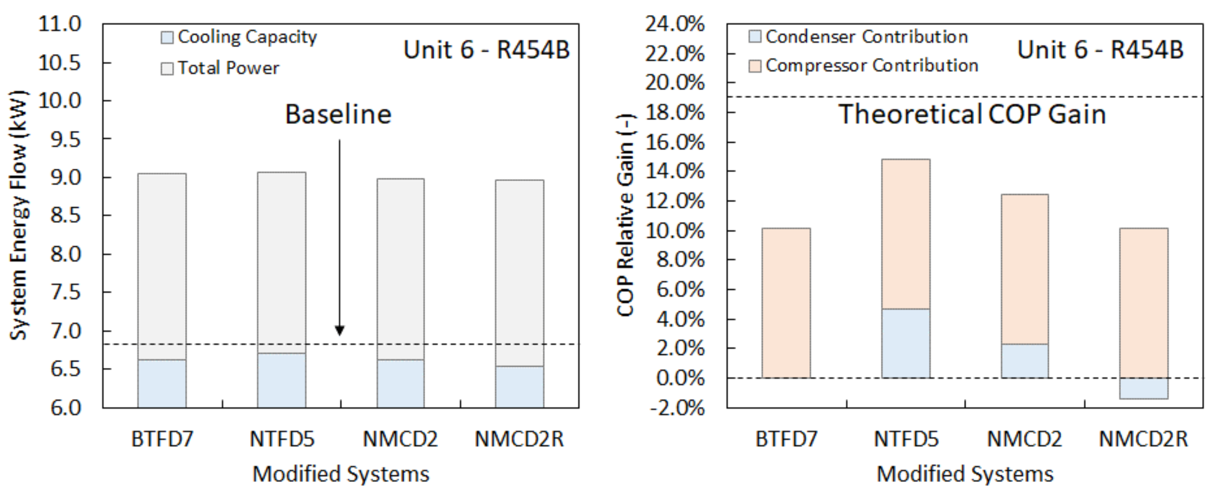

Figure 13. Unit 6 – System Level Analysis: Performance Results for R454B.

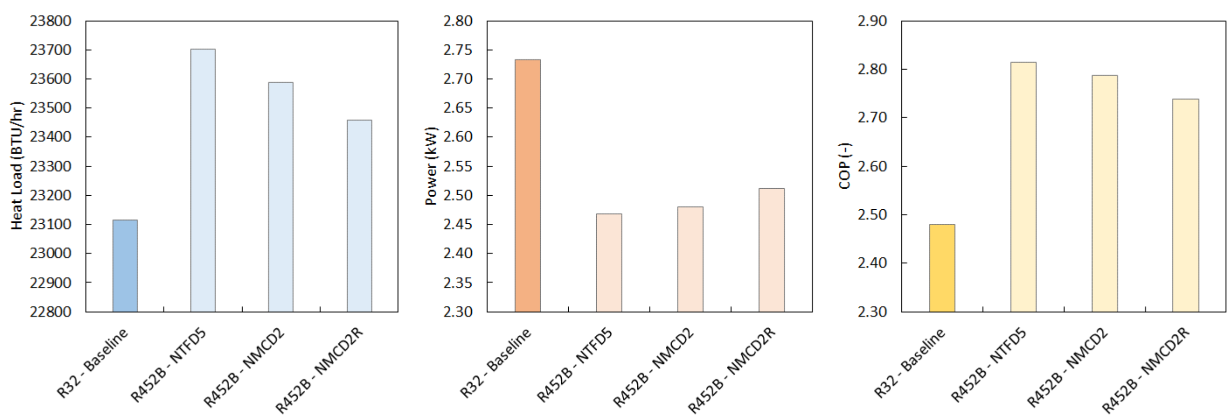

Figure 14. Unit 6 - Comparative System Performance Summary for R452B.

Table 28: Unit 10 – Theoretical Cycle Re-Design Summary.

System		*Baseline*	*Alternate 1*	*Alternate 2*	*Alternate 3*
		Simulation		**Target**	
Refrigerant	**-**	**R32**	**R452B**	**R447B**	**R454B**
Condenser	-	BTFD9	-	-	-
Compressor	-	ZP42K5E	ZP31K5E	ZP34K5E	ZP31K5E
Cooling Capacity	BTU/hr	29005	34311	31611	34608
Compressor Power	kW	3.84	2.81	2.31	2.65
Fan Power	kW	0.70	0.70	0.70	0.70
Total Power	kW	4.54	3.51	3.01	3.35
COP	-	1.87	2.87	3.08	3.03
COP Gain	-	1.00	1.53	1.64	1.62

Table 29: Unit 10 – HX Analysis for R32

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m^3/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3562	3562	3562	3562
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	10693	11074	11435	10669
Air Dry-Bulb Temperature	°C	54.1	57.0	54.9	55.8
Refrigerant Temperature	°C	55.2	52.9	49.3	55.4
LMTD	°C	22.8	19.8	15.9	22.5
UA	W/K	468	560	717	475
NTU	-	0.35	0.55	0.54	0.42
Refrigerant Pressure Drop	kPa	26.7	67.1	6.8	10.1
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	$W/m^2.K$	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	$W/m^2.K$	3823	4239	3050	3991
Subcooling	°C	0.00	1.75	6.17	0.00
Charge	kg	0.61	0.43	0.17	0.11

Table 30: Unit 10 – HX Analysis for R452B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m^3/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3247	3247	3247	3247
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	9549	9812	9751	9500
Air Dry-Bulb Temperature	°C	53.2	55.8	53.6	54.8
Refrigerant Temperature	°C	49.5	46.4	47.1	50.1
LMTD	°C	16.7	9.2	12.2	17.1
UA	W/K	573	1067	802	557
NTU	-	0.43	1.04	0.60	0.49
Refrigerant Pressure Drop	kPa	17.2	47.1	5.6	8.2
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	$W/m^2.K$	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	$W/m^2.K$	2974	3038	2537	2812
Subcooling	°C	4.82	7.51	7.34	4.38
Charge	kg	0.83	0.79	0.23	0.15

Table 31: Unit 10 – HX Analysis for R447B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m³/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3025	3025	3025	3025
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	9016	9632	9923	9085
Air Dry-Bulb Temperature	°C	52.9	55.6	53.8	54.4
Refrigerant Temperature	°C	52.4	51.7	49.9	52.7
LMTD	°C	20.4	18.9	17.1	20.3
UA	W/K	441	510	579	448
NTU	-	0.33	0.50	0.43	0.40
Refrigerant Pressure Drop	kPa	29.2	67.3	7.2	10.8
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	W/m².K	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	3528	3833	2999	3458
Subcooling	°C	0.00	0.00	2.67	0.00
Charge	kg	0.56	0.45	0.17	0.10

Table 32: Unit 10 – HX Analysis for R454B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m³/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3204	3204	3204	3204
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	9634	9953	9901	9597
Air Dry-Bulb Temperature	°C	53.3	55.9	53.8	54.9
Refrigerant Temperature	°C	50.4	46.7	47.3	50.8
LMTD	°C	17.9	10.5	12.7	18.0
UA	W/K	537	952	782	532
NTU	-	0.40	0.93	0.59	0.47
Refrigerant Pressure Drop	kPa	18.8	51.1	5.9	8.7
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	W/m².K	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	3095	3211	2633	2942
Subcooling	°C	3.71	6.98	6.98	3.40
Charge	kg	0.78	0.71	0.22	0.14

Table 33. Unit 10 - Compressor Performance Summary.

Compressor			Copeland ZP31K5E-PFV	Copeland ZP34K5E-PFV	Copeland ZP31K5E-PFV
Refrigerant		***R32***	***R452B***	***R447B***	***R454B***
Isentropic Efficiency	-	0.439	0.638	0.662	0.662
Volumetric Efficiency	-		0.760	0.803	0.790
Displacement Volume	cm³		29.350	29.350	29.350
Frequency	Hz	50	50	50	50
Effective Displacement Volume	cm³	19.646	22.301	23.581	23.183

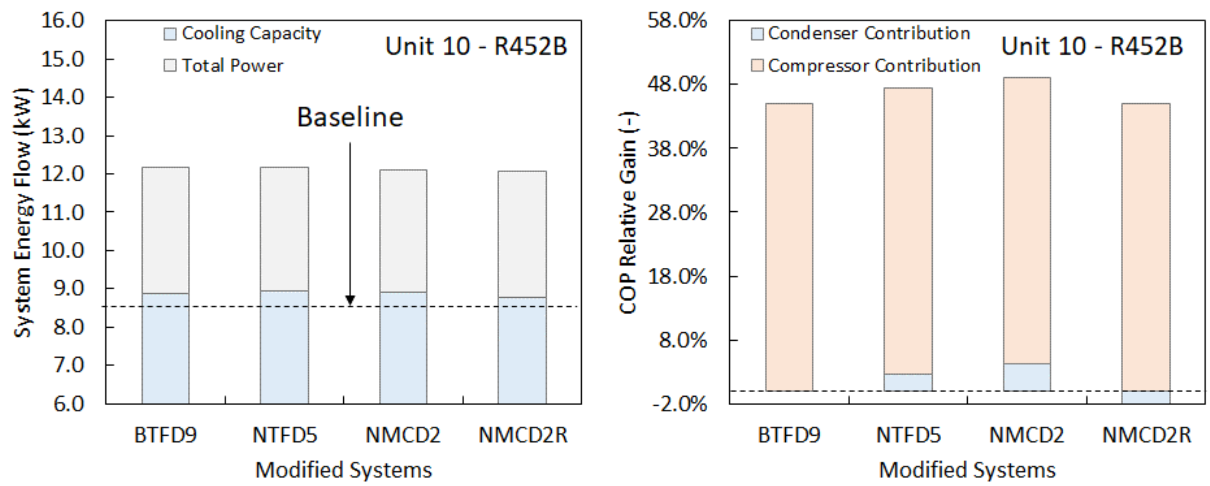

Figure 15. Unit 10 – System Level Analysis: Performance Results for R452B.

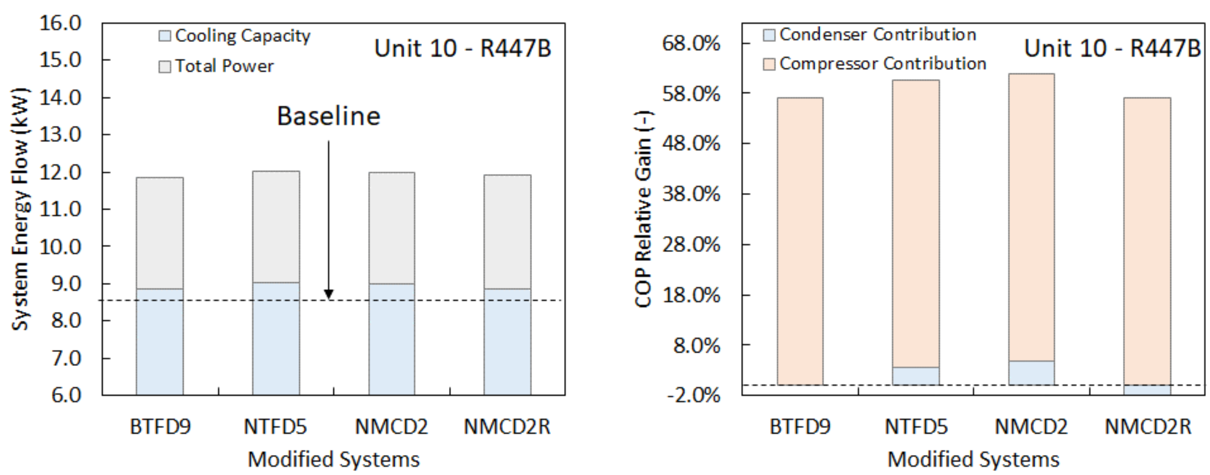

Figure 16. Unit 10 – System Level Analysis: Performance Results for R447B.

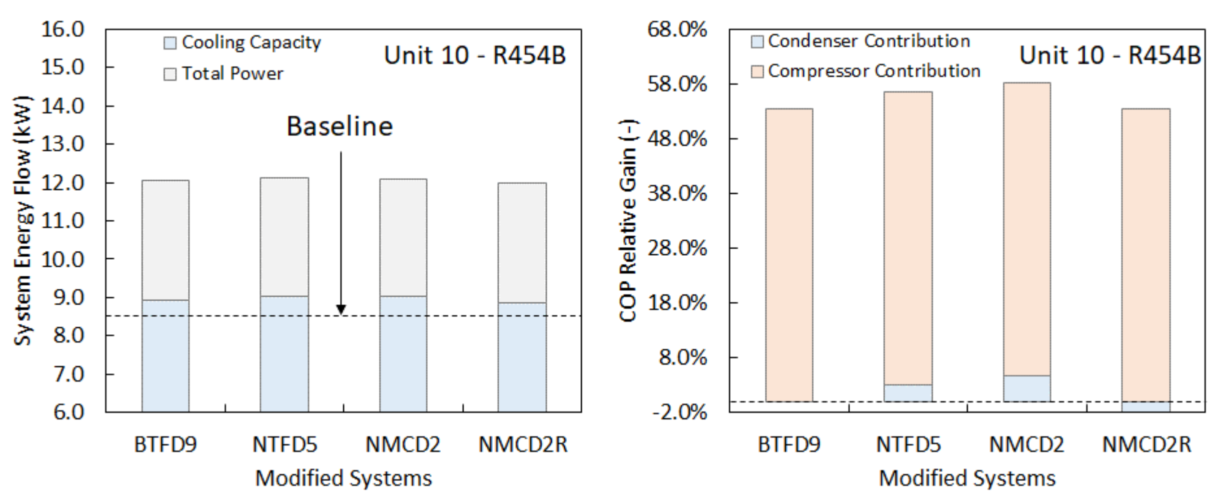

Figure 17. Unit 10 – System Level Analysis: Performance Results for R454B.

APPENDIX B – Unit 6 Initial Tests, Scope Change and Test Setup

Unit 6 was initially modified and tested at a separate facility and the test results exhibited a considerably lower cooling capacity than expected (~20%). Power consumption was also greater than designed. The condensing pressures were 20-30% above expectations, and the refrigerant pressure drop across the condenser was at least twice as high as expected. The outlet conditions of the condenser for R32 were possibly in two-phase. The condenser airflow rate was 10%-15% lower than expected. Superheat hardly met the setpoint values.

OTS formulated a hypothesis that the degraded performance was due to the condenser not being fully active; i.e. some regions were not transferring heat. One way for this to happen is by having severe maldistribution thus impeding heat transfer, increasing pressure drop – thus the condensing pressure – and possibly reducing the flow rate as well; all of which were observed in the test data. OTS tested the hypothesis by running hot water through the HX and observing with a thermal camera (Figure 18), which revealed the "dead zones". Upon inspection by the manufacturer, it was confirmed there were blockages in some of the tubes. A new HX was built, but the same pattern was observed, forcing OTS to remove the condenser replacement from the scope given the project schedule.

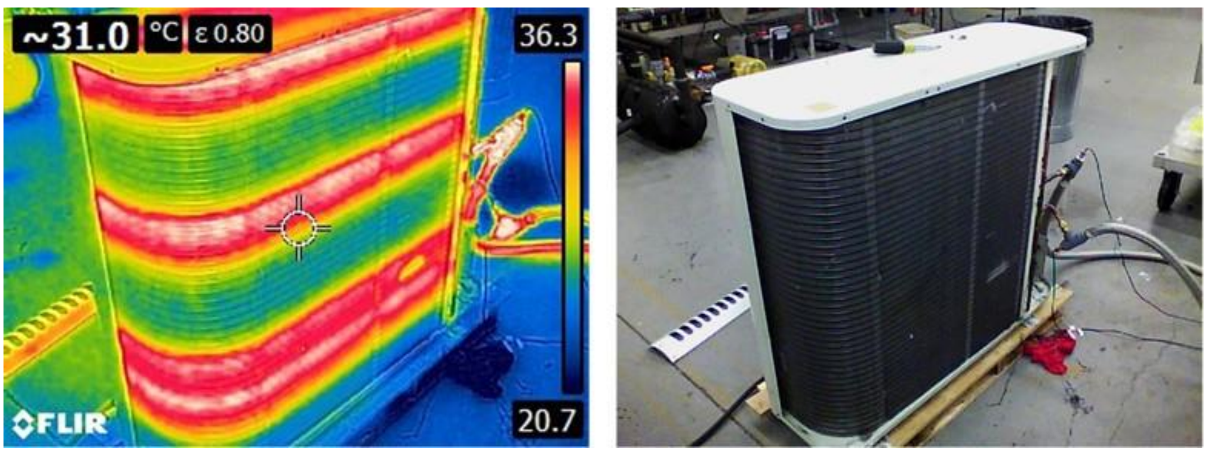

Figure 18. Hot Water Thermal Imaging.

Given the challenges with the initial tests and unit modification, the scope was re-defined. The original test plan was changed to accommodate time and resources as appropriate. Table 34 outlines the major changes to the scope. The tests were conducted at the OTS laboratory (Figure 19 to Figure 22). A summary of the key differences between the test setups (original and at OTS) is presented in Table 35.

Table 34: Test Scope Change.

Unit	Refrigerant	Test	Original Scope		New Scope	
			Planned	Actual	Planned	Actual
Unit 1	R290	Charge Optimization	Yes	No	No	No
		Performance Tests	Yes	No	No	No
Unit 6	R32 (Baseline)	Charge Optimization	No	No	Yes	Yes
		Performance Tests	No	No	Yes	Yes
	R32 (Modified)	Charge Optimization	Yes	Yes	Yes	Yes
		Performance Tests	Yes	Yes	Yes	Yes
	R454B	Charge Optimization	Yes	Yes	Yes	Yes
		Performance Tests	Yes	Yes	Yes	Yes
		Leak Tests	Yes	Yes	No	No
Unit 10	R32 (Baseline)	Charge Optimization	No	No	Yes	Yes*
		Performance Tests	No	No	Yes	Yes*
	R447B	Charge Optimization	Yes	No	Yes	Yes
		Performance Tests	Yes	No	Yes	Yes
		Leak Tests	Yes	No	Yes	Yes
	R452B	Charge Optimization	Yes	No	Yes	Yes
		Performance Tests	Yes	No	Yes	Yes
		Leak Tests	Yes	No	No	No

** Tests were conducted; however, no useful data was obtained (see section 5.2)*

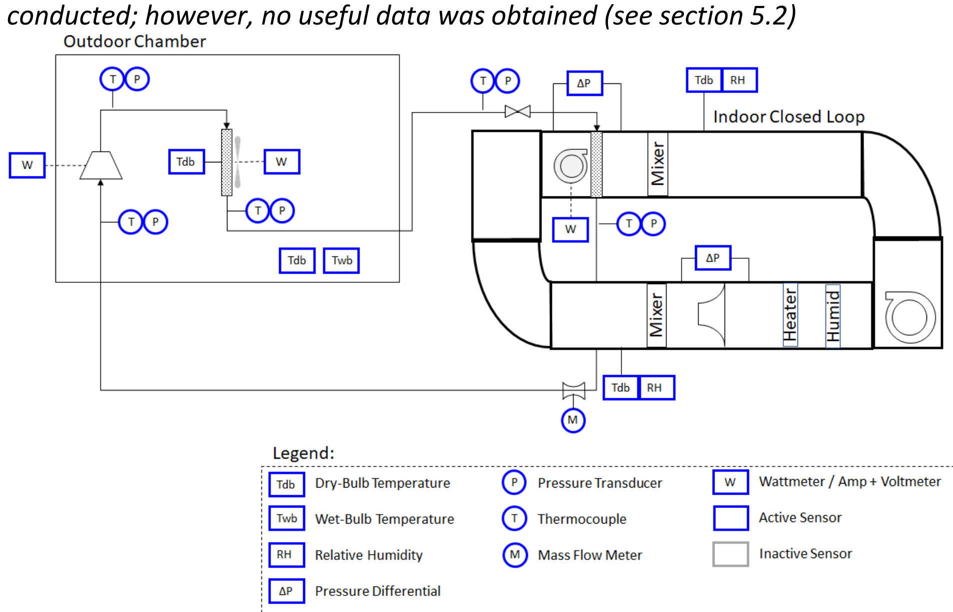

Figure 19. Test Diagram.

Figure 20. OTS Setup: outdoor chamber (left), Unit 10 and frequency converter inside chamber (right).

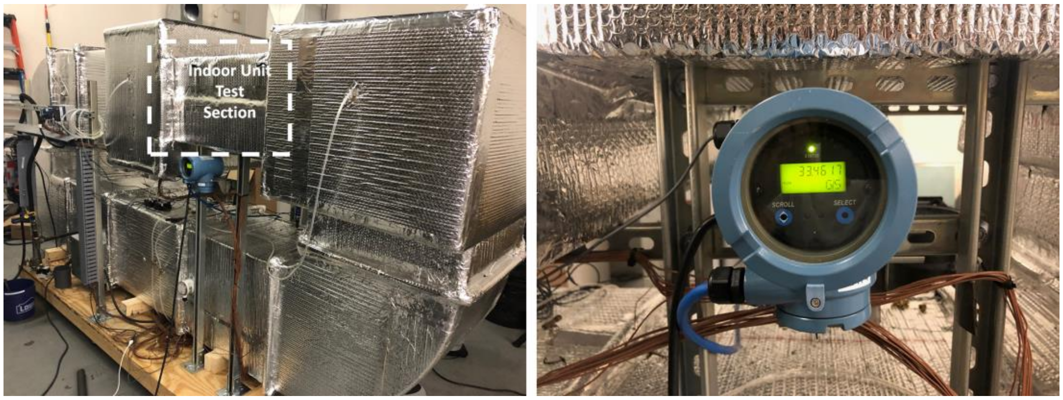

Figure 21. OTS Setup: indoor closed loop left side view (left), refrigerant mass flow meter (right).


Figure 22. OTS Setup: indoor closed loop right side view (left), vapor / liquid lines, sight glasses and TXV (right).

Table 35: List of Measurements.

Component	Refrigerant Side			Air Side		
	Measurement	Original Scope	New Scope	Measurement	Original Scope	New Scope
Condenser	Inlet Temperature	Yes	Yes	Air Flow Rate	Yes	**No**
	Inlet Pressure	Yes	Yes	Air Pressure Drop	No	No
	Outlet Temperature	Yes	Yes	Fan Power	No	**Yes**
	Outlet Pressure	Yes	Yes	Inlet Dry-bulb	Yes	Yes
	Subcooling	Yes*	**Yes**	Inlet Wet-Bulb / RH	Yes	Yes
				Outlet Dry-bulb	Yes	Yes
				Outlet Wet-Bulb / RH	Yes	Yes
Evaporator	Inlet Temperature	No	No	Air Flow Rate	Yes	Yes
	Inlet Pressure	No	No	Air Pressure Drop	No	**Yes****
	Outlet Temperature	Yes	Yes	Blower Power	No	**Yes**
	Outlet Pressure	Yes	Yes	Inlet Dry-bulb	Yes	Yes
	Superheat	Yes*	**Yes**	Inlet Wet-Bulb / RH	Yes	Yes
	Refrigerant Mass Flow Rate	No	**Yes**	Outlet Dry-bulb	Yes	Yes
				Outlet Wet-Bulb / RH	Yes	Yes
Compressor	Suction Temperature	Yes	Yes			
	Suction Pressure	Yes	Yes			
	Discharge Temperature	Yes	Yes			
	Discharge Pressure	Yes	Yes			
	Compressor Power	No	**Yes**			
Expansion Device	Suction Temperature	Yes	Yes			
	Suction Pressure	Yes	Yes			
	Discharge Temperature	No	No			
	Discharge Pressure	No	No			

Charge Optimization

The charge optimization procedure as originally scoped was not implemented due to the following:

a. The systems responded less sensitively to charge on subcooling and superheat, which were difficult to control with charging alone. A manual valve was added (Unit 10 exhibited little expansion) such that superheat could be better controlled. The valve also allowed for better control over the pressure levels compared to charge levels alone.

b. For the modified systems, the charge was gradually increased, departing from the original charge from PRAHA I tests, until it was observed that the superheat and subcooling better matched design conditions for validation purposes.

c. For the refrigerant blends, removing charge could result in fractionation (evaluated as a separate task), so it was decided to only incrementally increase charge, without removing it. For this procedure, a small gradual increment is necessary to avoid overcharging.

APPENDIX C - Unit 6 Raw and Processed Tested Data

Table 36: Unit 6 – Performance Tests

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	-	**R32**	**R32**	**R454B**	**R32**	**R32**	**R454B**
Charge	lb	3.83	4.27	5.02	3.83	4.27	5.02
Cooling Capacity	BTU/hr	25193	23585	21966	23390	21450	21821
Energy Balance	%	-2.28%	-4.66%	-3.06%	-1.78%	-4.42%	-7.61%
Compressor Power	kW	2.11	1.79	1.77	2.71	2.32	2.25
Fan Power	kW	0.32	0.33	0.33	0.40	0.42	0.42
Total Power	kW	2.43	2.12	2.10	3.10	2.74	2.67
EER	BTU/hr.W	10.36	11.12	10.44	7.54	7.84	8.17
Evaporator							
Airside							
Inlet							
Air Flow Rate	m^3/s	0.31	0.31	0.31	0.31	0.31	0.30

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	**-**	**R32**	**R32**	**R454B**	**R32**	**R32**	**R454B**
Temperature	°C	27.0	27.0	27.0	29.0	29.0	29.0
Wet Bulb	°C	19.68	19.68	19.68	21.33	21.33	21.34
Relative Humidity	%	51.0	51.0	51.0	51.0	51.0	51.0
Humidity Ratio	kg/kg	0.011	0.011	0.011	0.013	0.013	0.013
Density	kg/m³	1.15	1.15	1.15	1.14	1.14	1.14
Enthalpy	kJ/kg	56.3	56.2	56.2	61.9	62.0	62.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0	1.0
Outlet							
Air Flow Rate	m³/s	0.29	0.29	0.29	0.29	0.29	0.29
Temperature	°C	14.3	15.1	15.8	16.9	17.7	18.1
Wet Bulb	°C	14.35	14.35	14.35	14.35	14.35	14.35
Relative Humidity	%	83.6	82.4	80.0	84.5	83.3	81.3
Humidity Ratio	kg/kg	0.008	0.009	0.009	0.010	0.011	0.011
Density	kg/m³	1.21	1.20	1.20	1.19	1.19	1.19
Enthalpy	kJ/kg	35.8	37.5	38.5	42.7	44.7	45.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0	1.0
Refrigerant Side							
Inlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	4.58	6.19	4.76	7.49	8.33	8.47
Pressure	kPa	939.13	986.90	876.76	1026.70	1053.10	979.34
Quality	-	0.16	0.19	0.20	0.20	0.25	0.27
Enthalpy	kJ/kg	273.64	269.78	268.60	301.30	291.37	289.89
Entropy	kJ/kg.K	1.20	1.25	1.30	1.27	1.32	1.37
Outlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	8.08	9.26	9.46	9.08	13.54	11.80
Pressure	kPa	939	987	877	1027	1053	979
Superheat	K	3.50	3.07	4.89	1.59	5.20	3.58
Enthalpy	kJ/kg	520.49	520.22	473.43	518.52	523.27	472.93
Entropy	kJ/kg.K	2.15	2.15	2.03	2.13	2.15	2.02
HX Level							
Average Cooling Capacity	kW	7.384	6.912	6.438	6.855	6.287	6.395
Energy Balance (Qair - Qref)/Qref	%	-2.28%	-4.66%	-3.06%	-1.78%	-4.42%	-7.61%
Sensible Heat Ratio	-	0.64	0.66	0.65	0.64	0.67	0.66
Superheat	K	3.500	3.066	4.885	1.593	5.205	3.582
LMTD	K	13.783	12.822	14.015	13.985	12.184	13.041
UA	kW/K	0.573	0.539	0.459	0.550	0.516	0.490
Air Pressure Drop	Pa	N/A	N/A	N/A	N/A	N/A	N/A
Refrigerant Pressure Drop	kPa	N/A	N/A	N/A	N/A	N/A	N/A
Fan Power	kW	0.120	0.127	0.134	0.196	0.217	0.217
Condenser							
Airside							
Inlet							
Air Flow Rate	m³/s	0.9516	0.9838	1.0091	0.9580	0.9735	1.0613
Temperature	°C	35.01	34.76	35.12	46.06	45.93	46.05
Wet Bulb	°C	20.0	19.8	20.0	27.4	27.3	27.4
Humidity Ratio	kg/kg	0.008	0.008	0.009	0.015	0.015	0.015
Density	kg/m³	1.13	1.13	1.13	1.08	1.08	1.08
Enthalpy	kJ/kg	57.0	56.4	57.2	86.2	85.8	86.2
Specific Heat	kJ/kg.K	1.01	1.01	1.01	1.02	1.02	1.02
Outlet							
Air Flow Rate	m³/s	0.98	1.01	1.03	0.98	1.00	1.09
Temperature	°C	43.40	42.29	42.08	54.74	53.60	53.19
Wet Bulb	°C	22.4	22.0	22.1	29.3	29.0	29.0
Humidity Ratio	kg/kg	0.008	0.008	0.009	0.015	0.015	0.015
Density	kg/m³	1.10	1.10	1.10	1.05	1.05	1.05
Enthalpy	kJ/kg	65.6	64.1	64.3	95.2	93.7	93.6
Specific Heat	kJ/kg.K	1.01	1.01	1.01	1.02	1.02	1.02

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	**-**	**R32**	**R32**	**R454B**	**R32**	**R32**	**R454B**
Refrigerant Side							
Inlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	89.78	82.73	78.33	109.00	107.24	90.75
Pressure	kPa	2724.15	2643.18	2360.90	3464.77	3365.88	3010.13
Superheat	K	45.9	40.1	35.9	54.7	54.2	38.0
Enthalpy	kJ/kg	580.73	573.07	523.39	594.42	593.52	528.90
Entropy	kJ/kg.K	2.20	2.18	2.08	2.21	2.21	2.07
Outlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	39.17	34.52	34.68	51.79	45.63	45.79
Pressure	kPa	2675.81	2598.75	2310.89	3416.39	3324.50	2958.91
Subcooling	K	4.00	7.44	5.59	1.89	6.84	5.07
Enthalpy	kJ/kg	273.6	264.0	266.4	301.3	287.0	287.8
Entropy	kJ/kg.K	1.24	1.21	1.28	1.33	1.28	1.34
HX Level							
Heat Rejection	kW	9.19	8.53	8.08	9.25	8.31	8.42
Subcooling	K	4.00	7.44	5.59	1.89	6.84	5.07
Refrigerant Pressure Drop	kPa	48.34	44.43	50.01	48.38	41.38	51.22
Fan Power	kW	0.20	0.20	0.20	0.20	0.20	0.20
TXV							
Refrigerant							
Inlet		[4]			[4]		
Temperature	°C	30.64	37.31	35.83	39.70	47.55	46.78
Pressure	kPa	1991.01	2587.20	2301.38	2528.52	3317.42	2945.62
Subcooling	°C	*(Two-Phase)	4.47	4.27	*(Two-Phase)	4.83	3.88
Enthalpy	kJ/kg	*(Two-Phase)	269.8	268.6	*(Two-Phase)	291.4	289.9
Entropy	kJ/kg.K	*(Two-Phase)	1.233	1.284	*(Two-Phase)	1.299	1.349
Compressor							
Refrigerant							
Inlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	11.57	12.55	12.76	13.81	17.63	13.07
Pressure	kPa	936.06	984.95	874.98	1024.91	1052.17	969.56
Superheat	K	7.09	6.43	8.26	6.38	9.32	5.18
Enthalpy	kJ/kg	524.9	524.4	477.3	524.6	528.3	474.8
Entropy	kJ/kg.K	2.170	2.161	2.048	2.156	2.166	2.028
Outlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	89.8	82.7	78.3	109.0	107.2	90.8
Pressure	kPa	2724.2	2643.2	2360.9	3464.8	3365.9	3010.1
Superheat	K	45.9	40.1	35.9	54.7	54.2	38.0
Enthalpy	kJ/kg	580.7	573.1	523.4	594.4	593.5	528.9
Entropy	kJ/kg.K	2.200	2.183	2.084	2.205	2.207	2.074
Compressor Level							
Power Consumption	kW	2.11	1.79	1.77	2.71	2.32	2.25
Isentropic Efficiency	-	0.80	0.84	0.73	0.74	0.76	0.69
Frequency	Hz	60	60	60	60	60	60

[4] The baseline configuration does not have an expansion valve, the state point herein presented refers to measurement readings at indoor unit inlet.

APPENDIX D - Unit 10 Baseline Re-Test

Prior to modifying Unit 10, it was tested in its received, baseline condition with the components used to test during PRAHA I. Given the results of the data review in Activity 1, and the challenges experienced in the initial testing of Unit 6, the project team agreed that testing the units in their baseline configuration would be important for more accurate comparison.

The electrical components for Unit 10 have phase mismatch, i.e. the fan and blower are three-phase while the compressor is single-phase, but all operate in 50Hz. OTS does not have a Variable Frequency Drive (VFD) for single-phase motors, requiring the use of a frequency converter to reduce the compressor speed. According to the baseline data from PRAHA 1, the total power consumption of Unit 10 varied between 3.5-4.5kW; OTS has a 5.0kW converter, which should be sufficiently large to meet testing needs.

Initial tests suggested that the compressor peak start current exceeds the converter threshold, causing the latter to trip and shut off. Although the blower and the fan run normally with the converter, the compressor alone does not. The compressor motor was tested at 60Hz direct from the grid and it works, thus confirming that the issue is indeed the peak current. A soft starter was acquired with the objective to mitigate the issue. The soft starter capacitors weren't fast enough to smooth the peak current, however, thus requiring manual charging, which eventually lead to component failure.

The last tentative to run the baseline was connecting the compressor to 60Hz and the fans to 50Hz. The refrigerant mass flow rate was too high impeding full condensation and full evaporation. A manual TXV was added along with two sight glasses in the liquid and vapor lines and reasonable data was obtained for the 35°C ambient temperature condition. While attempting to test the system under the 46°C ambient temperature, the compressor overheats and shuts down. Heavier gauge wire, new contactors and switch bypass were unsuccessfully employed. In the interest of time, the baseline re-tests were discontinued. The analysis will be carried out using the original baseline performance for comparison purposes.

APPENDIX E - Unit 10 Raw and Processed Tested Data

Table 37: Unit 10 – Performance Tests.

		Alternate 1 (35°C)	Alternate 2 (35°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	-	**R447B**	**R452B**	**R447B**	**R452B**
Charge	lb	6.625	6.625	6.625	6.625
Cooling Capacity	BTU/hr	32195	28128	31073	30292
Energy Balance	%	7.52%	-3.29%	4.21%	1.21%
Compressor Power	kW	2.67	2.40	3.16	2.93
Fan Power	kW	0.95	0.98	0.95	0.97
Total Power	kW	3.62	3.38	4.11	3.90
EER	BTU/hr.W	8.88	8.33	7.55	7.76
Evaporator					
Airside					
Inlet					
Air Flow Rate	m^3/s	0.74	0.73	0.74	0.73
Temperature	°C	27.0	27.0	29.0	29.0
Wet Bulb	°C	19.68	19.69	21.33	21.34
Relative Humidity	%	51.0	51.0	51.0	51.0
Humidity Ratio	kg/kg	0.011	0.011	0.013	0.013
Density	kg/m^3	1.15	1.15	1.14	1.14
Enthalpy	kJ/kg	56.2	56.3	62.0	62.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0

		Alternate 1 (35°C)	Alternate 2 (35°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	**-**	**R447B**	**R452B**	**R447B**	**R452B**
Outlet					
Air Flow Rate	m³/s	0.72	0.71	0.71	0.70
Temperature	°C	17.4	19.1	19.7	19.8
Wet Bulb	°C	15.80	16.64	17.91	18.06
Relative Humidity	%	85.1	78.5	84.7	84.5
Humidity Ratio	kg/kg	0.011	0.011	0.012	0.012
Density	kg/m³	1.19	1.18	1.18	1.18
Enthalpy	kJ/kg	44.3	46.8	50.7	51.1
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0
Refrigerant Side					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	9.81	5.53	12.90	13.09
Pressure	kPa	996.41	907.20	1085.49	1133.86
Quality	-	0.19	0.19	0.27	0.25
Enthalpy	kJ/kg	272.43	264.74	296.09	288.71
Entropy	kJ/kg.K	1.32	1.30	1.40	1.38
Outlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	15.22	25.20	16.76	23.36
Pressure	kPa	996	907	1085	1134
Superheat	K	5.79	19.82	4.42	10.47
Enthalpy	kJ/kg	477.29	485.20	476.43	477.36
Entropy	kJ/kg.K	2.04	2.09	2.03	2.03
HX Level					
Average Cooling Capacity	kW	9.436	8.244	9.107	8.878
Energy Balance (Qair - Qref)/Qref	%	7.52%	-3.29%	4.21%	1.21%
Sensible Heat Ratio	-	0.81	0.85	0.83	0.87
Superheat	K	5.794	19.818	4.422	10.474
LMTD	K	9.534	5.829	9.222	6.171
UA	kW/K	0.990	1.414	0.988	1.439
Air Pressure Drop	Pa	N/A	N/A	N/A	N/A
Refrigerant Pressure Drop	kPa	N/A	N/A	N/A	N/A
Fan Power	kW	0.502	0.523	0.501	0.519
Condenser					
Airside					
Inlet					
Air Flow Rate	m³/s	1.44	1.50	1.44	1.42
Temperature	°C	35.03	35.08	46.14	46.22
Wet Bulb	°C	20.0	20.0	27.4	27.5
Humidity Ratio	kg/kg	0.008	0.009	0.016	0.016
Density	kg/m³	1.13	1.13	1.08	1.07
Enthalpy	kJ/kg	57.0	57.2	86.5	86.7
Specific Heat	kJ/kg.K	1.01	1.01	1.02	1.02
Outlet					
Air Flow Rate	m³/s	1.47	1.53	1.48	1.45
Temperature	°C	41.90	40.83	53.36	53.26
Wet Bulb	°C	22.0	21.7	29.0	29.1
Humidity Ratio	kg/kg	0.008	0.009	0.016	0.016
Density	kg/m³	1.10	1.11	1.05	1.05
Enthalpy	kJ/kg	64.0	63.0	94.0	94.0
Specific Heat	kJ/kg.K	1.01	1.01	1.02	1.02
		0.00010	0.00038	0.00011	-0.00001
Refrigerant Side					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047

		Alternate 1 (35°C)	Alternate 2 (35°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	**-**	**R447B**	**R452B**	**R447B**	**R452B**
Temperature	°C	78.84	92.46	93.29	97.45
Pressure	kPa	2493.84	2600.61	3199.13	3357.43
Superheat	K	31.5	46.5	35.3	40.4
Enthalpy	kJ/kg	522.20	532.28	529.64	527.68
Entropy	kJ/kg.K	2.09	2.11	2.08	2.07
Outlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	40.68	35.54	53.44	48.65
Pressure	kPa	2481.63	2599.27	3187.26	3351.92
Subcooling	K	3.37	9.26	1.62	7.33
Enthalpy	kJ/kg	274.8	266.6	300.2	291.9
Entropy	kJ/kg.K	1.32	1.29	1.39	1.37
HX Level					
Heat Rejection	kW	11.39	9.94	11.59	11.10
Energy Balance (Qair - Qref)	kW	N/A	N/A	N/A	N/A
Subcooling	K	3.37	9.26	1.62	7.33
Air Pressure Drop	Pa	-	-	-	-
Refrigerant Pressure Drop	kPa	12.21	1.34	11.87	5.51
Fan Power	kW	0.45	0.45	0.45	0.45
TXV					
Refrigerant					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	39.42	34.55	51.55	47.11
Pressure	kPa	2462.98	2583.59	3166.49	3331.97
Subcooling	°C	4.31	9.99	3.21	8.59
Enthalpy	kJ/kg	272.4	264.7	296.1	288.7
Entropy	kJ/kg.K	1.310	1.284	1.382	1.358
Compressor					
Refrigerant					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	16.84	26.01	17.17	24.96
Pressure	kPa	993.13	902.34	1082.17	1128.72
Superheat	K	7.52	20.81	4.94	12.23
Enthalpy	kJ/kg	479.3	486.2	477.0	479.4
Entropy	kJ/kg.K	2.052	2.090	2.035	2.042
Outlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	78.8	92.5	93.3	97.5
Pressure	kPa	2493.8	2600.6	3199.1	3357.4
Superheat	K	31.5	46.5	35.3	40.4
Enthalpy	kJ/kg	522.2	532.3	529.6	527.7
Entropy	kJ/kg.K	2.087	2.112	2.082	2.073
Compressor Level					
Power Consumption	kW	2.67	2.40	3.16	2.93
Isentropic Efficiency	-	0.72	0.83	0.68	0.77
Frequency	Hz	60	60	60	60

Table 38: Unit 10 – R447B Leak Tests

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Charge	lb	6.625	4.27	6.625	4.23	6.77

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Cooling Capacity	BTU/hr	31073	14216	30865	15171	30587
Energy Balance	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Compressor Power	kW	3.18	2.93	3.18	2.94	-
Fan Power	kW	0.95	0.98	0.98	0.98	0.98
Total Power	kW	4.13	3.90	4.16	3.92	-
EER	BTU/hr.W	7.52	3.64	7.42	3.87	-
Evaporator						
Airside						
Inlet						
Air Flow Rate	m³/s	0.74	0.73	0.74	0.73	0.74
Temperature	°C	29.0	29.0	29.0	29.0	29.0
Wet Bulb	°C	21.33	21.34	21.34	21.34	21.34
Relative Humidity	%	51.0	51.0	51.0	51.0	51.0
Humidity Ratio	kg/kg	0.013	0.013	0.013	0.013	0.013
Density	kg/m³	1.14	1.14	1.14	1.14	1.14
Enthalpy	kJ/kg	62.0	62.0	62.0	62.0	62.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0
Outlet						
Air Flow Rate	m³/s	0.71	0.72	0.71	0.72	0.71
Temperature	°C	19.7	23.3	19.6	23.2	19.7
Wet Bulb	°C	17.91	19.87	18.08	19.77	18.05
Relative Humidity	%	84.7	73.1	86.3	73.6	86.0
Humidity Ratio	kg/kg	0.012	0.013	0.012	0.013	0.012
Density	kg/m³	1.18	1.16	1.18	1.16	1.18
Enthalpy	kJ/kg	50.7	57.0	51.2	56.7	51.1
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0
Refrigerant Side						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	12.90	2.61	12.94	2.81	12.75
Pressure	kPa	1085.49	794.22	1086.62	799.23	1080.50
Quality	-	0.27	0.30	0.27	0.30	0.27
Enthalpy	kJ/kg	296.09	291.52	296.48	290.79	296.24
Entropy	kJ/kg.K	1.40	1.40	1.41	1.40	1.41
Outlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	16.76	28.23	17.07	27.95	17.01
Pressure	kPa	1085	794	1087	799	1080
Superheat	K	4.42	26.24	4.70	25.76	4.82
Enthalpy	kJ/kg	476.43	496.65	476.77	496.25	476.88
Entropy	kJ/kg.K	2.03	2.14	2.03	2.13	2.03
HX Level						
Average Cooling Capacity	kW	9.107	4.167	9.046	4.446	8.965
Energy Balance (Qair – Qref)/Qref	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Sensible Heat Ratio	-	0.83	1.18	0.90	1.12	0.89
Superheat	K	4.422	26.235	4.695	25.756	4.823
LMTD	K	9.222	6.051	9.065	6.501	9.217
UA	kW/K	0.988	0.689	0.998	0.684	0.973
Fan Power	kW	0.501	0.524	0.524	0.524	0.524
Condenser						
Airside						
Inlet						
Air Flow Rate	m³/s	1.44	1.49	1.42	1.48	1.42
Temperature	°C	46.14	46.08	46.21	45.77	46.02
Wet Bulb	°C	27.4	27.4	27.5	27.2	27.4
Humidity Ratio	kg/kg	0.016	0.015	0.016	0.015	0.015
Density	kg/m³	1.08	1.08	1.07	1.08	1.08
Enthalpy	kJ/kg	86.5	86.3	86.7	85.3	86.1
Specific Heat	kJ/kg.K	1.02	1.02	1.02	1.02	1.02

System			Liquid Line Leak		Vapor Line Leak	
		Full Charge	Low Charge	Re-Charged	Low Charge	Re-Charged
Refrigerant	-	R447B	R447B	R447B	R447B	R447B
Outlet						
Air Flow Rate	m³/s	1.48	1.52	1.46	1.50	1.46
Temperature	°C	53.36	51.27	53.52	51.05	53.28
Wet Bulb	°C	29.0	28.6	29.1	28.4	29.0
Humidity Ratio	kg/kg	0.016	0.015	0.016	0.015	0.015
Density	kg/m³	1.05	1.06	1.05	1.06	1.05
Enthalpy	kJ/kg	94.0	91.7	94.3	90.8	93.6
Specific Heat	kJ/kg.K	1.02	1.02	1.02	1.02	1.02
Refrigerant Side						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	93.29	121.77	94.07	120.31	94.34
Pressure	kPa	3199.13	2846.79	3200.02	2847.47	3175.47
Superheat	K	35.3	68.9	36.1	67.4	36.7
Enthalpy	kJ/kg	529.64	569.70	530.67	567.95	531.39
Entropy	kJ/kg.K	2.08	2.20	2.08	2.20	2.09
Outlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	53.44	50.27	53.37	50.13	53.28
Pressure	kPa	3187.26	2843.00	3188.61	2843.11	3164.31
Subcooling	K	1.62	-0.33	1.71	-0.19	1.45
Enthalpy	kJ/kg	300.2	293.2	300.0	293.2	299.9
Entropy	kJ/kg.K	1.39	1.37	1.39	1.37	1.39
HX Level						
Heat Rejection	kW	11.59	8.60	11.57	8.69	11.49
Energy Balance (Qair – Qref)	kW	N/A	N/A	N/A	N/A	N/A
Subcooling	K	1.62	-0.33	1.71	-0.19	1.45
Refrigerant Pressure Drop	kPa	11.87	3.79	11.40	4.36	11.16
Fan Power	kW	0.45	0.45	0.45	0.45	0.45
TXV						
Refrigerant						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	51.55	49.15	51.74	48.80	51.60
Pressure	kPa	3166.49	2827.45	3168.66	2827.31	3144.31
Subcooling	°C	3.21	0.54	3.06	0.89	2.84
Enthalpy	kJ/kg	296.1	291.5	296.5	290.8	296.2
Entropy	kJ/kg.K	1.382	1.369	1.383	1.366	1.382
Compressor						
Refrigerant						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	17.17	29.26	18.00	28.98	18.47
Pressure	kPa	1082.17	793.15	1082.65	797.99	1076.58
Superheat	K	4.94	27.30	5.75	26.83	6.41
Enthalpy	kJ/kg	477.0	497.7	478.0	497.3	478.8
Entropy	kJ/kg.K	2.035	2.140	2.038	2.138	2.041
Outlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	93.3	121.8	94.1	120.3	94.3
Pressure	kPa	3199.1	2846.8	3200.0	2847.5	3175.5
Superheat	K	35.3	68.9	36.1	67.4	36.7
Enthalpy	kJ/kg	529.6	569.7	530.7	568.0	531.4
Entropy	kJ/kg.K	2.082	2.200	2.085	2.195	2.087
Compressor Level						
Power Consumption	kW	3.18	2.93	3.18	2.94	0.00
Isentropic Efficiency	-	0.68	0.68	0.68	0.69	0.68
Frequency	Hz	60	60	60	60	60

System			Liquid Line Leak		Vapor Line Leak	
		Full Charge	Low Charge	Re-Charged	Low Charge	Re-Charged
Refrigerant	-	R447B	R447B	R447B	R447B	R447B

APPENDIX F - Model Verification and Validation

Table 39: Unit 6 – Model Verification and Validation for Alternative 1 – R32 @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	27	31	14%
Cooling Capacity	BTU/hr	21450	23653	10%
Total Power	kW	2.74	2.67	-2%
EER	BTU/hr.W	7.84	8.86	13%

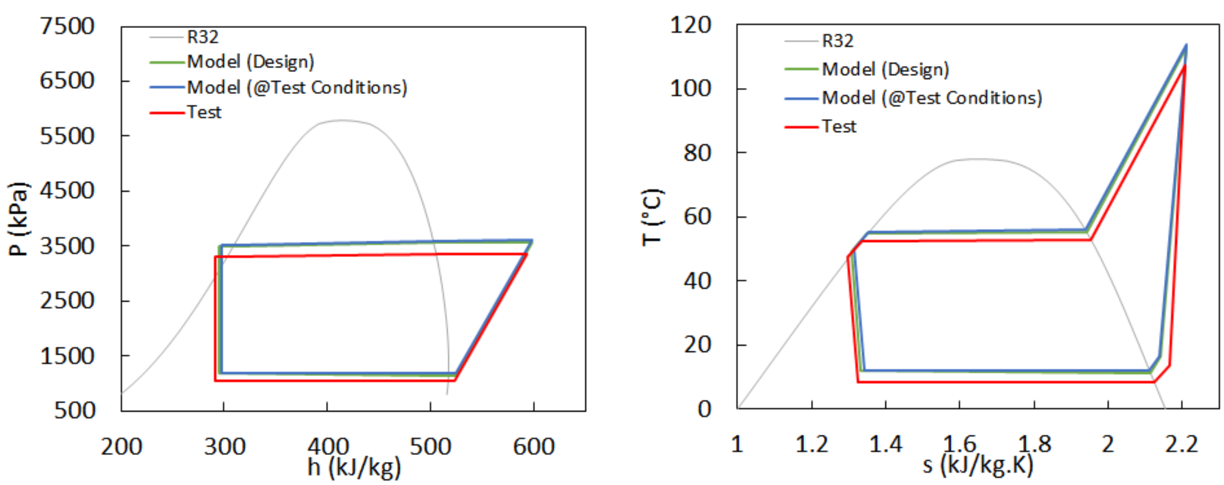

Figure 23. Unit 6 – R32 Performance Test Summary P-h and T-s Diagrams.

Table 40: Unit 6 – Model Verification and Validation for Alternative 2 – R454B @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	35	36	3%
Cooling Capacity	BTU/hr	21821	22969	5%
Total Power	kW	2.67	2.49	-7%
EER	BTU/hr.W	8.17	9.24	13%

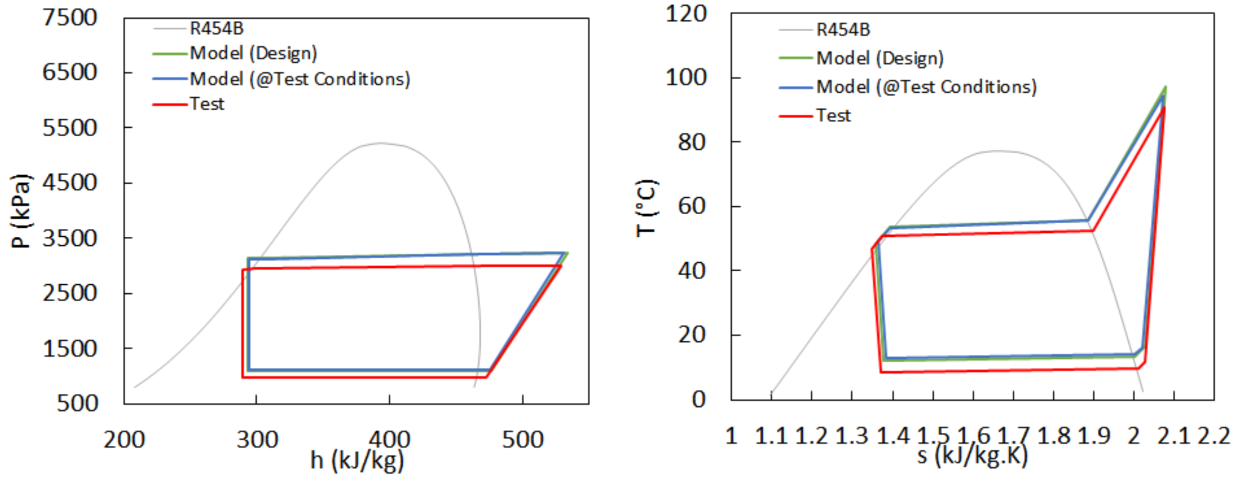

Figure 24. Unit 6 – R454B Performance Test Summary P-h and T-s Diagrams.

Table 41: Unit 10 – Model Verification and Validation for Alternative 1 – R447B @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	51	49	-3%
Cooling Capacity	BTU/hr	31169	31026	-0.5%
Total Power	kW	2.70	3.00	11%
EER	BTU/hr.W	11.54	10.34	-10%

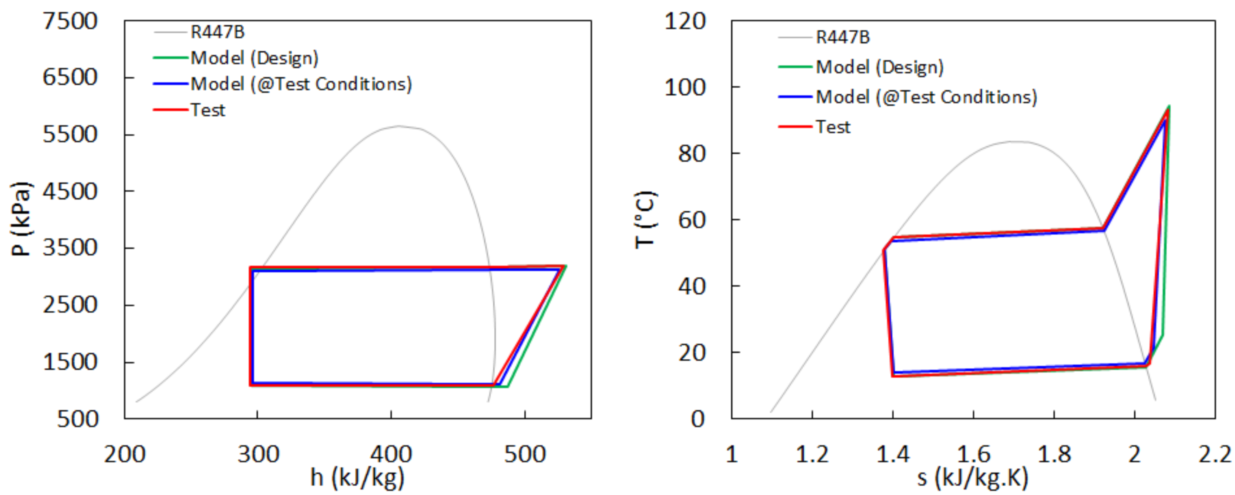

Figure 25. Unit 10 – R447B P-h and T-s Diagrams.

Table 42: Unit 10 – Model Verification and Validation for Alternative 2 – R452B @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	47	48	2%
Cooling Capacity	BTU/hr	30292	30704	1.4%
Total Power	kW	3.90	3.34	-14%
EER	BTU/hr.W	7.76	9.19	18%

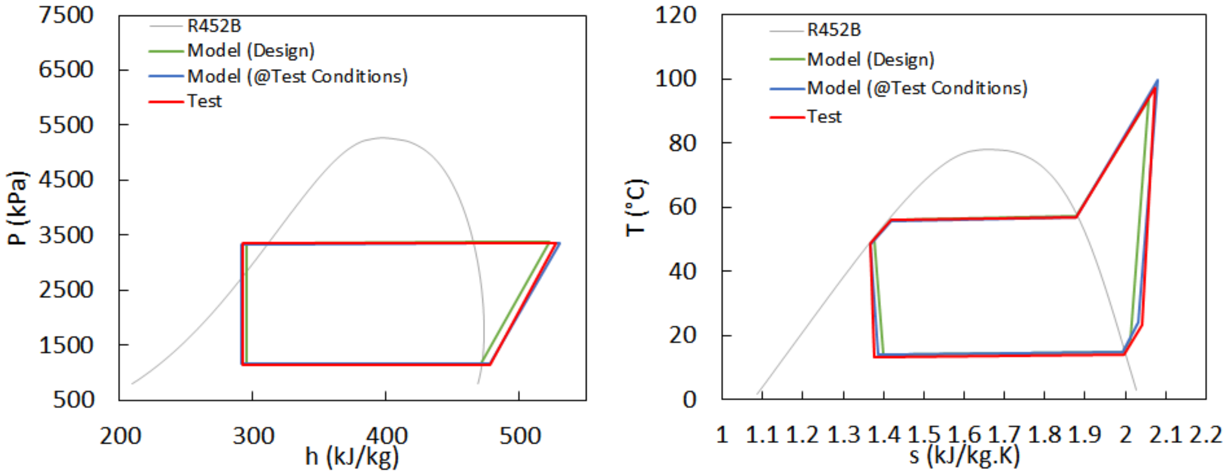

Figure 26. Unit 10 – R452B P-h and T-s Diagrams.

Final Report

AHRTI Report No. 9011

Promoting Alternative Refrigerants in High-Ambient Countries Phase II (PRAHA-II): Optimization Study on PRAHA I Equipment

Final Report

September 2019

By

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DISCLAIMER

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1. Executive Summary

Over the past several years through the Promoting low- Global Warming Potential (GWP) Refrigerants for Air-Conditioning Sectors in High-Ambient Temperature Countries (PRAHA-I) project, 18 different prototypes have been developed and compared to respective baselines to support the assessment of alternative lower-GWP refrigerants for air-conditioning applications. Since the work originally started in 2012, researchers have identified gaps in the performance and operation of the PRAHA-1 prototypes. These gaps include the need to redesign and optimize prototype air-conditioning units, evaluate new alternative refrigerants, and improve component selection. As such, a new project, *Advancing the Designs of PRAHA-I for Meeting or Exceeding the Baseline Designs Performance*, conducted by Optimized Thermal Systems, Inc. (OTS) is herein presented.

The objectives of this project include the following:

1) Evaluate the design limitation of the PRAHA-I prototypes;
2) Optimize and physically evaluate selected prototypes with new refrigerants not evaluated during PRAHA-I; and,
3) Assess potential refrigerant fractionation impact due to leakage.

The project was organized into six activities for which a summary of the results, conclusions and recommendations are presented below:

1) Activity 1: Analyzing the Design of PRAHA-I Prototypes
    a. Certification laboratories, such as the one used for testing the units in PRAHA I, provide limited information for the purposes of product design and development. For future reference it is recommended that for research-oriented efforts such as this one, the units undergo a more rigorous testing process along with full characterization of the system and its individual components operating conditions and performance.
    b. In applications of high ambient temperatures, it is expected that performance will degrade as compared to operating under more temperate conditions and the resultant impact on performance must be considered. The key components for performance improvement identified herein were the compressor, condenser and expansion device.
        i. At higher temperatures, the saturation temperatures and refrigerant density at compressor's suction port can be very different than that from the rated conditions. Larger displacement volumes and efficiency curves optimized for higher pressure lifts might be required. Therefore, the proper selection of the compressor is paramount.
        ii. A better performance condenser will reduce the approach temperature between refrigerant and air, helping the compressor not to discharge refrigerant at very high pressure and temperatures, which degrade performance.
    c. At high ambient conditions, the system is forced to operate in higher pressure lift than at rated conditions, but still requires a certain refrigerant mass flow rate. Passive devices such as capillary tubes and orifices may not be able to provide enough expansion to allow the system to operate in higher temperature conditions. An active expansion device such as EXV's can adequately control operating conditions and maintain stable superheat.

2) Activity 2: Design Improvements (Summary results in Table 1)
    a. R290 and R32 have wider saturation regions allowing the system to operate with smaller superheat and subcooling, while benefiting from two-phase heat transfer. Their cycles

may get closer to that of the ideal Carnot cycle compared to refrigerants with narrower saturation.

b. Refrigerants with high temperature glide may require new heat exchanger (HX) designs, namely condensers. The original designs proved to be sufficiently effective to allow for most systems to operate with the different refrigerants, however, better designs would allow for higher system efficiency and potentially less charge. HX designs are severely constrained by allowed envelope dimensions. A complete system re-design would provide an opportunity for designing HX's with even higher efficiency.

c. The results of this analysis suggest that for an effective refrigerant replacement, a proper compressor selection must be accompanied with it. Higher isentropic efficiencies are desired for higher temperatures, but most importantly, the displacement volume requirements can vary considerably from one refrigerant to another.

d. It is also imperative that having an active expansion device (preferably an Electronic Expansion valve (EXV)) to not only allow for more controlled superheat, but also to enable the unit to run with different refrigerants with very different thermophysical properties.

Table 1: Activity 2 Summary Modeling Results.

General Information			Hardware				Performance	
System	**Rated Capacity (@35°C)**	**System Configuration**	**Compressor**	**Condenser**	**Expansion Device**	**Ref.**	**Cooling Capacity (@46°C)**	**EER (@46°C)**
-	**BTU/hr**	**-**	**Efficiency (-)**	**Type**	**Type**	**-**	**BTU/hr**	**BTU/hr.W**
Unit 1	18000	**Baseline**	**0.66**	**Tube-Fin (5mm Tube)**	**Passive**	**R444B**	**17403**	**7.4**
		Alternate 1	0.7	Same as Baseline	Active (EXV)	R290	17639	8.01
		Alternate 2	0.69			R454C	18104	7.31
		Alternate 3	0.7			R444B	18140	8.14
		Alternate 4	0.68	MCHX		R457A	17749	7.63
Unit 4	24000	**Baseline**	**0.61**	**Tube-Fin (9.5mm Tube)**	**Passive**	**R290**	**17940**	**7.52**
		Alternate 1	0.7	Tube-Fin (5mm Tube)	Active (EXV)	R290	18147	9.12
		Alternate 2	0.7			R290	24120	6.72
Unit 6	24000	**Baseline**	**0.6**	**Tube-Fin (7mm Tube)**	**Passive**	**R32**	**23115**	**8.46**
		Alternate 1	0.65	Tube-Fin (5mm Tube)	Active (EXV)	R32	23798	9.41
		Alternate 2	0.67			R454B	22894	9.71
		Alternate 3	0.7			R452B	23702	9.6
Unit 10	36000	**Baseline**	**0.44**	**Tube-Fin (9.5mm Tube)**	**Passive**	**R32**	**29005**	**6.39**
		Alternate 1	0.65	Tube-Fin (5mm Tube)	Active (EXV)	R447B	30478	9.43
		Alternate 2	0.67			R452B	30796	10.27
		Alternate 3	0.67			R454B	30809	10

3) Activities 3-5: Prototype Modification and Testing (Summary results in Table 2)

a. Unit 6 re-tested baseline exhibited similar performance to that found in PRAHA I testing. It should be stressed that the baseline unit by design had its capillary tube located in the outdoor unit. This would cause liquid refrigerant leaving the outdoor unit to flash. The refrigerant enthalpy at the condenser outlet state was used to calculate the refrigerant-side capacity assuming an isentalphic expansion without heat loss in connecting pipe. This is different from the modified systems of which the capillary tube was removed, and a manual expansion valve was placed at the inlet of the indoor unit. For modified systems, the enthalpy at the expansion valve inlet was used to calculate the refrigerant-side capacity.

b. Unit 10 exhibited a considerable reduction in power consumption at the high ambient test condition (46°C) as compared to the original test data. This supports the hypothesis of low compressor efficiency during PRAHA I tests, which also indicates the importance of proper compressor selection.
c. The above is also evidenced by the fact that even with R447B and R452B (zeotropic mixtures), Unit 10 had higher cooling capacity and efficiency than the baseline for the 46°C test condition, as projected in activity 2. The tests at 35°C, however, did not have the same trend.
d. The impact of refrigerant replacement was not very clear, in part due to the hardware change along with it. But because of the differences in saturation curves from the Activity 2 analysis, R32 tends to result in systems with higher efficiency and less charge. The zeotropic mixtures consistently required compressors with larger displacement volumes and even higher mass flow rates for cooling capacities of the same magnitude.
e. Refrigerant fractionation as evidenced by the leak tests, does not appear to a great concern since less than 2% in cooling capacity was observed after the system's re-charge.
f. The Unit 6 modified systems had lower performance than expected from the Activity 2 models. The R32 system configuration exhibited around 10% less flow rate than anticipated, which corresponded to 10% lower capacity. The R454B configuration exhibited a deviation of 5% between model and test due also in part to a 3% flow rate over prediction in the model. Unit 10, on the other hand, exhibited an excellent agreement to the models with less than 2% deviation in cooling capacity.
g. The model's validation adds confidence in the numerical simulation findings and recommendations provided in activity 2.

Table 2: Tests Summary Results.

Syst.	Test	Refrigerant	Charge	35°C			46°C		
				Cooling Capacity	Total Power	EER	Cooling Capacity	Total Power	EER
			lb	BTU/hr	kW	BTU/hr. W	BTU/hr	kW	BTU/hr. W
Unit 6	Perfor mance	R32 (Baseline)	3.83	25192	2.43	10.4	23390	3.10	7.54
		R32 (Alternate 1)	4.27	23585	2.12	11.1	21450	2.74	7.84
		R454B (Alternate 2)	5.02	21966	2.10	10.4	21821	2.67	8.17
Unit 10	Perfor mance	R32 (Baseline)*	5.63	34517	3.76	9.18	29005	3.84	7.55
		R447B (Alternate 1)	6.63	32195	3.62	8.88	31073	3.90	7.96
		R452B (Alternate 2)	6.63	28128	3.38	8.33	30292	3.90	7.76
	Liquid Line	Low Charge	4.23	N/A			14216	3.90	3.64
		Re-Charged	6.63				30865	4.16	7.42
	Vapor Line	Low Charge	4.27				15171	3.92	3.87
		Re-Charged	6.77				30587	-	-

**Original baseline values from PRAHA*

4) Conclusions: This report presented a comprehensive set of activities with the objectives of advancing the PRAHA program. The original scope and schedule were modified during the project as new findings and challenges surfaced. The tests that were carried out for PRAHA-I, while sufficient for the purpose of measuring capacity and energy efficiency for the purposes of PRAHA-I, did not have enough essential data to enable a complete cycle evaluation for optimization purposes. This is primarily due to using standard test rig on systems with critical hardware configuration differences. The analyses presented in Activity 2 (design assessment through modeling) provided good insights on adequate component design and/or selection for proper system functioning when using novel refrigerants. The tests in activities 3-5 partially served as validation for the models developed, and as check for previous test data from PRAHA I. The final recommendations for future development are listed as follows:
    a. Establish a baseline system by conducting comprehensive testing including measurements and metrics not typically performed in energy certification tests. Furthermore, testing systems with different configurations require custom test rigs as such to adequately measure working fluid's states to avoid mischaracterization of the operating conditions and performance. Such approach is considerably more labor-intensive which should be factored in the scope in future developments.
    b. Using alternate low-GWP refrigerants is viable and can be competitive to commonly used pure refrigerants but doing so requires proper component design and selection; compressor and expansion device particularly. Drop-in replacement without hardware change is never recommended as evidenced by the change requirements in Activity 2 and performance tests in the subsequent activities.
    c. It is recommended to always perform numerical simulations, and to conduct at least some level of "soft" optimization analyses that will provide information for an educated system re-design / retrofit at much lower costs than gradual trial-and-error changes.
    d. Always test the modified systems with the same instrumentation as the baseline, however mindful of the modifications as such to properly place sensors to obtain adequate readings as suggested in item a above.

2. Introduction

Over the past several years through the Promoting low- Global Warming Potential (GWP) Refrigerants for Air-Conditioning Sectors in High-Ambient Temperature Countries (PRAHA-I) project, 18 different prototypes have been developed and compared to respective baselines to support the assessment of alternative lower-GWP refrigerants for air-conditioning applications. Since the work originally started in 2012, researchers have identified gaps in the performance and operation of the PRAHA-1 prototypes. These gaps include the need to redesign and optimize prototype air-conditioning units, evaluate new alternative refrigerants, and improve component selection. As such, a new project, *Advancing the Designs of PRAHA-I for Meeting or Exceeding the Baseline Designs Performance*, is desired.

The objectives of this project include the following:

4) Evaluate the design limitation of the PRAHA-I prototypes;
5) Optimize and physically evaluate selected prototypes with new refrigerants not evaluated during PRAHA-I; and,
6) Characterize leaks.

The project is divided into six activities namely:

- **Activity 1 – Analyzing the Design of PRAHA-I Prototypes**: evaluate systems performance from selected units tested in PRAHA-I, and assess potential design improvements
- **Activity 2 – Design Improvement**: improve design of specific units targeting higher efficiencies while using alternate low-GWP refrigerants
- **Activity 3 - Prototype Units Fabrication**: modify the a sub-set of the units according to modifications proposed in Activity 2
- **Activity 4 - Evaluation of the Optimized Prototypes**: conduct performance tests on modified units at standard and high ambient temperature conditions (35°C and 46°C)
- **Activity 5 - Analyzing Leaks of Alternatives**: simulate refrigerant leakage and evaluate possible impact of zeotropic mixtures fractionation on performance
- **Activity 6 - Reporting and Data Management**: simulation and test data processing, preparing progress and final reports

3. Activity 1 - Analyzing the Design of PRAHA-I Prototypes

Activity 1 was comprised of three major tasks including: reception of 12 physical units at the OTS facility followed by visual inspection and parts identification; review of performance test reports from PRAHA I tests; and lastly, analyze data and identify, for units of interest, opportunity for improvement targeting higher performance and minimal charge. OTS has completed this activity and an executive summary of the findings are presented herein.

3.1. Physical Units

All 12 units of interest to this project (Table 3) were received on November 8th, 2018. Visual inspection indicated no evident signs of damage. Relevant information to the project such as compressor model, heat exchanger (HX) geometry and circuiting, as well as expansion device were also received.

Table 3: Unit Specifications Summary.

Category	Unit #	Ref.	Designed Capacity Btu/h	Measured Cap. Btu/h	Voltage	Ref. (New designs)	Ref. (Tests)
Window	**1**	**L-20 (R-444B)**	**18,000**	**19,104**	**208-230/60/1**	**L-20, R454C, R290, R457A**	**R290**
	2	L-20 (R-444B)	18,000	16,924	208-230/60/1		
	3	DR-3 (R-454C)	18,000	18,063	208-230/60/1		
Decorative splits	**4**	**R-290**	**24000 (18,000)**	**19,000**	**208-230/60/1**	**R-290**	**R-290**
	5	R-32	24000 (18,000)	19,328	208-230/60/1		
	6	**R-32**	**24,000**	**25,456**	**208-230/60/1**	**R32, R459A**	**R32, R459A**
	7	L-41 (R-447A)	24,000	24,830	208-230/60/1		
	8	L-20 (R-444B)	24,000	22,740	208-230/60/1		
	9	DR-3	24,000	14,638	208-230/60/1		
Ducted splits	**10**	**R-32**	**36,000**	**35,500**	**220-240/50/1**	**R447B, R452B**	**R447B, R452B**
	11	L-20	36,000	36,553	220-240/50/1		
	12	DR-3 (R-454C)	36,000	33,032	220-240/50/1		

3.2. PRAHA-I Performance Reports Assessment

OTS received a complete package of files containing the performance reports for all units tested in PRAHA I. The tests conducted in PRAHA I were meant to assess high-level performance of these units focusing on a large control volume where only total energy in and out was evaluated. As such, these tests were not comprehensive in terms of measurements for cycle analysis required in PRAHA II. Refrigerant side measurements, in most cases, were very limited (few pressure and temperature measurements and no flow rates); thus, it is not possible to fully characterize the cycle and perform energy balances between air and refrigerant sides of the system. Common issues found in the reports include:

- Tag mislabeling and / or mismatching sensor location and tag
- No independent outdoor capacity reported – typically reported the same as indoor capacity
- Missing energy balance checks
- Missing measurement on either airside pressure drop and temperature or fan power
- Inconsistent reported measurements with thermophysical properties for units tested with L-20
- Systematic inconsistency in reported superheat and subcooling
- Missing measurements on refrigerant side at evaporator inlet
- Missing temperature and/or pressure measurements on refrigerant side
- Missing refrigerant mass flow measurements

A summary of the original PRAHA-1 data and results of the data reduction are provided under separate documentation.

3.3. Hardware Improvement Assessment

3.3.1. Heat Exchanger (HX) First Order Analysis (FOA)

This section outlines a FOA for the HXs of Units 1, 4, 6 and 10 to identify improvement potential. The project's objective, as stated above, is to improve performance while minimizing charge. One way of addressing both objectives is by reducing tube / channel diameter. Heat transfer coefficients are inversely proportional to surface hydraulic diameters, however, so is pressure drop. Smaller tubes result in more compact (C = surface area / footprint volume), with reduced internal volume, HXs.

A qualitative analysis using values from literature was carried out to demonstrate the relative impact of diameter over abovementioned metrics, specifically: heat transfer coefficient, compactness and overall thermal conductance (UA). The left-hand side plot in Figure 1 show three curves inversely proportional to the diameter; a 5mm tube can achieve, in this example, 70% greater UA than a conventional 9.5mm, within the same footprint volume (or cabinet).

These are further explored to illustrate the impact on a system level. Systems respond to UA of both condenser and evaporators, but for the purposes of this analysis, condenser only is considered. The UA represents the overall thermal conductance, which will impact the approach temperatures in the system (ΔT_{app}). If the heat rejection is kept constant, the higher the UA, the smaller are the ΔT_{app}'s, thus allowing the condenser to operate in lower pressure levels, which will consequently increase the system performance. An example using a hypothetical R32 cycle with an EER of 12 as base is shown in the right-hand side plot in Figure 1. Performance improvement is limited by the Second Law, when the approach temperatures near zero; however, in this illustration, the EER has potential to increase in over 20% with better condenser design alone.

It is imperative to note that the results presented in this section are for **illustration purposes only**. Further in this report it is presented in more detail a re-design framework, applied to the units of interest in this project, using the metrics outlined in this section.
Unit 1 already had a 5mm condenser, which limits the options for HX re-design. Unit 6 had a 7mm HX on both the indoor and outdoor units, which allows some room for improvement if reducing to 5mm. Lastly, both coils for Unit 10 had 9.5mm tubes, thus there is greater potential for charge reduction and performance improvement for that unit in particular.

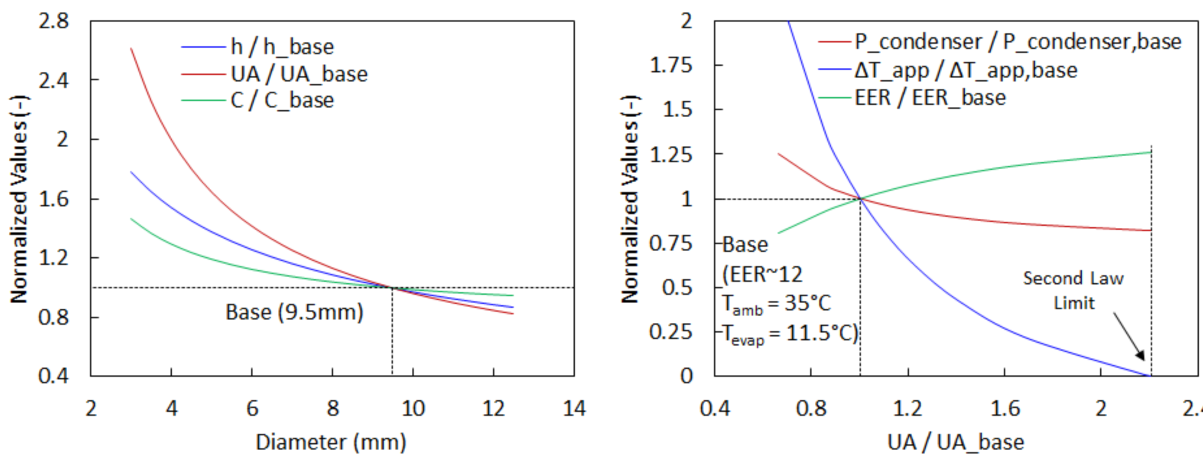

Figure 1. Heat Exchangers FOA.

3.3.2. Compressors

The existing units mostly use compressors sized specifically for R410A or R22 and in some cases custom made for this effort. There is, however, opportunity for a better compressor selection when migrating from R32 to R454B or R447B on Units 6 and 10, respectively.

3.3.3. Expansion Devices

Expansion devices such as TXV's and EXV's may allow for better control and reduced losses in connecting pipes if located near the evaporator. Some units, such as 6 and 10, have a capillary tube in the outdoor unit, which forces the refrigerant to travel in two-phase along the connecting pipes, and at lower temperatures, thus increasing pressure drop and heat gain.

3.3.4. Fan and Blower

Replacing the fan and blower may be necessary if newly designed HXs offer considerable change in pressure drop over the baseline since the flow rates are kept constant. The lack of test data on pressure drop forces us to rely on predicted values only. These will be considered for replacement as a last priority.

3.3.5. Units Component Modification Potential

Table 4 shows the detailed existing components for the units of interest for modification.

Table 4: Units 1, 4, 6 and 10 Components.

System	Unit 1	Unit 4	Unit 6	Unit 10
Refrigerant	**R444B**	**R290**	**R32**	**R32**
Compressor	HIGHLY SL260DG-C8EU	HIGHLY PSH356DG-C8DU3	GMCC KSG226N1UMT	Copeland ZP42K5E-PFJ-XXX
Condenser	5mm Louver TFHX	9.5mm Wavy TFHX	7mm Louver TFHX	9.5mm Louver TFHX
Expansion Device	Capillary Tube	Capillary Tube	Capillary Tube	Capillary Tube
Evaporator	9.5mm Louver TFHX	7mm Louver TFHX	7mm Slit TFHX	9.5mm Louver TFHX

3.4. Conclusions and Recommendations

The first part of this activity regarded data analysis and processing from the original tests conducted in the original PRAHA-I project, which was designed to conduct testing and comparison of cooling capacity vs. EER for the prototypes against the baseline units from same manufacturers. Since limited certification tests were required then, more testing parameters would have been needed to support the optimization and/or redesign process within the scope of PRAHA-II. The second part pertained assessing potential hardware modifications that could result in higher performance and less charge, with the intent of replacing the original refrigerants with alternative, low-GWP ones. The key conclusions and recommendations are:

1- Certification laboratories, such as the one used for testing the units in PRAHA I, provide limited information for the purposes of product design and development. For future reference it is recommended that for research-oriented efforts such as this one, the units undergo a more rigorous testing process along with full characterization of the system and its individual components operating conditions and performance.

2- In applications of high ambient temperatures, it is expected that performance will degrade as compared to operating under more temperate conditions and the resultant impact on performance must be considered. The key components for performance improvement identified herein were the compressor, condenser and expansion device.

   a. At higher temperatures, the saturation temperatures and refrigerant density at compressor's suction port can be very different than that from the rated conditions. Larger displacement volumes and efficiency curves optimized for higher pressure lifts might be required. Therefore, the proper selection of the compressor is paramount.
   b. A better performance condenser will reduce the approach temperature between refrigerant and air, helping the compressor not to discharge refrigerant at very high pressure and temperatures, which degrade performance.

3- At high ambient conditions, the system is forced to operate in higher pressure lift than at rated conditions, but still requires a certain refrigerant mass flow rate. Passive devices such as capillary tubes and orifices may not be able to provide enough expansion to allow the system to operate in higher temperature conditions. An active expansion device such as EXV's can adequately control operating conditions and maintain stable superheat.

4. Activity 2 - Design Improvements

The details of modeling and simulation results are provided in a separate document submitted in conjunction with this one, while in this section only the summarized performance results are presented.

4.1. Hardware

A general design improvement assessment was presented in the report for Activity 1, focusing on the units of interest to this study. A first order analysis on the HX's showed that moving towards smaller hydraulic diameter tubes can be beneficial from a material savings and charge reduction standpoint. Units 4 and 10 use conventional 9.5mm diameter tube condensers (Table 4), making them good candidates for condenser replacement with either a smaller tube diameter or a microchannel heat exchanger (MCHX). The compressors used on Units 1, 4 and 6 do not have available performance maps making it difficult to assess their fitness for the system. The focus of this study is on proper compressor selection and condenser re-design.

4.2. Refrigerant

R32 and R290 have wide saturation regions (Figure 2 and Figure 3) putting them at an advantage since they may operate with smaller superheat and subcooling, while benefiting from two-phase heat transfer. Their cycles may get closer to that of the ideal Carnot cycle compared to refrigerants with narrower saturation.

Amongst the blends investigated for Unit 1, R444B has the widest saturation region while also having the highest temperature glide (Figure 4). The latter is typically not beneficial, in particular for evaporators, but it may help the condenser. The glide enables the refrigerant temperature profile to get closer to the air temperature profile without crossing (Figure 4). From a thermodynamic perspective, this means R444B can have its condensing pressure reduced further, resulting in higher theoretical COP.

For Units 6 and 10, the investigated blends, although having narrower saturation than the baseline R32, have similar thermophysical characteristics (Figure 3) with lower temperature glides (Figure 4) making them more competitive from a capacity and performance perspective.

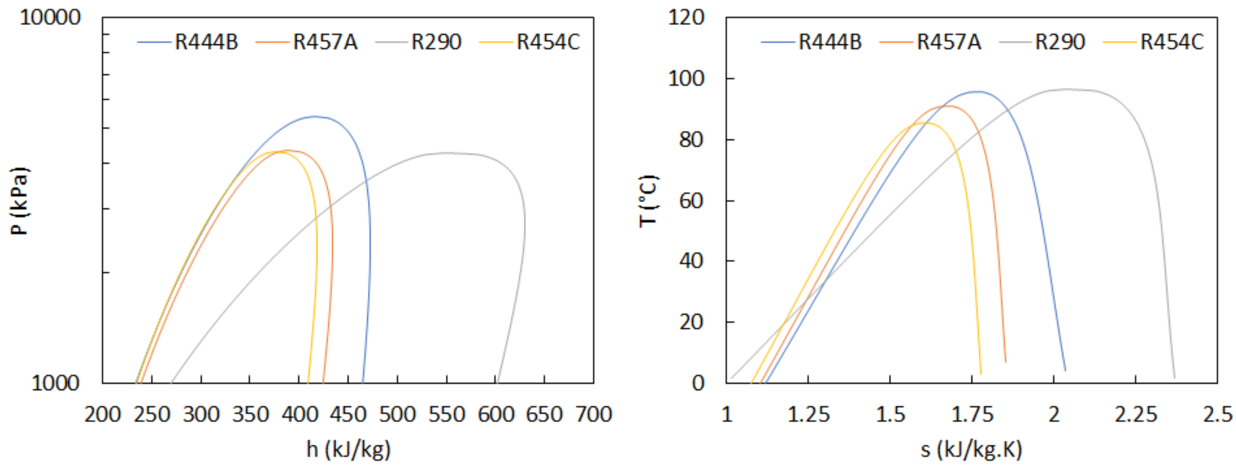

Figure 2. Refrigerants Investigated for Units 1 and 4.

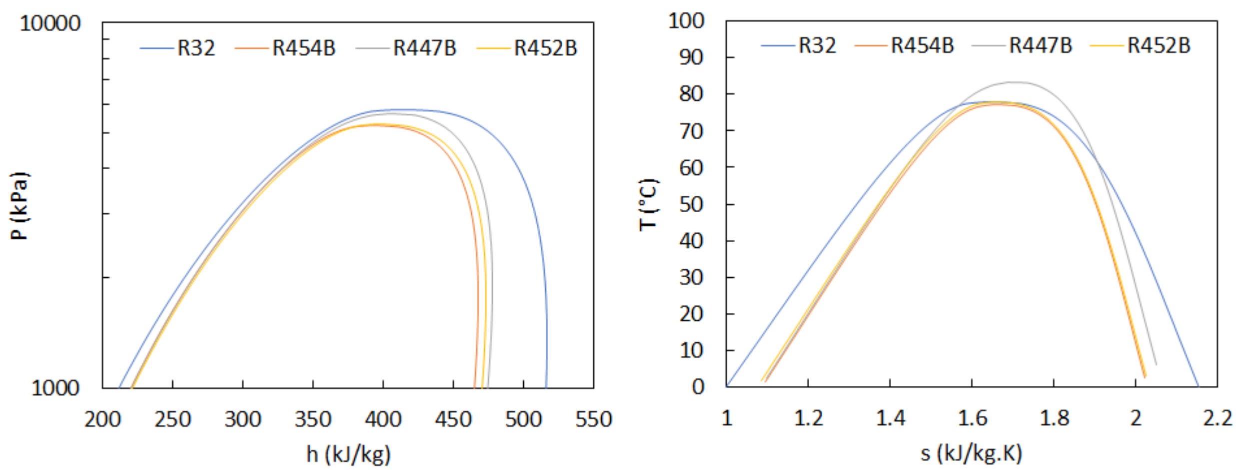

Figure 3. Refrigerants Investigated for Units 6 and 10.

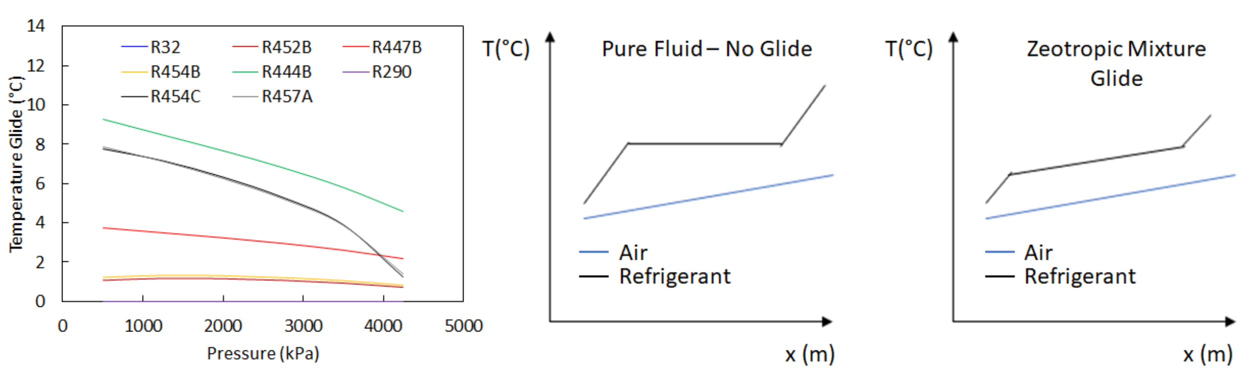

Figure 4. Refrigerant Temperature Glides.

4.3. System Design Modification Framework

The systems' re-design herein presented ultimately consists of a retrofit of the existing units by properly designing and selecting components that can be replaced as drop-ins, with minimal or no modification of the packaging (cabinets). In other words, any component replaced must occupy the same envelope as the baseline component. The focus of the re-design is on:

- Compressor
- Condenser, and
- Expansion valve

The evaporator designs were not changed for two main reasons: a) some are custom-made wrap-around the blower units, such as in Unit 6, making it harder to quickly find an off-the-shelf option; and, b) the goal is to deliver the same cooling capacity while improving efficiency. For the latter, there's more room for improvement in the condenser by reducing condensing pressure, assuming the evaporator can already deliver the expected capacity.

The fans and blowers were also not considered for change, in part due to the lack of information on the performance curves from the baseline models, but also due to potential high cost and lead time for replacement with secondary impact on performance since 80-90% of the power consumed comes from the compressor.

The first step to assess the level of performance required for each component is to investigate an improved theoretical cycle, which will indicate how much COP improvement can be expected, as well as refrigerant flow rate needs and HX size (UA). To improve the performance of a vapor compression cycle, the pressure lift between evaporating and condensing pressures must be reduced. Consequently, the approach temperatures between air and refrigerant will be reduced as well (Figure 5), thus the thermal capacitance of the heat exchangers must increase. Furthermore, the closer to the saturation region, the closer the cycle reaches the ideal Carnot efficiency (Figure 6).

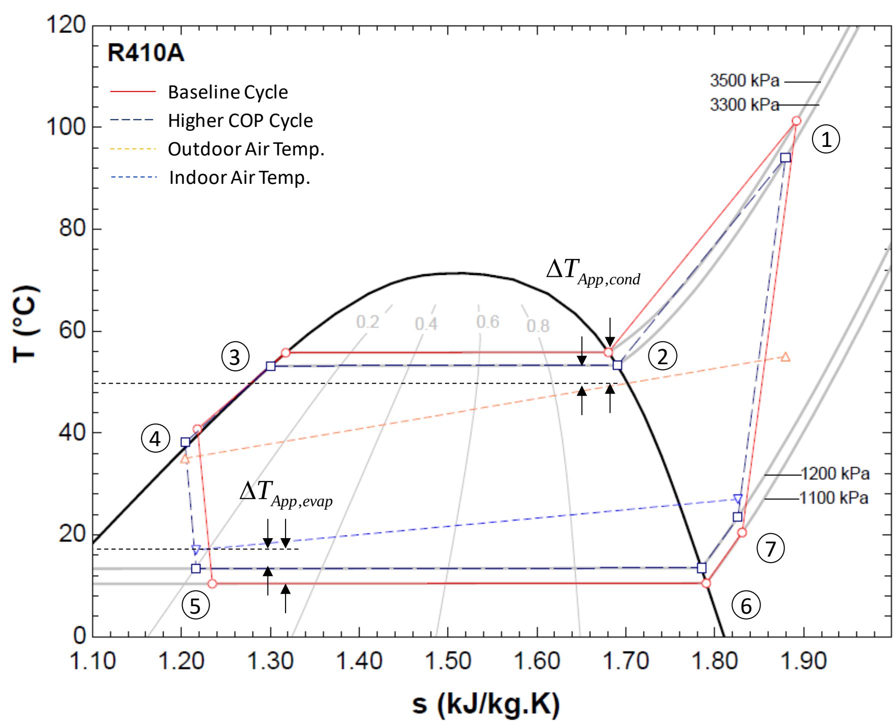

Figure 5. Illustrative T-s diagram for baseline and improved cycles.

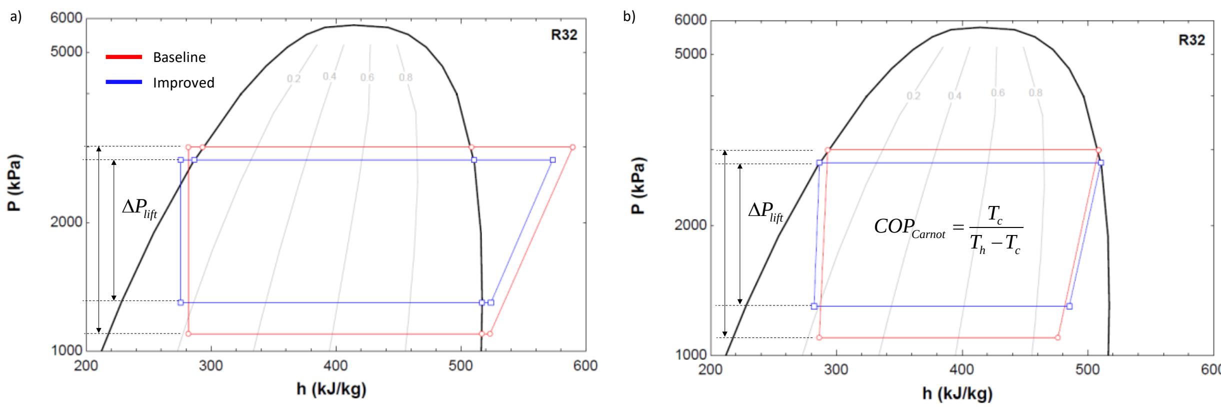

Figure 6. P-h Diagrams Illustrating COP Improvement: a) Real Cycle; b) Ideal Cycle (Carnot).

The system design framework is performed according to Figure 7.

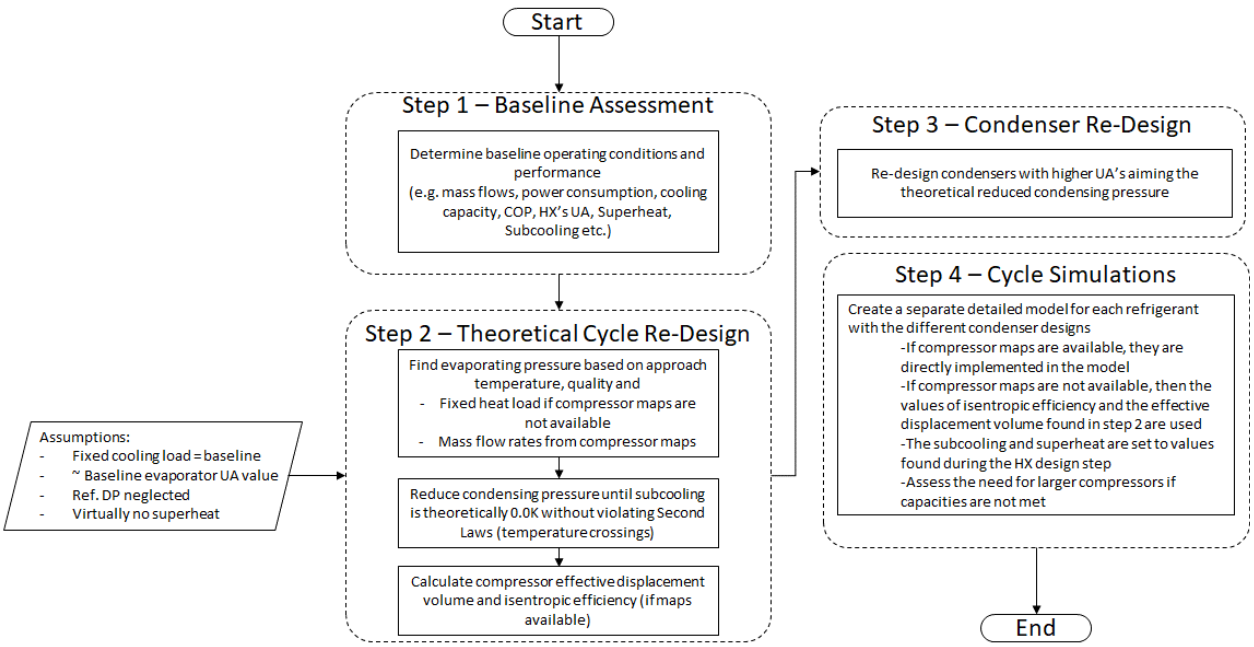

Figure 7. System Re-Design Framework,

4.3.1. Compressors

Modeling compressors are handled in two possible ways, as suggested previously: using performance maps when available or using fixed isentropic efficiency and effective displacement volume. For the larger capacity units (6 and 10), performance maps were provided. Although these compressors were originally designed for R410A refrigerant they may operate – not necessarily optimally – with other refrigerants. Compressor manufacturers supporting this project used proprietary simulation tools, with aid from available empirical data (tests with other refrigerants), to develop theoretical maps for the various refrigerants of interest (Table 5) and made them available to OTS for modeling purposes. It is understood that the predictions are for reference only, and the compressor manufacturer does not guarantee performance for any refrigerants for which the compressors haven't been fully tested.

Table 5: Compressor Models.

Model	Capacity (BTU/hr)	Frequency (Hz)	Refrigerants
ZP20K5E-PFV	24,000	60	R32, R459A, R454B, R410A
ZP21K5E-PFV	24,000		
ZP31K6E-PFV	36,000	50/60	R447B, R452B, R454B, R410A
ZP34K6E-PFV	36,000		

For the smaller units (1 and 4), which were re-designed using R290 (Propane), compressor performance maps were not available. The approach for these units then was to set a target isentropic efficiency of 0.7 (baseline data suggests that the compressor efficiencies ranged from 0.55 to 0.65). The required mass flow rate is calculated based on capacity in the theoretical cycle model described above. From there, the effective displacement volume can be determined (eq. (1))[1]. The latter serves to determine whether a system can use the same compressors for different refrigerants.

$$V_{eff} = \eta_{vol} \cdot V_{disp} = \frac{\dot{m}_{required}}{f \cdot \rho_{suction}} \quad (1)$$

4.3.2. HX Design and Selection

The condensers design procedure takes into consideration the following:

- **Face area**: baseline face area must be preserved or at most reduced. Furthermore, the aspect ratio must also match that of the baseline so the HX can be drop-in replaced in the same cabinet.
    - Find the number of tube rows and tube length to match as closely as possible to tube face area and aspect ratio

- **Airside pressure drop and flow rate**: the test data from reports contain only air flow rate measurements, while no information on pressure drop is provided. Additionally, the fan performance curves are also not available, which limits the ability to find the exact operating condition. The baseline models provide an estimate prediction for the pressure drop, which is used as reference.

- **Thermal performance**: this step must be iteratively conducted with the previous step, as such for each design change the air flow rate and capacity are evaluated under the new conditions found in the theoretical cycle re-design.
    - Gradually increment the condensing pressure until attainable performance is achieved. This process is done iteratively using the theoretical cycle model, to find new expected operating conditions for evaporating pressure, superheat, subcooling and refrigerant flow rate.

- **HX Form**: as indicated previously, the HX design is constrained by cabinet dimensions as well as form. In the case of units 1 and 4, the condensers are flat coils placed 90° inside the cabinet (Figure 8), which makes it simpler for drop-in replacement as long as new designs have the same overall dimensions. For units 6 and 10, however, the condensers are L-shaped inside the cabinet (Figure 8). Forming coils is widely done, however, for custom coils it may be a challenge, in particular for MCHX. For this reason, the MCHX designs for units 6 and 10 are sized for a full-face area, assuming the coil can be formed, and a second design that is a single flat slab placed in longer side of the "L" shape(Figure 9).

[1] Variable definitions in the Nomenclature list after final conclusions section in this document.

- **HX Name Tag Convention:** for practical purposes, the HX's will be tagged according to the following W XX YY Z
  - **W:** B = Baseline or N = New Design
  - **XX:** TF **=** Tube-Fin or MC = Microchannel
  - **YY:** D# = Tube Diameter or Height
  - **Z:** R = Reduced Face Area
  - **Example:** New Tube Fin Design with 5.0mm diameter with same face area as the baseline → NTFD5

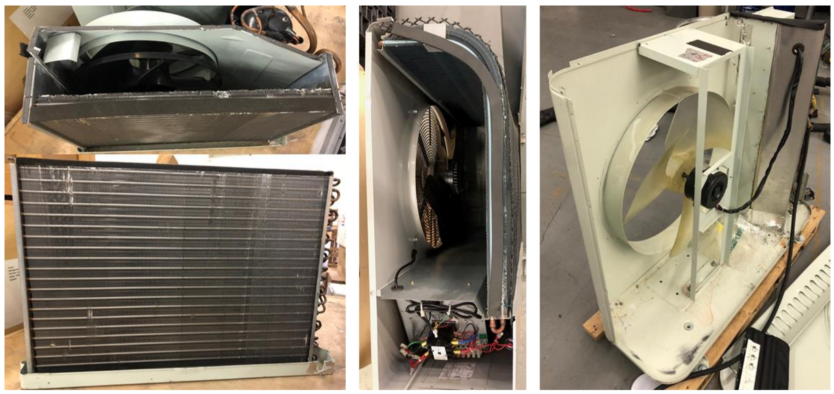

Figure 8. Condenser Forms: Unit 1 (left), Unit 10 (center), Unit 6 Cabinet (right).

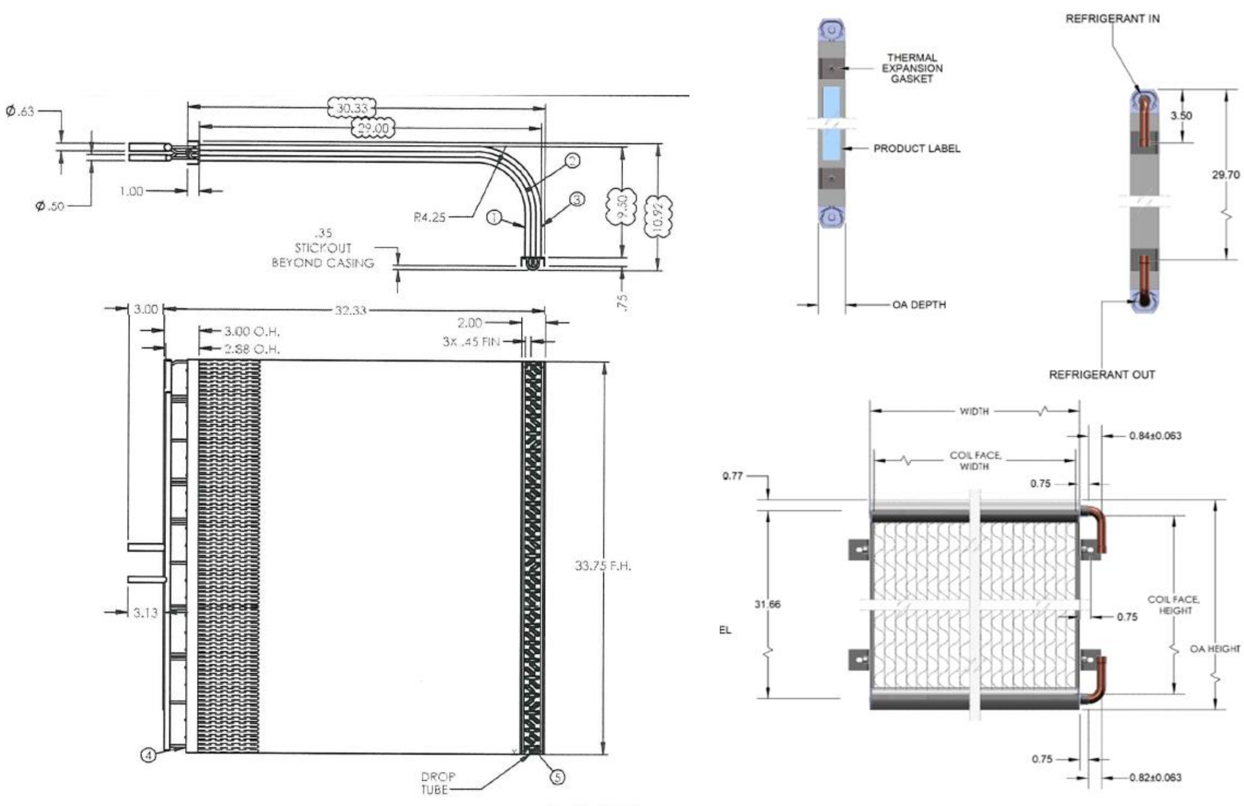

Figure 9. HX Form Examples: L-shape (left), Flat (right).

4.3.3. System Design

In the final step, the modified systems are evaluated holistically through system level modeling and simulation using an in-house Steady-State vapor compression cycle software that has the capability to integrate with the HX and compressor models (performance maps, generic etc.). For each modified system and each refrigerant, a system model was created.

4.4. Modified Systems Results Summary

The final results of Activity 2 are summarized in Table 6. For more detailed results in the framework steps refer to APPENDIX A .

4.5. Conclusions and Recommendations

This section presents a systematic approach based on first order analysis providing educated guidance towards the direction of more efficient systems with fewer simulations and minimal changes to the systems. The study includes a wide variety of refrigerants as well as condenser designs and compressor model options. Given the challenges with original test data the baseline models serve as a numerical reference only. The findings are strictly valid to comparisons against the baseline models and OTS does not guarantee that results would be reflected in actual systems as herein reported. The key conclusions and recommendations are:

1- R290 and R32 have wider saturation regions allowing the system to operate with smaller superheat and subcooling, while benefiting from two-phase heat transfer.

2- Refrigerants with high temperature glide may require new heat exchanger (HX) designs, namely condensers. The original designs proved to be sufficiently effective to allow for most systems to operate with the different refrigerants, however, better designs would allow for higher system efficiency and potentially less charge. HX designs are severely constrained by allowed envelope dimensions. A complete system re-design would provide an opportunity for designing HX's with even higher efficiency.

3- The results of this analysis suggest that for an effective use of alternate low-GWP refrigerant, a proper compressor selection must be accompanied with it. Higher isentropic efficiencies are desired for higher temperatures, but most importantly, the displacement volume requirements can vary considerably from one refrigerant to another.

4- It is also imperative that having an active expansion device (preferably an EXV) to not only allow for more controlled superheat, but also to enable the unit to run with different refrigerants with very different thermophysical properties.

Table 6: Activity 2 Results.

General Information			Hardware					Ref.	Performance			
System	Rated Capacity (@35°C)	System Configuration	Compressor		Condenser		Expansion Device		Cooling Capacity (@46°C)		EER (@46°C)	
-	BTU/hr	-	Effective Disp. Vol. (cm³)*	Efficiency (-)	Type	Effectiveness (-)	Type	-	BTU/hr	%	BTU/hr. W	%
Unit 1	18000	**Baseline**	**19.8**	**0.66**	**Tube-Fin (5mm Tube)**	**0.20**	**Passive**	**R444B**	**17403**	**0.00%**	**7.4**	**0.00%**
		Alternate 1	25.9	0.70	Same as Baseline	0.35	Active (EXV)	R290	17639	1.40%	8.01	8.20%
		Alternate 2	24.8	0.69		0.26		R454C	18104	4.00%	7.31	-1.30%
		Alternate 3	19.6	0.70		0.23		R444B	18140	4.20%	8.14	9.90%
		Alternate 4	25.3	0.68	MCHX	0.24		R457A	17749	2.00%	7.63	3.10%
Unit 4	24000	**Baseline**	**26.4**	**0.61**	**Tube-Fin (9.5mm Tube)**	**0.24**	**Passive**	**R290**	**17940**	**0.00%**	**7.52**	**0.00%**
		Alternate 1	26.3	0.70	Tube-Fin (5mm Tube)	0.26	Active (EXV)	R290	18147	1.20%	9.12	21.40%
		Alternate 2	37.9	0.70		0.20		R290	24120	34.40%	6.72	-10.60%
Unit 6	24000	**Baseline**	**16.0**	**0.60**	**Tube-Fin (7mm Tube)**	**0.12**	**Passive**	**R32**	**23115**	**0.00%**	**8.46**	**0.00%**
		Alternate 1	16.9	0.65	Tube-Fin (5mm Tube)	0.15	Active (EXV)	R32	23798	3.00%	9.41	11.20%
		Alternate 2	18.4	0.67		0.19		R454B	22894	-1.00%	9.71	14.80%
		Alternate 3	19.0	0.70		0.17		R452B	23702	2.50%	9.6	13.50%
Unit 10	36000	**Baseline**	**19.6**	**0.44**	**Tube-Fin (9.5mm Tube)**	**0.13**	**Passive**	**R32**	**29005**	**0.00%**	**6.39**	**0.00%**
		Alternate 1	22.3	0.65	Tube-Fin (5mm Tube)	0.25	Active (EXV)	R447B	30478	5.10%	9.43	47.50%
		Alternate 2	23.0	0.67		0.25		R452B	30796	6.20%	10.27	60.70%
		Alternate 3	23.3	0.67		0.25		R454B	30809	6.20%	10	56.50%

** Product of displacement volume and volumetric efficiency*

5. Activities 3, 4 & 5 - Prototype Units Fabrication, Evaluation of the Optimized Prototypes and Analyzing Leaks of Alternatives

Activities 3-5 officially began in April 2019 when the first round of tests on modified Unit 6 were carried out. Initial tests resulting in unsuccessful outcomes leading OTS to change the system modifications and the scope. Additional information found in APPENDIX B . The detailed test data and charge optimization for Units 6 and 10 are presented in APPENDIX C through APPENDIX E . Comparisons between Activity 2 model validations and experimental data are presented in APPENDIX F .

5.1. Unit 6

Some modifications were made to Unit 6 to improve its efficiency. The baseline compressor was replaced with alternate models to account for the change in refrigerant and to improve efficiency. The compressor used with R454B had a higher displacement volume than the one used with R32. Furthermore, the capillary tubes were replaced with a manual TXV that was installed directly at the evaporator inlet to increase the cooling capacity of the evaporator. A summary of the design modifications evaluated for Unit 6 is listed in Table 7, while Table 8 and Table 9 show the performance of Unit 6 for baseline and modifications at 35°C and 46°C ambient, respectively. The baseline system performed similar, within 2%, to reported performance in PRAHA I. There is a discrepancy in the measurements from condenser outlet to expansion inlet in the baseline case, since the capillary tube (removed in the modified systems) was located in the outdoor unit The expansion causes the refrigerant to flash in the liquid line thus compromising the readings at the expansion device. For calculation purposes, the condenser outlet enthalpy was used instead of the expansion inlet.

Table 7: Unit 6 Modifications for Testing.

System	Unit 6		
	Baseline	Alternate 1	Alternate 2
Refrigerant	R32	R32	R454B
Compressor	GMCC KSG226N1UMT	Copeland ZP20K5E	Copeland ZP21K5E
Expansion Device	Capillary Tube (Outdoor unit)	Manual Valve (Indoor Unit)[2]	Manual Valve (Indoor Unit)[2]

Cooling capacity for the modified unit with either refrigerant was consistently lower by 6-12% than the baseline. The modified R32 system reportedly showed lower mass flow rate than expected, likely the main cause for the lower-than-expected thermal performance. The R454B system resulted in a poorer performance but was less sensitive to ambient temperature than its R32 counterpart - i.e. cooling capacity was near the same at both 35°C and 46°C, while for R32 there was a ~2,000BTU/hr reduction with the temperature increase. It is also possible that there is a mismatch between thermophysical property library and actual refrigerant properties for R454B which can happen with newer fluids. The libraries need periodic update as more test data become available.

[2] A manual valve was used to mimic a TXV or EXV recommended as component modification in these systems configurations.

Table 8: Unit 6 - Performance Test Summary for R32 Baseline (OTS) @ 35°C.

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	**R32**	**R32**	**R454B**	-	-
Charge	lb	3.83	4.27	5.02	11.5%	31.1%
Cooling Capacity	BTU/hr	25192	23585	21966	-6.4%	-12.8%
Energy Balance	%	-2.28%	-4.66%	-3.06%	-	-
Compressor Power	kW	2.11	1.79	1.77	-15.1%	-16.2%
Fan Power	kW	0.32	0.33	0.33	2.2%	4.2%
Total Power	kW	2.43	2.12	2.10	-12.8%	-13.5%
EER	BTU/hr.W	10.37	11.12	10.44	7.2%	0.68%

Table 9: Unit 6 - Performance Test Summary for R32 Baseline (OTS) @ 46°C.

		Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	-	**R32**	**R32**	**R454B**	-	-
Charge	lb	3.83	4.27	5.02	11.5%	31.1%
Cooling Capacity	BTU/hr	23390	21450	21821	-8.3%	-6.7%
Energy Balance	%	-1.78%	-4.42%	-7.61%	-	-
Compressor Power	kW	2.71	2.32	2.25	-14.2%	-16.6%
Fan Power	kW	0.40	0.42	0.42	5.3%	5.3%
Total Power	kW	3.10	2.74	2.67	-11.7%	-13.8%
EER	BTU/hr.W	7.55	7.84	8.17	3.8%	8.2%

5.2. Unit 10

Applying what was learned in the initial modifications to Unit 6, modifications to Unit 10 were limited to include the compressor and expansion device only. Unlike Unit 6, however, the re-test of the baseline system was not successful; refer to APPENDIX D for additional information. However since Unit 6 baseline re-test showed good reproducibility from original data, it is assumed that the Unit 10 original baseline is appropriate for comparison against the modified system configurations. A summary of the design modifications evaluated for Unit 10 is listed in Table 10. The detailed test data is presented in APPENDIX E .

At 35°C the modified units exhibited almost 20% less cooling capacity with 10% less power consumption, resulting in up to 11% less EER (Table 11). These results were not unexpected since the modified units were re-designed using the 46°C temperature, when the baseline system's performance showed a great degradation of performance. At 46°C condition, the tests exhibited 2-5% greater cooling capacity with up to 12% less power consumption compared to the baseline, which was equivalent to 13-17% greater system performance.

In Activity 2 the compressor power consumptions were underestimated, as well as the total fan power consumption, leaving the impression the overall performance improvement would considerably be greater than the observed. The cooling capacity, on the other hand, was predicted with less than 2% deviation from test data, validating at least the models created.

Table 10: Unit 10 Modifications for Testing.

System	Unit 10		
	Baseline	Alternate 1	Alternate 2
Refrigerant	R32	R447B	R452B
Compressor	Copeland ZP42K6E	Copeland ZP34K5E	Copeland ZP31K5E
Expansion Device	Orifice	Manual Valve	Manual Valve

Table 11: Unit 10 - Performance Test Summary for R32 Baseline @ 35°C.

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	**-**	**R32**	**447B**	**452B**	**-**	**-**
Charge	lb	5.625	6.625	6.625	17.78%	17.78%
Cooling Capacity	BTU/hr	35543	32195	28128	-9.42%	-20.86%
Energy Balance	%	---	7.52%	-3.29%	-	-
Compressor Power	kW	-	2.67	2.4	-	-
Fan Power	kW	-	0.95	0.98	-	-
Total Power	kW	3.761	3.62	3.38	-3.75%	-10.13%
EER	BTU/hr.W	9.451	8.894	8.322	-5.89%	-11.94%

Table 12: Unit 10 - Performance Test Summary for R32 Baseline @ 46°C.

		Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)	Alt. 1 vs. Baseline	Alt. 2 vs. Baseline
Refrigerant	**-**	**R32**	**447B**	**452B**	**-**	**-**
Charge	lb	5.625	6.625	6.625	17.78%	17.78%
Cooling Capacity	BTU/hr	29633	31073	30292	4.86%	2.22%
Energy Balance	%	---	4.21%	1.21%	-	-
Compressor Power	kW	---	3.18	2.93	-	-
Fan Power	kW	---	0.95	0.97	-	-
Total Power	kW	4.466	4.13	3.9	-7.52%	-12.67%
EER	BTU/hr.W	6.64	7.52	7.76	13.33%	16.95%

5.3. Leak Tests

In the interest of time the leak tests were conducted only on Unit 10 for R447B. The choice of refrigerant was based on temperature glide, where R447B exhibits the highest glide amongst the refrigerants evaluated between Unit 6 and Unit 10 (refer to Figure 4). The leak tests were conducted to closely represent field operation. The procedure applied includes the following steps:

1- Run unit until steady-state is achieved (repeat 46°C performance test), monitoring capacity and subcooling
2- Gradually remove refrigerant from vapor line until capacity is reduced to approximately 50%, if possible
3- Store and weigh removed refrigerant
4- Re-charge with new refrigerant until same subcooling is achieved
5- Compare cooling capacities; if more than 5% deviation is observed, repeat steps 1-4, however in step 2, reduce capacity to 25% only
6- Repeat steps 1-5 for the liquid line

The comparison herein presented refers to a leakage of approximately 30% of charge, while reducing capacity by approximately 50% based on airside only. The leak tests showed less than 2% deviation in cooling capacity after re-charge from both vapor and liquid lines (Table 13). Since the capacity deviation was less than 5%, no further testing for 25% capacity reduction was conducted. The results suggest little impact due to fractionation.

Table 13: Unit 10 – R447B Leak Test Summary Results.

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Charge	lb	6.625	4.27	6.625	4.23	6.77
Cooling Capacity	BTU/hr	31073	14216	30865	15171	30587
Energy Balance	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Compressor Power	kW	3.18	2.93	3.18	2.94	-[3]
Fan Power	kW	0.95	0.98	0.98	0.98	0.98
Total Power	kW	4.13	3.90	4.16	3.92	-[3]
EER	BTU/hr.W	7.52	3.64	7.42	3.87	-[3]

5.4. Conclusions and Recommendations

This section presented the performance tests conducted on units 6 and 10. The key conclusions and recommendations are:

1- Unit 6 re-tested baseline exhibited similar performance to that found in PRAHA I testing. It should be stressed that the baseline unit by design had its capillary tube located in the outdoor unit. This would cause liquid refrigerant leaving the outdoor unit to flash. The refrigerant enthalpy at the condenser outlet state was used to calculate the refrigerant-side capacity assuming an isentalphic expansion without heat loss in connecting pipe. This is different from the modified systems of which the capillary tube was removed, and a manual expansion valve was placed at the inlet of the indoor unit. For modified systems, the enthalpy at the expansion valve inlet was used to calculate the refrigerant-side capacity.

2- Unit 10 exhibited a considerable reduction in power consumption at the high ambient test condition (46°C) as compared to the original test data. This also indicates the importance of proper compressor selection.

3- The higher-than-expected power consumption in the Unit 10 baseline tests is also evidenced by the fact that even with zeotropic mixtures (R447B and R452B), Unit 10 had higher cooling capacity and efficiency than the baseline for the 46°C test condition, as projected in activity 2.

4- Because of the differences in saturation curves from the Activity 2 analysis, R32 tends to result in systems with higher efficiency and less charge when no modifications to the hardware are made. The results showed however, that making appropriate component selection, such as compressors with larger displacement volumes and higher mass flow rates for the zeotropic mixtures, cooling capacities and overall performance were of the same order of magnitude.

5- Refrigerant fractionation as evidenced by the leak tests, does not appear to be a great concern since less than 2% deviation in cooling capacity was observed after the system's re-charge.

6- The Unit 6 modified systems had lower performance than expected from the Activity 2 models. The R32 system configuration exhibited more than 10% less flow rate than anticipated due to performance

[3] Compressor power consumption was not properly recorded for this test; the error was identified after the fact and the team was unable to retrieve that information. While that compromises the assessment of the overall system performance, the deviations are expected to be marginal. The leak test on liquid line suggest minimal impact on power consumption after re-charge, while cooling capacity was reportedly fully recovered after recharge on both leak tests.

maps overprediction, which corresponded to 10% lower capacity. The R454B configuration exhibited a deviation of 5% between model and test due also in part to a 3% flow rate over prediction in the model. Unit 10, on the other hand, exhibited an excellent agreement to the models with less than 2% deviation in cooling capacity.

7- The model's validation adds confidence in the numerical simulation findings and recommendations provided in activity 2.

6. Conclusions

This report presents a comprehensive set of activities with the objectives of advancing the PRAHA program. The original scope and schedule were modified during the project as new findings and challenges surfaced. The tests that were carried out for PRAHA-I, while sufficient for the purpose of measuring capacity and energy efficiency for the purposes of PRAHA-I, did not have enough essential data to enable a complete cycle evaluation for optimization purposes. This is primarily due to using standard test rig on systems with critical hardware configuration differences. The analyses presented in Activity 2 (design assessment through modeling) provided good insights on adequate component design and/or selection for proper system functioning, when using novel refrigerants.

The final recommendations for future development are listed as follows:

1- Establish a baseline system by conducting comprehensive testing including measurements and metrics not typically performed in energy certification tests. Furthermore, testing systems with different configurations require custom test rigs as such to adequately measure working fluid's states to avoid mischaracterization of the operating conditions and performance. Such approach is considerably more labor-intensive which should be factored in the scope in future developments.

2- Using alternate low-GWP refrigerants is viable and can be competitive to presently used refrigerants but doing so requires proper component design and selection; compressor and expansion device particularly. Drop-in replacement without hardware change is never recommended as evidenced by the change requirements in Activity 2 and performance tests in the subsequent activities.

3- It is recommended to always perform numerical simulations, and to conduct at least some level of "soft" optimization analyses that will provide information for an educated system re-design / retrofit at much lower costs than gradual trial-and-error changes.

4- Always test the modified systems with the same instrumentation as the baseline, however mindful of the modifications as such to properly place sensors to obtain adequate readings as suggested in item 1 above.

Nomenclature

COP	Coefficient of Performance	-
D_o	Tube Outer Diameter	mm
f	Frequency	Hz
FPI	Fins per Inch	1/in
h	Enthalpy	kJ/kg
h_t	Tube Height	mm
HX	Heat Exchanger	-
$\dot{m}$	Mass Flow Rate	kg/s
MCHX	Microchannel Heat Exchanger	-
P	Pressure	kPa
P_l	Tube Longitudinal Pitch	mm
P_t	Tube Transverse Pitch	mm
s	Entropy	kJ/kg.K
T	Temperature	°C
TFHX	Tube-Fin Heat Exchanger	-
UA	Thermal Conductance	kW/K
V	Volume	m^3
w_t	Tube Width	mm
η_{vol}	Volumetric Efficiency	-
ρ	Density	kg/m^3

APPENDIX A - Activity 2 Design Framework Results

Table 14: Unit 1 – Theoretical Cycle Re-Design Summary.

System		*Baseline*	*Alternative 1*	*Alternative 2*	*Alternative 3*	*Alternative 4*
Case	-	**Simulation**	**Target**			
Refrigerant	**-**	**R444B**	**R290**	**R454C**	**R444B**	**R457A**
Condenser	-	BTFD5	-	-	-	-
Compressor	-	SL260DG-C8EU	-	-	-	-
Cooling Capacity	BTU/hr	17403	17477	17477	17477	17477
Compressor Power	kW	1.92	1.49	1.49	1.33	1.43
Fan Power	kW	0.43	0.43	0.43	0.43	0.43
Total Power	kW	2.35	1.92	1.93	1.76	1.86
COP	-	2.17	2.66	2.66	2.91	2.75
COP Gain	-	1.00	1.23	1.23	1.34	1.27

Table 15: Unit 1 – HX Analysis Summary

Condenser		**R444B**		**R290**		**R454C**		**R457A**	
Inputs		***BTFD5***	***NMCD2***	***BTFD5***	***NMCD2***	***BTFD5***	***NMCD2***	***BTFD5***	***NMCD2***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37	16.37	16.37	16.37	16.37
Air Flowrate	m^3/s	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Refrigerant Pressure	kPa	2875.0	2875.0	2170.7	2170.7	2436.4	2436.4	2183.9	2183.9
Saturation Temperature at Inlet	°C	61	61	61	61	61	61	61	61
Refrigerant Temperature	°C	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
Mass Flow Rate	kg/s	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03
Outputs									
Heat Load	W	7512.9	7441.2	8232.4	8016.6	6168.0	6040.0	6592.0	6429.0
Air Dry-Bulb Temperature	°C	58.6	58.2	59.7	59.6	56.3	56.3	57.0	56.9
Refrigerant Temperature	°C	46.7	48.1	50.3	53.8	47.2	49.5	48.0	51.1
LMTD	°C	12	15	19	23	14	18	16	21
UA	W/K	635.57	482.84	439.36	350.35	451.67	327.93	424.35	313.48
NTU	-	1.04	0.79	0.72	0.57	0.74	0.53	0.69	0.51
Effectiveness	-	0.1915	0.1896	0.2098	0.2043	0.1572	0.1539	0.1680	0.1638
Refrigerant Pressure Drop	kPa	78.2	1.4	85.0	1.7	79.3	1.4	87.2	1.7
Airside DP	Pa	75.1	75.5	75.1	75.5	75.1	75.5	75.1	75.5
Air Heat Transfer Coefficient (Average)	$W/m^2.K$	130.0	148.3	130.0	148.3	130.0	148.3	130.0	148.3
Refrigerant Heat Transfer Coefficient (Average)	$W/m^2.K$	3341.0	1721.0	4113.0	2033.0	3040.0	1382.0	3423.0	1601.0
Subcooling	°C	13.20	13.14	8.96	7.35	6.77	5.93	5.34	4.05
Charge	kg	0.3822	0.1143	0.1079	0.0352	0.3097	0.094	0.2522	0.0764

Table 16: Unit 1 – Compressor Performance Summary.

Compressor		Baseline				
Refrigerant	-	**R444B**	**R290**	**R454C**	**R444B**	**R457A**
Isentropic efficiency	-	0.66	0.70	0.69	0.70	0.68
Power	kW	1.9175	1.7682	2.0449	1.7966	1.8932
Pressure Lift	kPa	2284.8	1556.0	2087.7	1902.2	1904.9
Effective Displacement Volume	cm^3	19.80	25.87	24.80	19.64	25.35
Rotation Speed	RPM	3600	3600	3600	3600	3600

Table 17: Unit 1 – Expected Modified System Performances.

System		*Baseline*				
Case	-	**Simulation**	**Expected**			
Refrigerant	**-**	**R444B**	**R290**	**R454C**	**R444B**	**R457A**
Condenser	-	BTFD5	BTFD5	BTFD5	BTFD5	NMCD2
Compressor	-	SL260DG-C8EU	-	-	-	-
Cooling Capacity	BTU/hr	17403	17639	18104	18140	17749
Compressor Power	kW	1.92	1.77	2.04	1.80	1.89
Fan Power	kW	0.43	0.43	0.43	0.43	0.43
Total Power	kW	2.35	2.20	2.48	2.23	2.33
COP	-	2.17	2.35	2.14	2.38	2.24
COP Gain	-	1.00	1.08	0.99	1.10	1.03

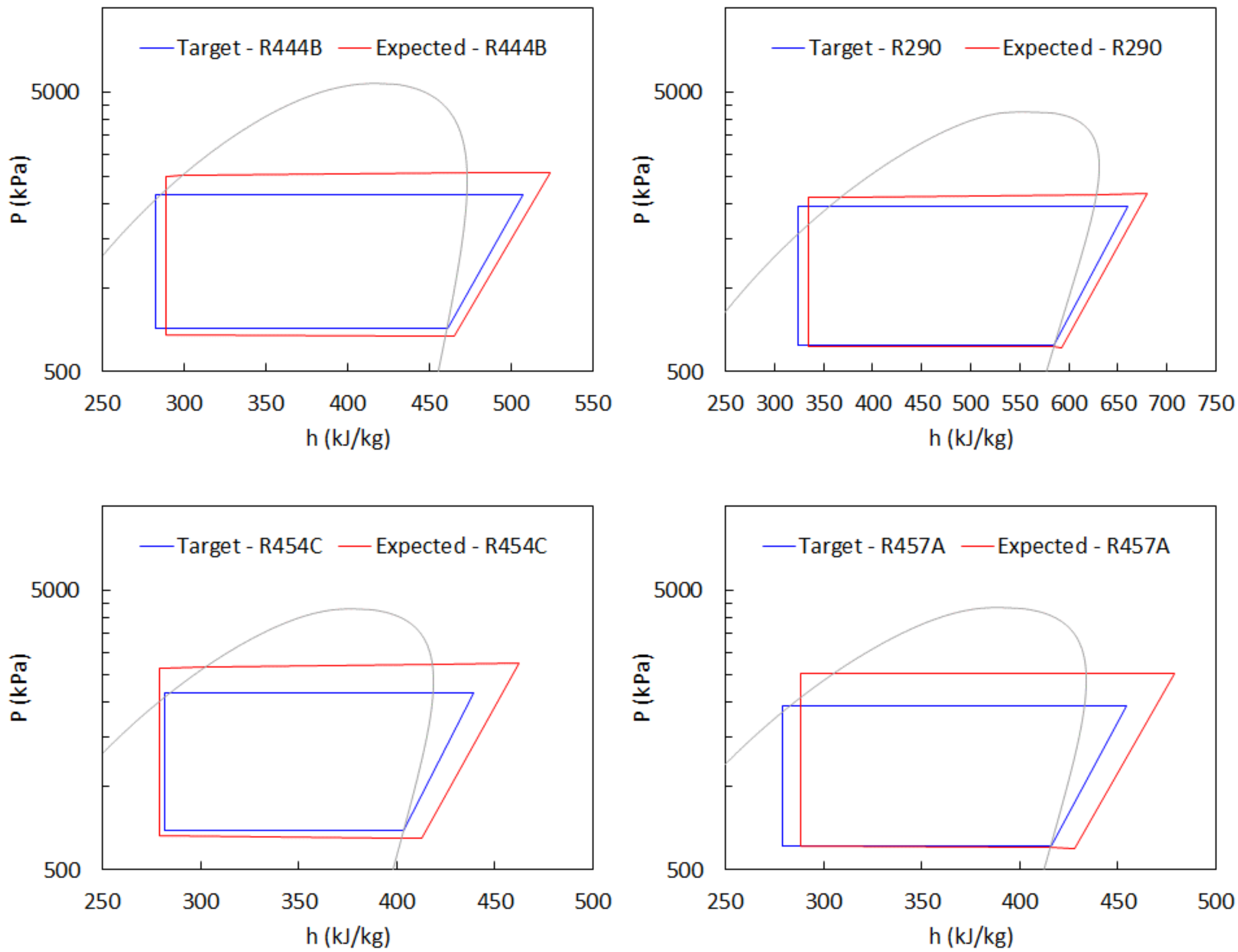

Figure 10. Unit 1 – Modified Systems P-h Diagrams.

Table 18: Unit 4 – Theoretical Cycle Re-Design Summary.

System		*Baseline*	*Alternative 1*	*Alternative 2*
			Target	
Refrigerant	-	**R290**	**R290**	**R290**
Condenser	-	BTFD9	-	-
Compressor	-	PSH356DG-C8DU4	-	-
Cooling Capacity	BTU/hr	17940	17940	23920
Compressor Power	kW	2.11	1.40	3.23
Fan Power	kW	0.28	0.28	0.28
Total Power	kW	2.39	1.68	3.51
COP	-	2.20	3.14	2.00
COP Gain	-	1.00	1.42	0.91

Table 19: Unit 4 – HX Analysis Summary.

Condenser		**R290 - 18kBTU**		**R290 - 24kBTU**	
Inputs		***BTFD9***	***NTFD5***	***BTFD9***	***NTFD5***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m^3/s	0.81	0.76	0.81	0.76
Refrigerant Pressure	kPa	2875	2875	2875	2875
Saturation Temperature at Inlet	°C	75.5	75.5	75.5	75.5

Condenser		R290 - 18kBTU		R290 - 24kBTU	
Inputs		***BTFD9***	***NTFD5***	***BTFD9***	***NTFD5***
Refrigerant Temperature	°C	110	110	110	110
Mass Flow Rate	kg/s	0.02	0.02	0.03	0.03
Outputs					
Heat Load	W	8139	8148	12080	12190
Air Dry-Bulb Temperature	°C	55.0	56.1	59.5	61.2
Refrigerant Temperature	°C	46.2	46.0	47.7	46.4
LMTD	°C	9.6	7.4	14.3	10.0
UA	W/K	848	1097	846	1216
NTU	-	0.97	1.34	0.97	1.48
Effectiveness	-	0.15	0.16	0.22	0.23
Refrigerant Pressure Drop	kPa	4.2	13.4	11.0	35.2
Airside DP	Pa	16.0	15.9	16.0	15.9
Air Heat Transfer Coefficient (Average)	W/m².K	82.9	100.7	82.9	100.7
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	1535.2	1493.7	2382.4	2505.6
Subcooling	°C	29.2	29.2	27.6	28.4
Charge in Tubes	kg	0.90	0.46	0.76	0.39

Table 20: Unit 4 – Compressor Performance Summary.

Compressor		**Baseline**	**18kBTU/Hr**		**24kBTU/Hr**	
Refrigerant	**-**	**R290**	**R290**	**R290**	**R290**	**R290**
Isentropic efficiency	-	0.61	0.70	0.70	0.70	0.70
Power	kW	2.1067	1.7364	1.7093	3.3152	3.31
Pressure Lift	kPa	1457.6	1556.3	1513.7	2947.1	2937.4
Effective Displacement Volume	cm³	26.394	26.309	26.309	37.866	37.866
Rotation Speed	RPM	3600	3600	3600	3600	3600

Table 21: Unit 4 – Expected Modified System Performances.

System		***Baseline***	***Alternative 1***		***Alternative 2***	
			Expected			
Refrigerant	**-**	**R290**	**R290**	**R290**	**R290**	**R290**
Condenser	-	BTFD9	BTFD9	NTFD5	BTFD9	NTFD5
Compressor	-	PSH356DG-C8DU4	-	-	-	-
Cooling Capacity	BTU/hr	17940	17991	18147	24045	24120
Compressor Power	kW	2.11	1.74	1.71	3.32	3.31
Fan Power	kW	0.28	0.28	0.28	0.28	0.28
Total Power	kW	2.39	2.02	1.99	3.60	3.59
COP	-	2.20	2.61	2.67	1.96	1.97
COP Gain	-	1.00	1.19	1.21	0.89	0.89

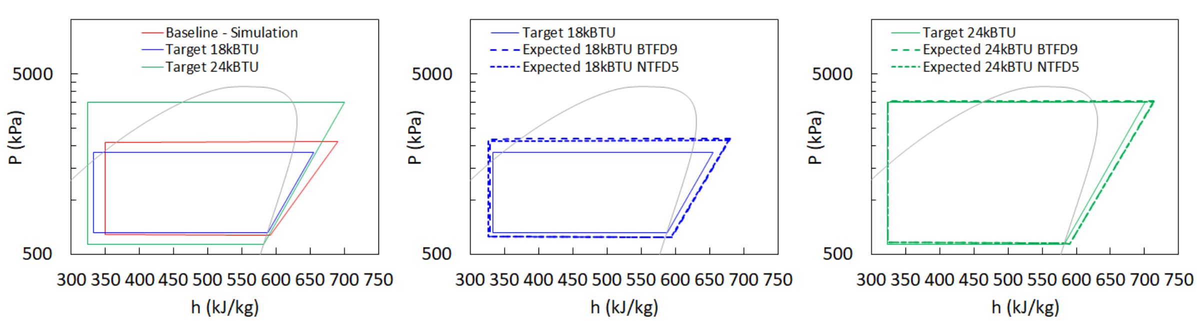

Figure 11. Unit 4 – Modified Systems P-h Diagrams.

Table 22: Unit 6 – Theoretical Cycle Re-Design Summary.

System			*Alternate 1*	*Alternate 2*	*Alternate 3*
		Simulation	**Target**		
Refrigerant	**-**	**R32**	**R32**	**R454B**	**R452B**
Condenser	-	BTFD9	-	-	-
Compressor	-	GMCC KSG226N1UMT	ZP20K5E	ZP21K5E	-
Cooling Capacity	BTU/hr	23115	23114	23114	23115
Compressor Power	kW	2.73	2.37	2.29	2.04
Fan Power	kW	8.46	9.75	10.10	11.31
Total Power	kW	2.73	2.37	2.29	2.04
COP	-	2.48	2.86	2.96	3.32
COP Gain	-	1.00	1.15	1.19	1.34

Table 23: Unit 6 – HX Analysis for R32

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3562	3562	3562	3562
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	9159	9416	9332	9113
Air Dry-Bulb Temperature	°C	53.63	55.35	54.27	55.24
Refrigerant Temperature	°C	49.78	46.15	47.40	50.47
LMTD	°C	19.94	9.46	15.13	20.57
UA	W/K	459.40	995.12	616.75	443.09
NTU	-	0.39	0.97	0.52	0.43
Refrigerant Pressure Drop	kPa	100.98	26.10	3.06	4.70
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	5543.00	2624.00	2353.00	2978.00
Subcooling	°C	4.48	9.04	8.10	5.07
Charge	kg	0.39	0.71	0.17	0.11

Table 24: Unit 6 – HX Analysis for R452B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3247	3247	3247	3247
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	7876	7964	7936	7866
Air Dry-Bulb Temperature	°C	52.52	53.94	53.06	53.99
Refrigerant Temperature	°C	47.41	46.05	46.53	47.61
LMTD	°C	15.49	8.09	12.37	15.72
UA	W/K	508.37	984.95	641.46	500.33
NTU	-	0.43	0.96	0.55	0.49
Refrigerant Pressure Drop	kPa	71.90	21.03	2.60	3.70
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	4252.00	2077.00	2103.00	2112.00
Subcooling	°C	6.14	8.20	7.99	6.89
Charge	kg	0.55	0.90	0.21	0.15

Table 25: Unit 6 – HX Analysis for R447B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3025	3025	3025	3025
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	7607	8241	8157	7914
Air Dry-Bulb Temperature	°C	52.41	54.19	53.25	54.04
Refrigerant Temperature	°C	50.00	46.24	47.63	51.40
LMTD	°C	20.58	10.45	15.92	22.14
UA	W/K	369.65	788.34	512.32	357.47
NTU	-	0.31	0.77	0.44	0.35
Refrigerant Pressure Drop	kPa	185.90	27.30	3.18	4.90
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	5396.00	2439.00	2397.00	3281.00
Subcooling	°C	0.00	6.05	5.17	1.22
Charge	kg	0.33	0.70	0.16	0.11

Table 26: Unit 6 – HX Analysis for R454B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46.01	46.01	46.01	46.01
Relative Humidity	%	16.37	16.37	16.37	16.37
Air Flowrate	m³/s	1.08	0.94	1.08	0.94
Refrigerant Pressure	kPa	3204	3204	3204	3204
Saturation Temperature at Inlet	°C	55.53	55.53	55.53	55.53
Refrigerant Temperature	°C	112.00	112.00	112.00	112.00
Mass Flow Rate	kg/s	0.03	0.03	0.03	0.03
Outputs					
Heat Load	W	7993	8094	8060	7976
Air Dry-Bulb Temperature	°C	52.61	54.06	53.16	54.10
Refrigerant Temperature	°C	47.59	46.06	46.61	47.91
LMTD	°C	15.95	8.28	12.72	16.40
UA	W/K	501.09	977.17	633.67	486.37
NTU	-	0.43	0.96	0.54	0.48
Refrigerant Pressure Drop	kPa	74.70	22.02	2.70	4.10
Airside DP	Pa	26.30	29.30	27.70	28.90
Air Heat Transfer Coefficient (Average)	W/m².K	109.57	126.69	128.70	130.84
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	4445.93	2140.00	2008.00	2201.00
Subcooling	°C	5.75	8.03	7.75	6.43
Charge	kg	0.51	0.87	0.20	0.14

Table 27: Unit 6 – Compressor Performance Summary.

		Baseline	***Alternate 1***	***Alternate 2***	***Alternate 3***
Refrigerant		***R32***	***R32***	***R454B***	***R452B***
Isentropic Efficiency	-	0.60	0.64	0.66	0.70
Volumetric Efficiency	-	-	0.87	0.90	-
Displacement Volume	cm³	-	19.34	20.31	-
Frequency	Hz	60	60	60	60
Effective Displacement	cm³	16.0	16.8	18.3	19.0
Compressor Power	kW	2.4	2.3	2.3	2.1

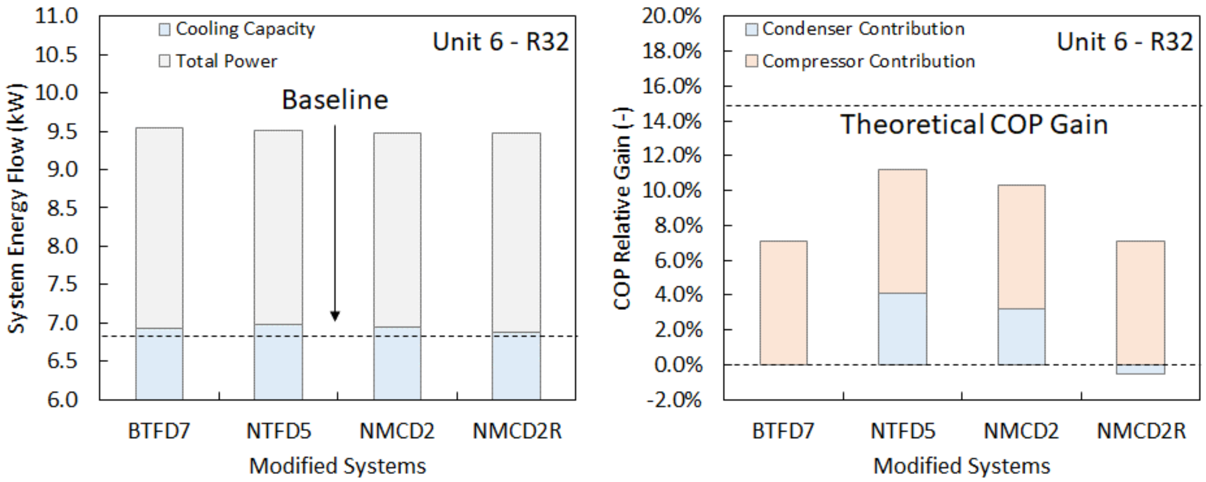

Figure 12. Unit 6 – System Level Analysis: Performance Results for R32.

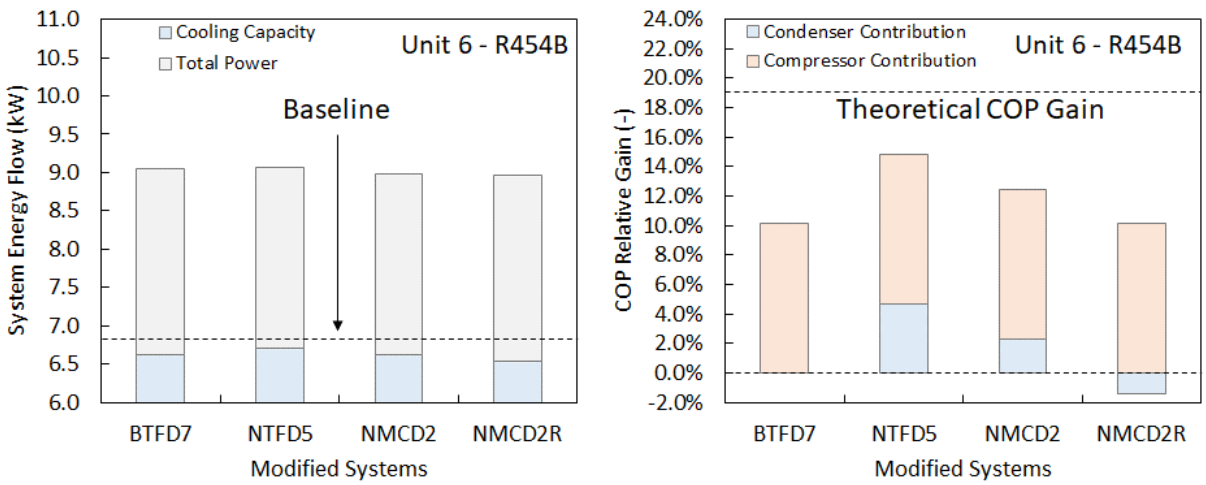

Figure 13. Unit 6 – System Level Analysis: Performance Results for R454B.

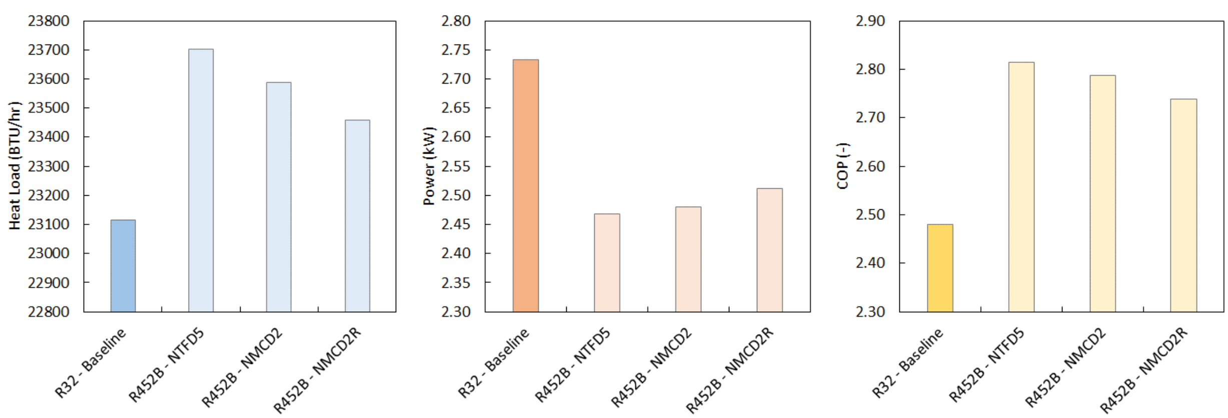

Figure 14. Unit 6 - Comparative System Performance Summary for R452B.

Table 28: Unit 10 – Theoretical Cycle Re-Design Summary.

System		*Baseline*	*Alternate 1*	*Alternate 2*	*Alternate 3*
		Simulation		**Target**	
Refrigerant	**-**	**R32**	**R452B**	**R447B**	**R454B**
Condenser	-	BTFD9	-	-	-
Compressor	-	ZP42K5E	ZP31K5E	ZP34K5E	ZP31K5E
Cooling Capacity	BTU/hr	29005	34311	31611	34608
Compressor Power	kW	3.84	2.81	2.31	2.65
Fan Power	kW	0.70	0.70	0.70	0.70
Total Power	kW	4.54	3.51	3.01	3.35
COP	-	1.87	2.87	3.08	3.03
COP Gain	-	1.00	1.53	1.64	1.62

Table 29: Unit 10 – HX Analysis for R32

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m^3/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3562	3562	3562	3562
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	10693	11074	11435	10669
Air Dry-Bulb Temperature	°C	54.1	57.0	54.9	55.8
Refrigerant Temperature	°C	55.2	52.9	49.3	55.4
LMTD	°C	22.8	19.8	15.9	22.5
UA	W/K	468	560	717	475
NTU	-	0.35	0.55	0.54	0.42
Refrigerant Pressure Drop	kPa	26.7	67.1	6.8	10.1
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	$W/m^2.K$	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	$W/m^2.K$	3823	4239	3050	3991
Subcooling	°C	0.00	1.75	6.17	0.00
Charge	kg	0.61	0.43	0.17	0.11

Table 30: Unit 10 – HX Analysis for R452B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m^3/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3247	3247	3247	3247
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	9549	9812	9751	9500
Air Dry-Bulb Temperature	°C	53.2	55.8	53.6	54.8
Refrigerant Temperature	°C	49.5	46.4	47.1	50.1
LMTD	°C	16.7	9.2	12.2	17.1
UA	W/K	573	1067	802	557
NTU	-	0.43	1.04	0.60	0.49
Refrigerant Pressure Drop	kPa	17.2	47.1	5.6	8.2
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	$W/m^2.K$	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	$W/m^2.K$	2974	3038	2537	2812
Subcooling	°C	4.82	7.51	7.34	4.38
Charge	kg	0.83	0.79	0.23	0.15

Table 31: Unit 10 – HX Analysis for R447B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m³/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3025	3025	3025	3025
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	9016	9632	9923	9085
Air Dry-Bulb Temperature	°C	52.9	55.6	53.8	54.4
Refrigerant Temperature	°C	52.4	51.7	49.9	52.7
LMTD	°C	20.4	18.9	17.1	20.3
UA	W/K	441	510	579	448
NTU	-	0.33	0.50	0.43	0.40
Refrigerant Pressure Drop	kPa	29.2	67.3	7.2	10.8
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	W/m².K	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	3528	3833	2999	3458
Subcooling	°C	0.00	0.00	2.67	0.00
Charge	kg	0.56	0.45	0.17	0.10

Table 32: Unit 10 – HX Analysis for R454B

Condenser					
Inputs		***BTFD7***	***NTFD5***	***NMCD2***	***NMCD2R***
Air Dry-Bulb Temperature	°C	46	46	46	46
Relative Humidity	%	16.4	16.4	16.4	16.4
Air Flowrate	m³/s	1.23	0.94	1.23	1.04
Refrigerant Pressure	kPa	3204	3204	3204	3204
Saturation Temperature at Inlet	°C	56	56	56	56
Refrigerant Temperature	°C	100	100	100	100
Mass Flow Rate	kg/s	0.04	0.04	0.04	0.04
Outputs					
Heat Load	W	9634	9953	9901	9597
Air Dry-Bulb Temperature	°C	53.3	55.9	53.8	54.9
Refrigerant Temperature	°C	50.4	46.7	47.3	50.8
LMTD	°C	17.9	10.5	12.7	18.0
UA	W/K	537	952	782	532
NTU	-	0.40	0.93	0.59	0.47
Refrigerant Pressure Drop	kPa	18.8	51.1	5.9	8.7
Airside DP	Pa	29.6	26.7	25.7	26.0
Air Heat Transfer Coefficient (Average)	W/m².K	100.4	117.0	124.8	125.3
Refrigerant Heat Transfer Coefficient (Average)	W/m².K	3095	3211	2633	2942
Subcooling	°C	3.71	6.98	6.98	3.40
Charge	kg	0.78	0.71	0.22	0.14

Table 33. Unit 10 - Compressor Performance Summary.

Compressor			Copeland ZP31K5E-PFV	Copeland ZP34K5E-PFV	Copeland ZP31K5E-PFV
Refrigerant		***R32***	***R452B***	***R447B***	***R454B***
Isentropic Efficiency	-	0.439	0.638	0.662	0.662
Volumetric Efficiency	-		0.760	0.803	0.790
Displacement Volume	cm³		29.350	29.350	29.350
Frequency	Hz	50	50	50	50
Effective Displacement Volume	cm³	19.646	22.301	23.581	23.183

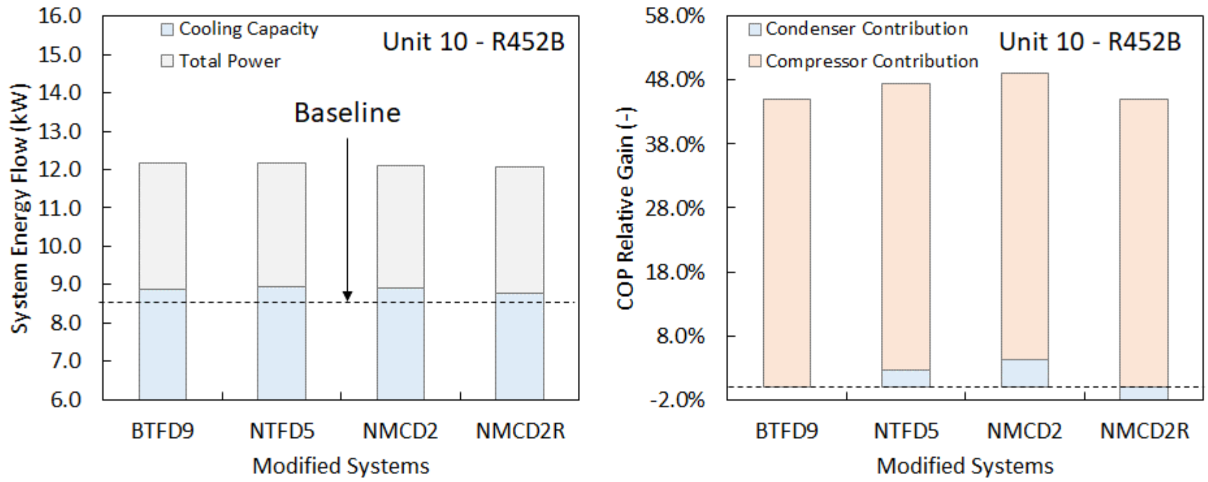

Figure 15. Unit 10 – System Level Analysis: Performance Results for R452B.

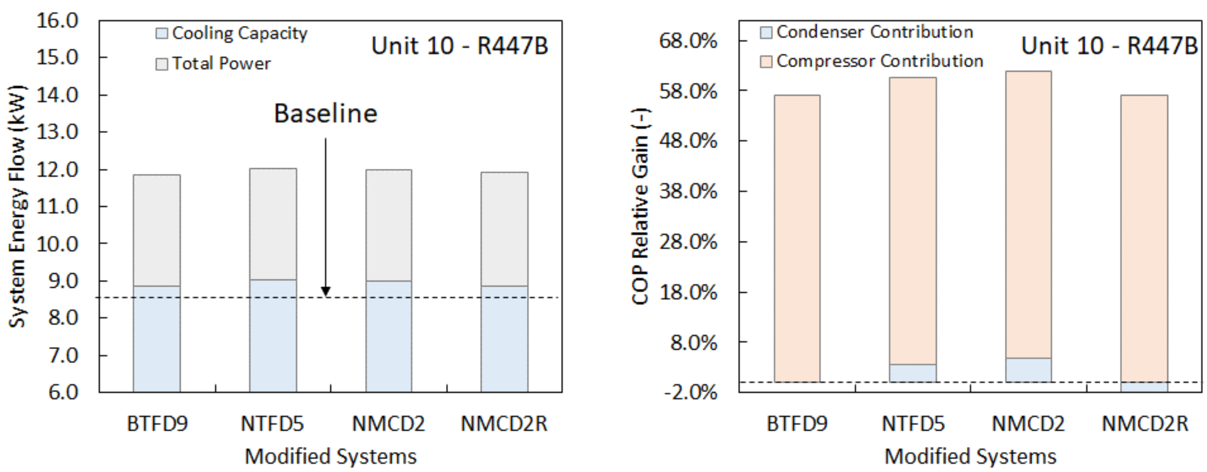

Figure 16. Unit 10 – System Level Analysis: Performance Results for R447B.

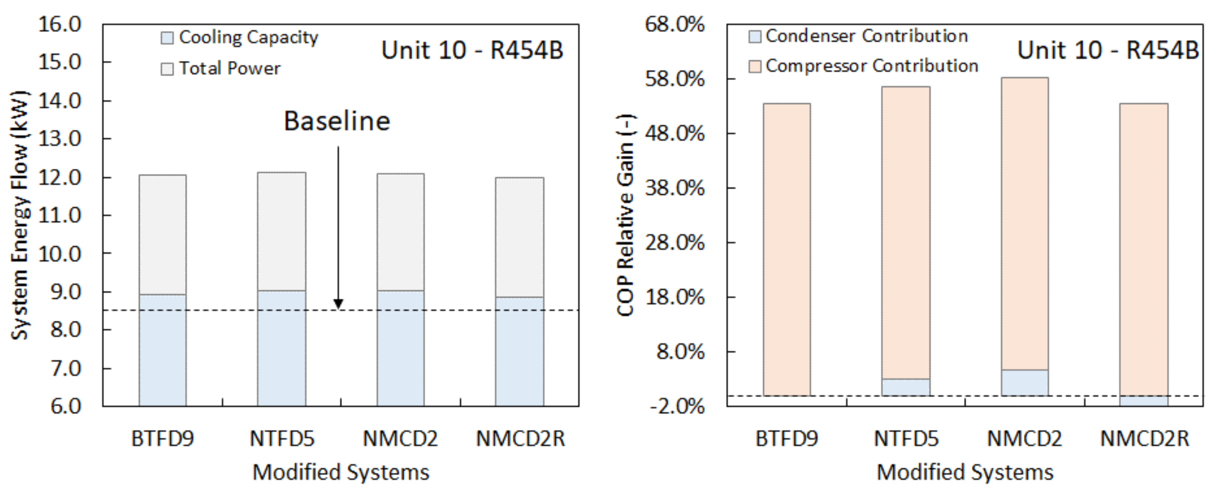

Figure 17. Unit 10 – System Level Analysis: Performance Results for R454B.

APPENDIX B – Unit 6 Initial Tests, Scope Change and Test Setup

Unit 6 was initially modified and tested at a separate facility and the test results exhibited a considerably lower cooling capacity than expected (~20%). Power consumption was also greater than designed. The condensing pressures were 20-30% above expectations, and the refrigerant pressure drop across the condenser was at least twice as high as expected. The outlet conditions of the condenser for R32 were possibly in two-phase. The condenser airflow rate was 10%-15% lower than expected. Superheat hardly met the setpoint values.

OTS formulated a hypothesis that the degraded performance was due to the condenser not being fully active; i.e. some regions were not transferring heat. One way for this to happen is by having severe maldistribution thus impeding heat transfer, increasing pressure drop – thus the condensing pressure – and possibly reducing the flow rate as well; all of which were observed in the test data. OTS tested the hypothesis by running hot water through the HX and observing with a thermal camera (Figure 18), which revealed the "dead zones". Upon inspection by the manufacturer, it was confirmed there were blockages in some of the tubes. A new HX was built, but the same pattern was observed, forcing OTS to remove the condenser replacement from the scope given the project schedule.

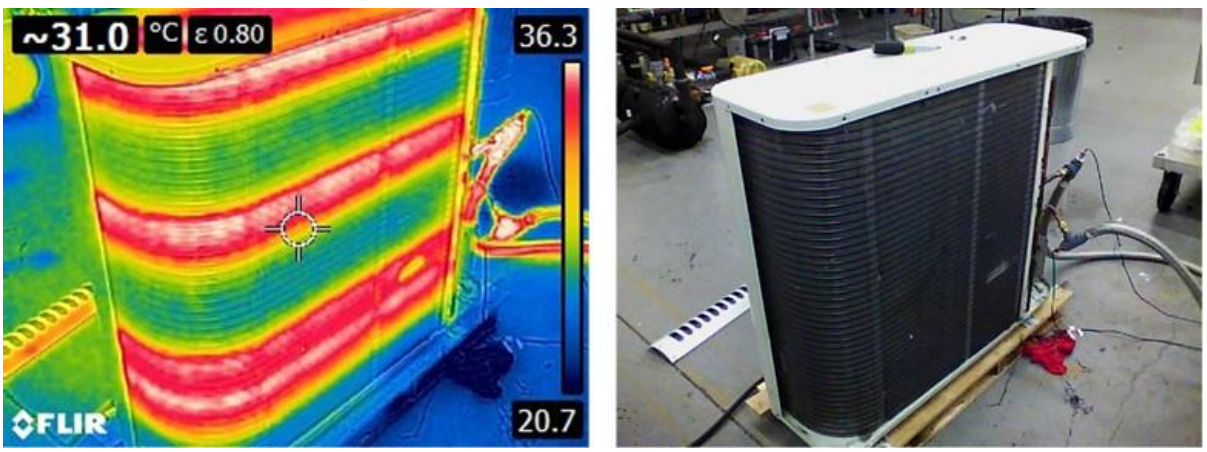

Figure 18. Hot Water Thermal Imaging.

Given the challenges with the initial tests and unit modification, the scope was re-defined. The original test plan was changed to accommodate time and resources as appropriate. Table 34 outlines the major changes to the scope. The tests were conducted at the OTS laboratory (Figure 19 to Figure 22). A summary of the key differences between the test setups (original and at OTS) is presented in Table 35.

Table 34: Test Scope Change.

Unit	Refrigerant	Test	Original Scope		New Scope	
			Planned	Actual	Planned	Actual
Unit 1	R290	Charge Optimization	Yes	No	No	No
		Performance Tests	Yes	No	No	No
Unit 6	R32 (Baseline)	Charge Optimization	No	No	Yes	Yes
		Performance Tests	No	No	Yes	Yes
	R32 (Modified)	Charge Optimization	Yes	Yes	Yes	Yes
		Performance Tests	Yes	Yes	Yes	Yes
	R454B	Charge Optimization	Yes	Yes	Yes	Yes
		Performance Tests	Yes	Yes	Yes	Yes
		Leak Tests	Yes	Yes	No	No
Unit 10	R32 (Baseline)	Charge Optimization	No	No	Yes	Yes*
		Performance Tests	No	No	Yes	Yes*
	R447B	Charge Optimization	Yes	No	Yes	Yes
		Performance Tests	Yes	No	Yes	Yes
		Leak Tests	Yes	No	Yes	Yes
	R452B	Charge Optimization	Yes	No	Yes	Yes
		Performance Tests	Yes	No	Yes	Yes
		Leak Tests	Yes	No	No	No

** Tests were conducted; however, no useful data was obtained (see section 5.2)*

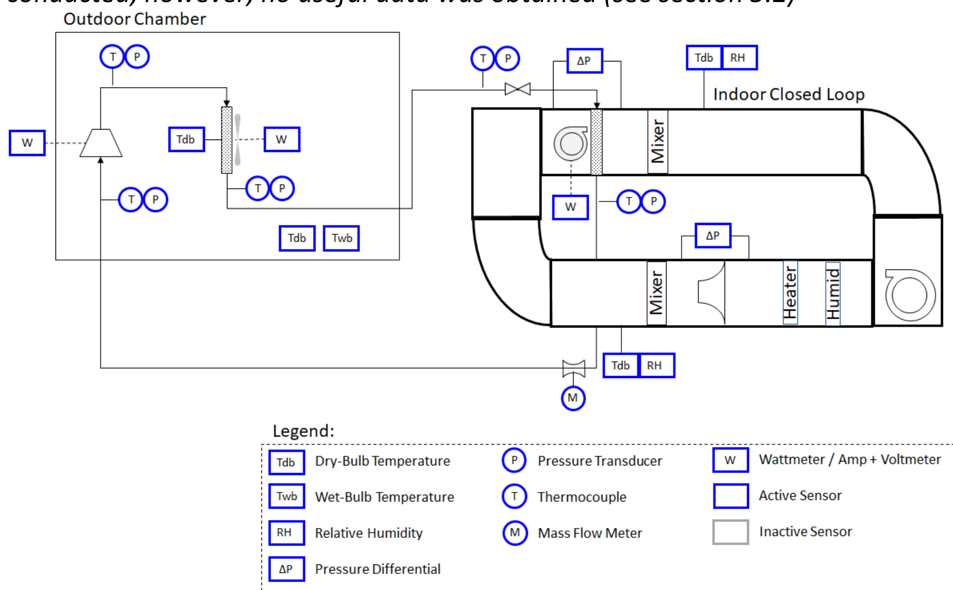

Figure 19. Test Diagram.

Figure 20. OTS Setup: outdoor chamber (left), Unit 10 and frequency converter inside chamber (right).

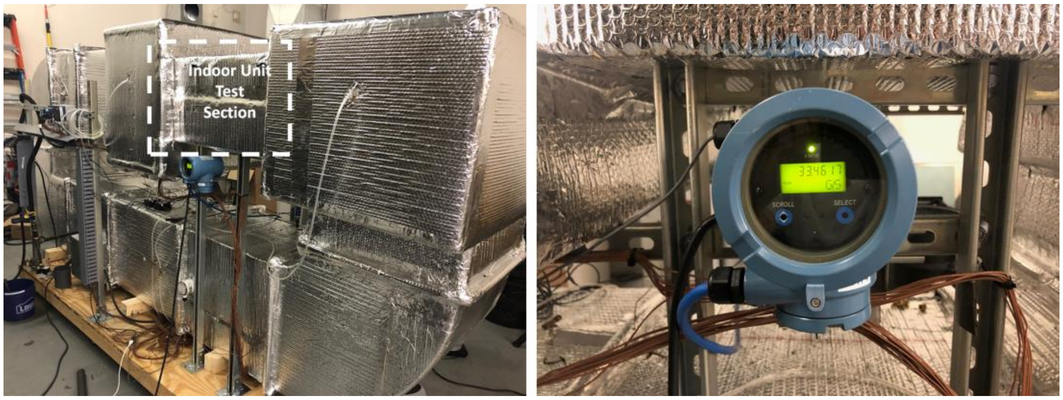

Figure 21. OTS Setup: indoor closed loop left side view (left), refrigerant mass flow meter (right).

Figure 22. OTS Setup: indoor closed loop right side view (left), vapor / liquid lines, sight glasses and TXV (right).

Table 35: List of Measurements.

Component	Refrigerant Side			Air Side		
	Measurement	**Original Scope**	**New Scope**	**Measurement**	**Original Scope**	**New Scope**
Condenser	Inlet Temperature	Yes	Yes	Air Flow Rate	Yes	**No**
	Inlet Pressure	Yes	Yes	Air Pressure Drop	No	No
	Outlet Temperature	Yes	Yes	Fan Power	No	**Yes**
	Outlet Pressure	Yes	Yes	Inlet Dry-bulb	Yes	Yes
	Subcooling	Yes*	**Yes**	Inlet Wet-Bulb / RH	Yes	Yes
				Outlet Dry-bulb	Yes	Yes
				Outlet Wet-Bulb / RH	Yes	Yes
Evaporator	Inlet Temperature	No	No	Air Flow Rate	Yes	Yes
	Inlet Pressure	No	No	Air Pressure Drop	No	**Yes****
	Outlet Temperature	Yes	Yes	Blower Power	No	**Yes**
	Outlet Pressure	Yes	Yes	Inlet Dry-bulb	Yes	Yes
	Superheat	Yes*	**Yes**	Inlet Wet-Bulb / RH	Yes	Yes
	Refrigerant Mass Flow Rate	No	**Yes**	Outlet Dry-bulb	Yes	Yes
				Outlet Wet-Bulb / RH	Yes	Yes
Compressor	Suction Temperature	Yes	Yes			
	Suction Pressure	Yes	Yes			
	Discharge Temperature	Yes	Yes			
	Discharge Pressure	Yes	Yes			
	Compressor Power	No	**Yes**			
Expansion Device	Suction Temperature	Yes	Yes			
	Suction Pressure	Yes	Yes			
	Discharge Temperature	No	No			
	Discharge Pressure	No	No			

Charge Optimization

The charge optimization procedure as originally scoped was not implemented due to the following:

a. The systems responded less sensitively to charge on subcooling and superheat, which were difficult to control with charging alone. A manual valve was added (Unit 10 exhibited little expansion) such that superheat could be better controlled. The valve also allowed for better control over the pressure levels compared to charge levels alone.

b. For the modified systems, the charge was gradually increased, departing from the original charge from PRAHA I tests, until it was observed that the superheat and subcooling better matched design conditions for validation purposes.

c. For the refrigerant blends, removing charge could result in fractionation (evaluated as a separate task), so it was decided to only incrementally increase charge, without removing it. For this procedure, a small gradual increment is necessary to avoid overcharging.

APPENDIX C - Unit 6 Raw and Processed Tested Data

Table 36: Unit 6 – Performance Tests

		Baseline (35°C)	**Alternate 1 (35°C)**	**Alternate 2 (35°C)**	**Baseline (46°C)**	**Alternate 1 (46°C)**	**Alternate 2 (46°C)**
Refrigerant	-	**R32**	**R32**	**R454B**	**R32**	**R32**	**R454B**
Charge	lb	3.83	4.27	5.02	3.83	4.27	5.02
Cooling Capacity	BTU/hr	25193	23585	21966	23390	21450	21821
Energy Balance	%	-2.28%	-4.66%	-3.06%	-1.78%	-4.42%	-7.61%
Compressor Power	kW	2.11	1.79	1.77	2.71	2.32	2.25
Fan Power	kW	0.32	0.33	0.33	0.40	0.42	0.42
Total Power	kW	2.43	2.12	2.10	3.10	2.74	2.67
EER	BTU/hr.W	10.36	11.12	10.44	7.54	7.84	8.17
Evaporator							
Airside							
Inlet							
Air Flow Rate	m^3/s	0.31	0.31	0.31	0.31	0.31	0.30

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	-	**R32**	**R32**	**R454B**	**R32**	**R32**	**R454B**
Temperature	°C	27.0	27.0	27.0	29.0	29.0	29.0
Wet Bulb	°C	19.68	19.68	19.68	21.33	21.33	21.34
Relative Humidity	%	51.0	51.0	51.0	51.0	51.0	51.0
Humidity Ratio	kg/kg	0.011	0.011	0.011	0.013	0.013	0.013
Density	kg/m³	1.15	1.15	1.15	1.14	1.14	1.14
Enthalpy	kJ/kg	56.3	56.2	56.2	61.9	62.0	62.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0	1.0
Outlet							
Air Flow Rate	m³/s	0.29	0.29	0.29	0.29	0.29	0.29
Temperature	°C	14.3	15.1	15.8	16.9	17.7	18.1
Wet Bulb	°C	14.35	14.35	14.35	14.35	14.35	14.35
Relative Humidity	%	83.6	82.4	80.0	84.5	83.3	81.3
Humidity Ratio	kg/kg	0.008	0.009	0.009	0.010	0.011	0.011
Density	kg/m³	1.21	1.20	1.20	1.19	1.19	1.19
Enthalpy	kJ/kg	35.8	37.5	38.5	42.7	44.7	45.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0	1.0
Refrigerant Side							
Inlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	4.58	6.19	4.76	7.49	8.33	8.47
Pressure	kPa	939.13	986.90	876.76	1026.70	1053.10	979.34
Quality	-	0.16	0.19	0.20	0.20	0.25	0.27
Enthalpy	kJ/kg	273.64	269.78	268.60	301.30	291.37	289.89
Entropy	kJ/kg.K	1.20	1.25	1.30	1.27	1.32	1.37
Outlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	8.08	9.26	9.46	9.08	13.54	11.80
Pressure	kPa	939	987	877	1027	1053	979
Superheat	K	3.50	3.07	4.89	1.59	5.20	3.58
Enthalpy	kJ/kg	520.49	520.22	473.43	518.52	523.27	472.93
Entropy	kJ/kg.K	2.15	2.15	2.03	2.13	2.15	2.02
HX Level							
Average Cooling Capacity	kW	7.384	6.912	6.438	6.855	6.287	6.395
Energy Balance (Qair - Qref)/Qref	%	-2.28%	-4.66%	-3.06%	-1.78%	-4.42%	-7.61%
Sensible Heat Ratio	-	0.64	0.66	0.65	0.64	0.67	0.66
Superheat	K	3.500	3.066	4.885	1.593	5.205	3.582
LMTD	K	13.783	12.822	14.015	13.985	12.184	13.041
UA	kW/K	0.573	0.539	0.459	0.550	0.516	0.490
Air Pressure Drop	Pa	N/A	N/A	N/A	N/A	N/A	N/A
Refrigerant Pressure Drop	kPa	N/A	N/A	N/A	N/A	N/A	N/A
Fan Power	kW	0.120	0.127	0.134	0.196	0.217	0.217
Condenser							
Airside							
Inlet							
Air Flow Rate	m³/s	0.9516	0.9838	1.0091	0.9580	0.9735	1.0613
Temperature	°C	35.01	34.76	35.12	46.06	45.93	46.05
Wet Bulb	°C	20.0	19.8	20.0	27.4	27.3	27.4
Humidity Ratio	kg/kg	0.008	0.008	0.009	0.015	0.015	0.015
Density	kg/m³	1.13	1.13	1.13	1.08	1.08	1.08
Enthalpy	kJ/kg	57.0	56.4	57.2	86.2	85.8	86.2
Specific Heat	kJ/kg.K	1.01	1.01	1.01	1.02	1.02	1.02
Outlet							
Air Flow Rate	m³/s	0.98	1.01	1.03	0.98	1.00	1.09
Temperature	°C	43.40	42.29	42.08	54.74	53.60	53.19
Wet Bulb	°C	22.4	22.0	22.1	29.3	29.0	29.0
Humidity Ratio	kg/kg	0.008	0.008	0.009	0.015	0.015	0.015
Density	kg/m³	1.10	1.10	1.10	1.05	1.05	1.05
Enthalpy	kJ/kg	65.6	64.1	64.3	95.2	93.7	93.6
Specific Heat	kJ/kg.K	1.01	1.01	1.01	1.02	1.02	1.02

		Baseline (35°C)	Alternate 1 (35°C)	Alternate 2 (35°C)	Baseline (46°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	-	R32	R32	R454B	R32	R32	R454B
Refrigerant Side							
Inlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	89.78	82.73	78.33	109.00	107.24	90.75
Pressure	kPa	2724.15	2643.18	2360.90	3464.77	3365.88	3010.13
Superheat	K	45.9	40.1	35.9	54.7	54.2	38.0
Enthalpy	kJ/kg	580.73	573.07	523.39	594.42	593.52	528.90
Entropy	kJ/kg.K	2.20	2.18	2.08	2.21	2.21	2.07
Outlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	39.17	34.52	34.68	51.79	45.63	45.79
Pressure	kPa	2675.81	2598.75	2310.89	3416.39	3324.50	2958.91
Subcooling	K	4.00	7.44	5.59	1.89	6.84	5.07
Enthalpy	kJ/kg	273.6	264.0	266.4	301.3	287.0	287.8
Entropy	kJ/kg.K	1.24	1.21	1.28	1.33	1.28	1.34
HX Level							
Heat Rejection	kW	9.19	8.53	8.08	9.25	8.31	8.42
Subcooling	K	4.00	7.44	5.59	1.89	6.84	5.07
Refrigerant Pressure Drop	kPa	48.34	44.43	50.01	48.38	41.38	51.22
Fan Power	kW	0.20	0.20	0.20	0.20	0.20	0.20
TXV							
Refrigerant							
Inlet		[4]			[4]		
Temperature	°C	30.64	37.31	35.83	39.70	47.55	46.78
Pressure	kPa	1991.01	2587.20	2301.38	2528.52	3317.42	2945.62
Subcooling	°C	*(Two-Phase)	4.47	4.27	*(Two-Phase)	4.83	3.88
Enthalpy	kJ/kg	*(Two-Phase)	269.8	268.6	*(Two-Phase)	291.4	289.9
Entropy	kJ/kg.K	*(Two-Phase)	1.233	1.284	*(Two-Phase)	1.299	1.349
Compressor							
Refrigerant							
Inlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	11.57	12.55	12.76	13.81	17.63	13.07
Pressure	kPa	936.06	984.95	874.98	1024.91	1052.17	969.56
Superheat	K	7.09	6.43	8.26	6.38	9.32	5.18
Enthalpy	kJ/kg	524.9	524.4	477.3	524.6	528.3	474.8
Entropy	kJ/kg.K	2.170	2.161	2.048	2.156	2.166	2.028
Outlet							
Mass Flow Rate	kg/s	0.030	0.028	0.031	0.032	0.027	0.035
Temperature	°C	89.8	82.7	78.3	109.0	107.2	90.8
Pressure	kPa	2724.2	2643.2	2360.9	3464.8	3365.9	3010.1
Superheat	K	45.9	40.1	35.9	54.7	54.2	38.0
Enthalpy	kJ/kg	580.7	573.1	523.4	594.4	593.5	528.9
Entropy	kJ/kg.K	2.200	2.183	2.084	2.205	2.207	2.074
Compressor Level							
Power Consumption	kW	2.11	1.79	1.77	2.71	2.32	2.25
Isentropic Efficiency	-	0.80	0.84	0.73	0.74	0.76	0.69
Frequency	Hz	60	60	60	60	60	60

[4] The baseline configuration does not have an expansion valve, the state point herein presented refers to measurement readings at indoor unit inlet.

APPENDIX D - Unit 10 Baseline Re-Test

Prior to modifying Unit 10, it was tested in its received, baseline condition with the components used to test during PRAHA I. Given the results of the data review in Activity 1, and the challenges experienced in the initial testing of Unit 6, the project team agreed that testing the units in their baseline configuration would be important for more accurate comparison.

The electrical components for Unit 10 have phase mismatch, i.e. the fan and blower are three-phase while the compressor is single-phase, but all operate in 50Hz. OTS does not have a Variable Frequency Drive (VFD) for single-phase motors, requiring the use of a frequency converter to reduce the compressor speed. According to the baseline data from PRAHA 1, the total power consumption of Unit 10 varied between 3.5-4.5kW; OTS has a 5.0kW converter, which should be sufficiently large to meet testing needs.

Initial tests suggested that the compressor peak start current exceeds the converter threshold, causing the latter to trip and shut off. Although the blower and the fan run normally with the converter, the compressor alone does not. The compressor motor was tested at 60Hz direct from the grid and it works, thus confirming that the issue is indeed the peak current. A soft starter was acquired with the objective to mitigate the issue. The soft starter capacitors weren't fast enough to smooth the peak current, however, thus requiring manual charging, which eventually lead to component failure.

The last tentative to run the baseline was connecting the compressor to 60Hz and the fans to 50Hz. The refrigerant mass flow rate was too high impeding full condensation and full evaporation. A manual TXV was added along with two sight glasses in the liquid and vapor lines and reasonable data was obtained for the 35°C ambient temperature condition. While attempting to test the system under the 46°C ambient temperature, the compressor overheats and shuts down. Heavier gauge wire, new contactors and switch bypass were unsuccessfully employed. In the interest of time, the baseline re-tests were discontinued. The analysis will be carried out using the original baseline performance for comparison purposes.

APPENDIX E - Unit 10 Raw and Processed Tested Data

Table 37: Unit 10 – Performance Tests.

		Alternate 1 (35°C)	Alternate 2 (35°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	-	**R447B**	**R452B**	**R447B**	**R452B**
Charge	lb	6.625	6.625	6.625	6.625
Cooling Capacity	BTU/hr	32195	28128	31073	30292
Energy Balance	%	7.52%	-3.29%	4.21%	1.21%
Compressor Power	kW	2.67	2.40	3.16	2.93
Fan Power	kW	0.95	0.98	0.95	0.97
Total Power	kW	3.62	3.38	4.11	3.90
EER	BTU/hr.W	8.88	8.33	7.55	7.76
Evaporator					
Airside					
Inlet					
Air Flow Rate	m^3/s	0.74	0.73	0.74	0.73
Temperature	°C	27.0	27.0	29.0	29.0
Wet Bulb	°C	19.68	19.69	21.33	21.34
Relative Humidity	%	51.0	51.0	51.0	51.0
Humidity Ratio	kg/kg	0.011	0.011	0.013	0.013
Density	kg/m^3	1.15	1.15	1.14	1.14
Enthalpy	kJ/kg	56.2	56.3	62.0	62.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0

		Alternate 1 (35°C)	Alternate 2 (35°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	**-**	**R447B**	**R452B**	**R447B**	**R452B**
Outlet					
Air Flow Rate	m³/s	0.72	0.71	0.71	0.70
Temperature	°C	17.4	19.1	19.7	19.8
Wet Bulb	°C	15.80	16.64	17.91	18.06
Relative Humidity	%	85.1	78.5	84.7	84.5
Humidity Ratio	kg/kg	0.011	0.011	0.012	0.012
Density	kg/m³	1.19	1.18	1.18	1.18
Enthalpy	kJ/kg	44.3	46.8	50.7	51.1
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0
Refrigerant Side					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	9.81	5.53	12.90	13.09
Pressure	kPa	996.41	907.20	1085.49	1133.86
Quality	-	0.19	0.19	0.27	0.25
Enthalpy	kJ/kg	272.43	264.74	296.09	288.71
Entropy	kJ/kg.K	1.32	1.30	1.40	1.38
Outlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	15.22	25.20	16.76	23.36
Pressure	kPa	996	907	1085	1134
Superheat	K	5.79	19.82	4.42	10.47
Enthalpy	kJ/kg	477.29	485.20	476.43	477.36
Entropy	kJ/kg.K	2.04	2.09	2.03	2.03
HX Level					
Average Cooling Capacity	kW	9.436	8.244	9.107	8.878
Energy Balance (Qair - Qref)/Qref	%	7.52%	-3.29%	4.21%	1.21%
Sensible Heat Ratio	-	0.81	0.85	0.83	0.87
Superheat	K	5.794	19.818	4.422	10.474
LMTD	K	9.534	5.829	9.222	6.171
UA	kW/K	0.990	1.414	0.988	1.439
Air Pressure Drop	Pa	N/A	N/A	N/A	N/A
Refrigerant Pressure Drop	kPa	N/A	N/A	N/A	N/A
Fan Power	kW	0.502	0.523	0.501	0.519
Condenser					
Airside					
Inlet					
Air Flow Rate	m³/s	1.44	1.50	1.44	1.42
Temperature	°C	35.03	35.08	46.14	46.22
Wet Bulb	°C	20.0	20.0	27.4	27.5
Humidity Ratio	kg/kg	0.008	0.009	0.016	0.016
Density	kg/m³	1.13	1.13	1.08	1.07
Enthalpy	kJ/kg	57.0	57.2	86.5	86.7
Specific Heat	kJ/kg.K	1.01	1.01	1.02	1.02
Outlet					
Air Flow Rate	m³/s	1.47	1.53	1.48	1.45
Temperature	°C	41.90	40.83	53.36	53.26
Wet Bulb	°C	22.0	21.7	29.0	29.1
Humidity Ratio	kg/kg	0.008	0.009	0.016	0.016
Density	kg/m³	1.10	1.11	1.05	1.05
Enthalpy	kJ/kg	64.0	63.0	94.0	94.0
Specific Heat	kJ/kg.K	1.01	1.01	1.02	1.02
		0.00010	0.00038	0.00011	-0.00001
Refrigerant Side					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047

		Alternate 1 (35°C)	Alternate 2 (35°C)	Alternate 1 (46°C)	Alternate 2 (46°C)
Refrigerant	**-**	**R447B**	**R452B**	**R447B**	**R452B**
Temperature	°C	78.84	92.46	93.29	97.45
Pressure	kPa	2493.84	2600.61	3199.13	3357.43
Superheat	K	31.5	46.5	35.3	40.4
Enthalpy	kJ/kg	522.20	532.28	529.64	527.68
Entropy	kJ/kg.K	2.09	2.11	2.08	2.07
Outlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	40.68	35.54	53.44	48.65
Pressure	kPa	2481.63	2599.27	3187.26	3351.92
Subcooling	K	3.37	9.26	1.62	7.33
Enthalpy	kJ/kg	274.8	266.6	300.2	291.9
Entropy	kJ/kg.K	1.32	1.29	1.39	1.37
HX Level					
Heat Rejection	kW	11.39	9.94	11.59	11.10
Energy Balance (Qair - Qref)	kW	N/A	N/A	N/A	N/A
Subcooling	K	3.37	9.26	1.62	7.33
Air Pressure Drop	Pa	-	-	-	-
Refrigerant Pressure Drop	kPa	12.21	1.34	11.87	5.51
Fan Power	kW	0.45	0.45	0.45	0.45
TXV					
Refrigerant					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	39.42	34.55	51.55	47.11
Pressure	kPa	2462.98	2583.59	3166.49	3331.97
Subcooling	°C	4.31	9.99	3.21	8.59
Enthalpy	kJ/kg	272.4	264.7	296.1	288.7
Entropy	kJ/kg.K	1.310	1.284	1.382	1.358
Compressor					
Refrigerant					
Inlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	16.84	26.01	17.17	24.96
Pressure	kPa	993.13	902.34	1082.17	1128.72
Superheat	K	7.52	20.81	4.94	12.23
Enthalpy	kJ/kg	479.3	486.2	477.0	479.4
Entropy	kJ/kg.K	2.052	2.090	2.035	2.042
Outlet					
Mass Flow Rate	kg/s	0.046	0.037	0.051	0.047
Temperature	°C	78.8	92.5	93.3	97.5
Pressure	kPa	2493.8	2600.6	3199.1	3357.4
Superheat	K	31.5	46.5	35.3	40.4
Enthalpy	kJ/kg	522.2	532.3	529.6	527.7
Entropy	kJ/kg.K	2.087	2.112	2.082	2.073
Compressor Level					
Power Consumption	kW	2.67	2.40	3.16	2.93
Isentropic Efficiency	-	0.72	0.83	0.68	0.77
Frequency	Hz	60	60	60	60

Table 38: Unit 10 – R447B Leak Tests

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Charge	lb	6.625	4.27	6.625	4.23	6.77

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Cooling Capacity	BTU/hr	31073	14216	30865	15171	30587
Energy Balance	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Compressor Power	kW	3.18	2.93	3.18	2.94	-
Fan Power	kW	0.95	0.98	0.98	0.98	0.98
Total Power	kW	4.13	3.90	4.16	3.92	-
EER	BTU/hr.W	7.52	3.64	7.42	3.87	-
Evaporator						
Airside						
Inlet						
Air Flow Rate	m³/s	0.74	0.73	0.74	0.73	0.74
Temperature	°C	29.0	29.0	29.0	29.0	29.0
Wet Bulb	°C	21.33	21.34	21.34	21.34	21.34
Relative Humidity	%	51.0	51.0	51.0	51.0	51.0
Humidity Ratio	kg/kg	0.013	0.013	0.013	0.013	0.013
Density	kg/m³	1.14	1.14	1.14	1.14	1.14
Enthalpy	kJ/kg	62.0	62.0	62.0	62.0	62.0
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0
Outlet						
Air Flow Rate	m³/s	0.71	0.72	0.71	0.72	0.71
Temperature	°C	19.7	23.3	19.6	23.2	19.7
Wet Bulb	°C	17.91	19.87	18.08	19.77	18.05
Relative Humidity	%	84.7	73.1	86.3	73.6	86.0
Humidity Ratio	kg/kg	0.012	0.013	0.012	0.013	0.012
Density	kg/m³	1.18	1.16	1.18	1.16	1.18
Enthalpy	kJ/kg	50.7	57.0	51.2	56.7	51.1
Specific Heat	kJ/kg.K	1.0	1.0	1.0	1.0	1.0
Refrigerant Side						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	12.90	2.61	12.94	2.81	12.75
Pressure	kPa	1085.49	794.22	1086.62	799.23	1080.50
Quality	-	0.27	0.30	0.27	0.30	0.27
Enthalpy	kJ/kg	296.09	291.52	296.48	290.79	296.24
Entropy	kJ/kg.K	1.40	1.40	1.41	1.40	1.41
Outlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	16.76	28.23	17.07	27.95	17.01
Pressure	kPa	1085	794	1087	799	1080
Superheat	K	4.42	26.24	4.70	25.76	4.82
Enthalpy	kJ/kg	476.43	496.65	476.77	496.25	476.88
Entropy	kJ/kg.K	2.03	2.14	2.03	2.13	2.03
HX Level						
Average Cooling Capacity	kW	9.107	4.167	9.046	4.446	8.965
Energy Balance (Qair – Qref)/Qref	%	4.21%	-34.72%	0.35%	-31.55%	1.87%
Sensible Heat Ratio	-	0.83	1.18	0.90	1.12	0.89
Superheat	K	4.422	26.235	4.695	25.756	4.823
LMTD	K	9.222	6.051	9.065	6.501	9.217
UA	kW/K	0.988	0.689	0.998	0.684	0.973
Fan Power	kW	0.501	0.524	0.524	0.524	0.524
Condenser						
Airside						
Inlet						
Air Flow Rate	m³/s	1.44	1.49	1.42	1.48	1.42
Temperature	°C	46.14	46.08	46.21	45.77	46.02
Wet Bulb	°C	27.4	27.4	27.5	27.2	27.4
Humidity Ratio	kg/kg	0.016	0.015	0.016	0.015	0.015
Density	kg/m³	1.08	1.08	1.07	1.08	1.08
Enthalpy	kJ/kg	86.5	86.3	86.7	85.3	86.1
Specific Heat	kJ/kg.K	1.02	1.02	1.02	1.02	1.02

System			***Liquid Line Leak***		***Vapor Line Leak***	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	**-**	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**
Outlet						
Air Flow Rate	m³/s	1.48	1.52	1.46	1.50	1.46
Temperature	°C	53.36	51.27	53.52	51.05	53.28
Wet Bulb	°C	29.0	28.6	29.1	28.4	29.0
Humidity Ratio	kg/kg	0.016	0.015	0.016	0.015	0.015
Density	kg/m³	1.05	1.06	1.05	1.06	1.05
Enthalpy	kJ/kg	94.0	91.7	94.3	90.8	93.6
Specific Heat	kJ/kg.K	1.02	1.02	1.02	1.02	1.02
Refrigerant Side						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	93.29	121.77	94.07	120.31	94.34
Pressure	kPa	3199.13	2846.79	3200.02	2847.47	3175.47
Superheat	K	35.3	68.9	36.1	67.4	36.7
Enthalpy	kJ/kg	529.64	569.70	530.67	567.95	531.39
Entropy	kJ/kg.K	2.08	2.20	2.08	2.20	2.09
Outlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	53.44	50.27	53.37	50.13	53.28
Pressure	kPa	3187.26	2843.00	3188.61	2843.11	3164.31
Subcooling	K	1.62	-0.33	1.71	-0.19	1.45
Enthalpy	kJ/kg	300.2	293.2	300.0	293.2	299.9
Entropy	kJ/kg.K	1.39	1.37	1.39	1.37	1.39
HX Level						
Heat Rejection	kW	11.59	8.60	11.57	8.69	11.49
Energy Balance (Qair – Qref)	kW	N/A	N/A	N/A	N/A	N/A
Subcooling	K	1.62	-0.33	1.71	-0.19	1.45
Refrigerant Pressure Drop	kPa	11.87	3.79	11.40	4.36	11.16
Fan Power	kW	0.45	0.45	0.45	0.45	0.45
TXV						
Refrigerant						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	51.55	49.15	51.74	48.80	51.60
Pressure	kPa	3166.49	2827.45	3168.66	2827.31	3144.31
Subcooling	°C	3.21	0.54	3.06	0.89	2.84
Enthalpy	kJ/kg	296.1	291.5	296.5	290.8	296.2
Entropy	kJ/kg.K	1.382	1.369	1.383	1.366	1.382
Compressor						
Refrigerant						
Inlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	17.17	29.26	18.00	28.98	18.47
Pressure	kPa	1082.17	793.15	1082.65	797.99	1076.58
Superheat	K	4.94	27.30	5.75	26.83	6.41
Enthalpy	kJ/kg	477.0	497.7	478.0	497.3	478.8
Entropy	kJ/kg.K	2.035	2.140	2.038	2.138	2.041
Outlet						
Mass Flow Rate	kg/s	0.051	0.031	0.050	0.032	0.050
Temperature	°C	93.3	121.8	94.1	120.3	94.3
Pressure	kPa	3199.1	2846.8	3200.0	2847.5	3175.5
Superheat	K	35.3	68.9	36.1	67.4	36.7
Enthalpy	kJ/kg	529.6	569.7	530.7	568.0	531.4
Entropy	kJ/kg.K	2.082	2.200	2.085	2.195	2.087
Compressor Level						
Power Consumption	kW	3.18	2.93	3.18	2.94	0.00
Isentropic Efficiency	-	0.68	0.68	0.68	0.69	0.68
Frequency	Hz	60	60	60	60	60

System			*Liquid Line Leak*		*Vapor Line Leak*	
		Full Charge	**Low Charge**	**Re-Charged**	**Low Charge**	**Re-Charged**
Refrigerant	-	**R447B**	**R447B**	**R447B**	**R447B**	**R447B**

APPENDIX F - Model Verification and Validation

Table 39: Unit 6 – Model Verification and Validation for Alternative 1 – R32 @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	27	31	14%
Cooling Capacity	BTU/hr	21450	23653	10%
Total Power	kW	2.74	2.67	-2%
EER	BTU/hr.W	7.84	8.86	13%

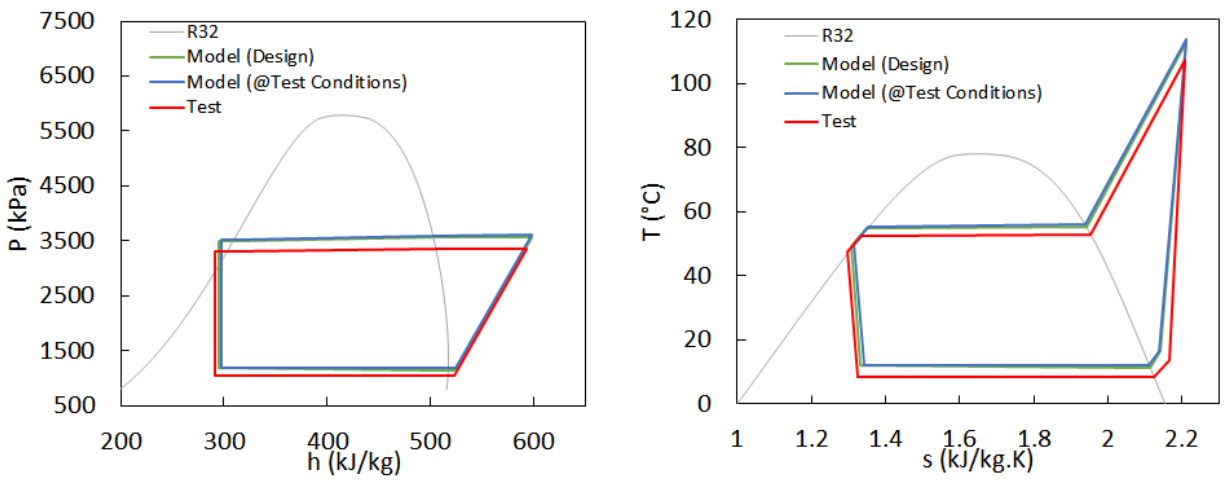

Figure 23. Unit 6 – R32 Performance Test Summary P-h and T-s Diagrams.

Table 40: Unit 6 – Model Verification and Validation for Alternative 2 – R454B @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	35	36	3%
Cooling Capacity	BTU/hr	21821	22969	5%
Total Power	kW	2.67	2.49	-7%
EER	BTU/hr.W	8.17	9.24	13%

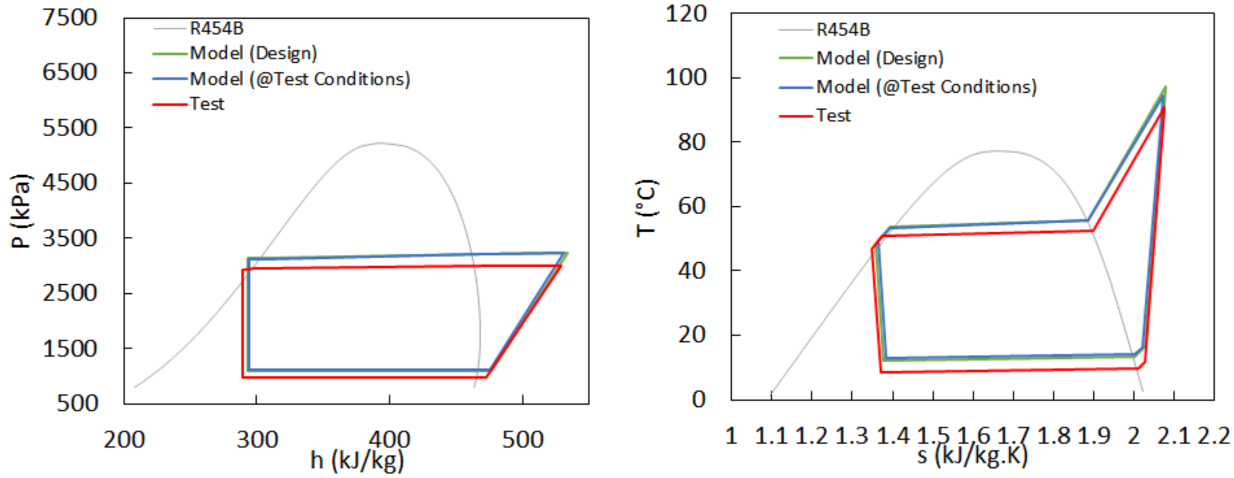

Figure 24. Unit 6 – R454B Performance Test Summary P-h and T-s Diagrams.

Table 41: Unit 10 – Model Verification and Validation for Alternative 1 – R447B @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	51	49	-3%
Cooling Capacity	BTU/hr	31169	31026	-0.5%
Total Power	kW	2.70	3.00	11%
EER	BTU/hr.W	11.54	10.34	-10%

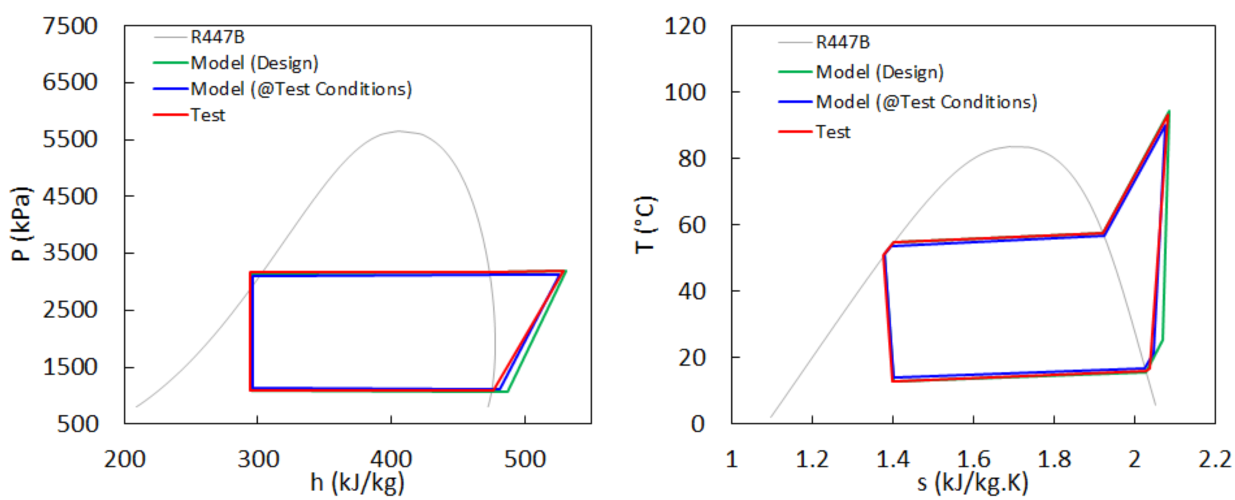

Figure 25. Unit 10 – R447B P-h and T-s Diagrams.

Table 42: Unit 10 – Model Verification and Validation for Alternative 2 – R452B @ 46°C.

		Test	Model (Test Conditions)	Relative Difference
Refrigerant Mass Flow Rate	g/s	47	48	2%
Cooling Capacity	BTU/hr	30292	30704	1.4%
Total Power	kW	3.90	3.34	-14%
EER	BTU/hr.W	7.76	9.19	18%

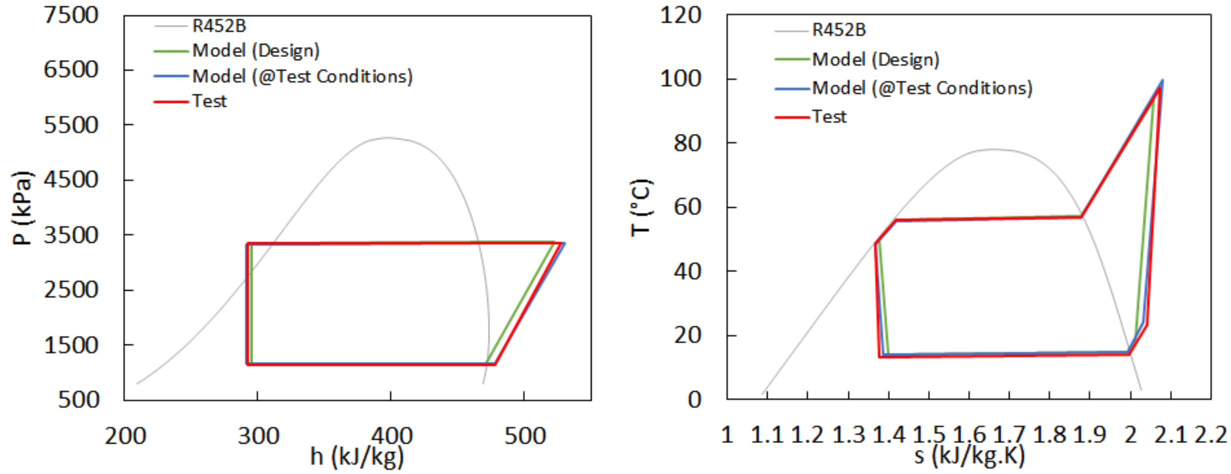

Figure 26. Unit 10 – R452B P-h and T-s Diagrams.

Annex VIII

LIST OF ENTERPRISES WITH REPORTS RELATING TO DECISIONS 84/27 AND 84/42

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Algeria	UNIDO	REF	Air-conditioning	Condor Electronics	HCFC-22	HFC-32	Delay due to higher costs of HFC-32-based units compared to HCFC-22-based units	
Argentina	UNIDO	FOA	Rigid	Friostar	HCFC-141b	Cyclopentane		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Argenpur	HCFC-141b	Cyclopentane		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Alkanos	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	BASF	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Dow	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Ecopur	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Huntsman	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Poliresinas San Luis	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Rigid	Química del Caucho	HCFC-141b	HFO-based blowing agent		Delay due to change in agency
Argentina	UNIDO	FOA	Polystyrene/ polyethylene	Celpak	HCFC-22	Carbon dioxide		Delay due to financial difficulties faced by enterprise
Argentina	UNIDO	FOA	Polystyrene/ polyethylene	Perfiles Revestidos	HCFC-22	Carbon dioxide		Delay due to change in agency
Bahrain	UNIDO	REF	Domestic	Awal Gulf Manufacturing Company	HCFC-22	HFC-410A or HFC-407C	Project cancelled; enterprise not inclined to adopt R-290/HFC-32 as R-410A technology is available in favorable commercial terms	
Bangladesh	UNDP	REF	Residential air-conditioning	Walton	HCFC-22	R-290		Delay in signing of project agreement with the Government
Bangladesh	UNDP	REF	Residential air-conditioning	Elite	HCFC-22	R-290		Delay in signing of project agreement with the Government
Bangladesh	UNDP	REF	Residential air-conditioning	AC Bazar	HCFC-22	R-290		Delay in signing of project agreement with the Government

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Bangladesh	UNDP	REF	Residential air-conditioning	Supreme AC	HCFC-22	R-290		Delay in signing of project agreement with the Government
Bangladesh	UNDP	REF	Residential air-conditioning	Unitech Products	HCFC-22	R-290		Delay in signing of project agreement with the Government
Bangladesh	UNDP	REF	Chiller	Cooling Point	HCFC-22	R-290		Delay in signing of project agreement with the Government
Brazil	UNDP	FOA	Rigid	Panisol	HCFC-141b	Methyl formate/HFO		Enterprise not going to be supported as they were not satisfied with the alternative technology and safety issues faced due to location in urban area
Brazil	UNDP	FOA	Systems house	Ecopur (Rodza)	HCFC-141b	HFOs	Delay due to high cost of HFO formulations	
Brazil	UNDP	FOA	Systems house	M.Cassab	HCFC-141b	HFOs	Delay due to high cost of HFO formulations	
Brazil	UNDP	FOA	Systems house	Polisystem	HCFC-141b	HFOs		Enterprise decided not to participate in HPMP due to business reasons
Brazil	UNDP	FOA	Systems house	Shimtek	HCFC-141b	HFOs	Delay due to non-availability of HFOs	
Brazil	UNDP	FOA	Systems house	U-Tech	HCFC-141b	HFOs	Delay due to non-availability of HFOs	
Brazil	UNIDO	REF	Air-conditioning	S.A. ELGIN	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs	Delay as enterprise not inclined to adopt R-290/HFC-32 as R-410A technology is available in favorable commercial terms and R-410A-based equipment have higher energy efficiency	
Brazil	UNIDO	REF	Air-conditioning	GREE	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs	Delay as enterprise not inclined to adopt R-290/HFC-32 as R-410A technology is available in favorable commercial terms and R-410A-based equipment have higher energy efficiency	
Brazil	UNIDO	REF	Air-conditioning	CLIMAZON	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs	Delay as enterprise not inclined to adopt R-290/HFC-32 as R-410A technology is available in favorable commercial terms and R-410A-based equipment have higher energy efficiency	

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Brazil	UNIDO	REF	Commercial	CMR Refrigeração	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs		Change in enterprise due to economic situation in country and financial difficulties for enterprises
Brazil	UNIDO	REF	Commercial	Fermara Refrigeração Indústria e Comércio Ltda	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs		Change in enterprise due to economic situation in country and financial difficulties for enterprises
Brazil	UNIDO	REF	Commercial	Freeart Seral Brasil Metalúrgica Ltda.	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs		Change in enterprise due to economic situation in country and financial difficulties for enterprises
Brazil	UNIDO	REF	Commercial	Polifrio	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs		Change in enterprise due to economic situation in country and financial difficulties for enterprises
Brazil	UNIDO	REF	Commercial	Spacinox	HCFC-22	TBD: "alternative fluids": propane, Carbon dioxide and HFOs		Change in enterprise due to economic situation in country and financial difficulties for enterprises
Chile	UNDP	FOA	Rigid	Superfrigo ingenieria y Refrigeracion Ltda.	HCFC-141b	Different non-ODSs		Delay due to long time taken by enterprise in assessing technology options and review of agreement for project implementation
Chile	UNDP	FOA	Rigid	Ixom group project (6 companies)	HCFC-141b	Different non-ODSs	Delayed due to non-availability and high price of HFOs	
China	UNDP	ICR	Freezers and refrigeration and condensing units	Nanjing TICA	HCFC-22	NH_3/CO2		Delay due to enterprise works relocation
China	UNDP	ICR	Water Chiller (Heat pump)	Dalian Refrigeration	HCFC-22	R-290		Delay due to internal enterprise-level operational delays in project implementation

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
China	UNDP	SOL	Metal and Electronics	Guangdong Dechang Micromotor Co., Ltd.	HCFC-141b	HC solvent, Tans-1,2-dichloroethylene		Delay in testing of new alternatives for adoption
China	UNDP	SOL	Metal and Electronics	Dechang Micromotor (Beihai)Co., Ltd.	HCFC-141b	HC solvent, Tans-1,2-dichloroethylene		Delay in testing of new alternatives for adoption
China	UNDP	SOL	Metal and Electronics	Johnson Electric Industrial Manufactory Co., Ltd.	HCFC-141b	HC solvent, Tans-1,2-dichloroethylene		Delay in testing of new alternatives for adoption
China	UNDP	SOL	DMD	Jiangsu Yile Medical Device Co., Ltd.	HCFC-141b	HC diluent/solvent-free silicon		Delay in manufacturing equipment delivery
Colombia	UNDP	FOA	Demonstration	Espumlatex S.A.	HCFC-141b	Different non-ODSs	Delay due to non-availability and high price of HFOs	
Colombia	UNDP	FOA	Polyol production	Olaflex S.A.	HCFC-141b	Different non-ODSs	Delay due to non-availability and high price of HFOs	
Colombia	UNDP	FOA	Polyol production	Química Industrial y Comercial Limitada	HCFC-141b	Different non-ODSs	Delay due to non-availability and high price of HFOs	
Colombia	UNDP	FOA	Polyol production	Espumlatex S.A.	HCFC-141b	Different non-ODSs	Delay due to non-availability and high price of HFOs	
Colombia	UNDP	FOA	Polyol production	G.m.p. productos químicos S.A.	HCFC-141b	Different non-ODSs	Delay due to non-availability and high price of HFOs	
Colombia	UNDP	FOA	Rigid	Espumlatex S.A.	HCFC-141b	Water/carbon dioxide	Delay due to non-availability and high price of HFOs	
Colombia	UNDP	FOA	Rigid	Olaflex S.A.	HCFC-141b	Cyclopentane	Delay due to non-availability and high price of HFOs	
Croatia	UNIDO	FOA	Rigid	Pavusin	HCFC-141b	Pentane		Cancelled project – due to enterprise financial situation
Cuba	UNDP	FOA	Rigid	Friarc	HCFC-141b	Water/carbon dioxide	Delay due to non-availability and high price of HFOs	
Democratic People’s Republic of Korea	UNIDO	FOA	Rigid	Pyongyang Sonbong Foam Factory	HCFC-141b	n.a.		Delay due to UN Security Council (UNSC) resolution resulting in inability to implement project

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Democratic People's Republic of Korea	UNIDO	FOA	Rigid	Puhung Building Materials Factory	HCFC-142b	n.a.		Delay due to UNSC resolution resulting in inability to implement project
Egypt	UNIDO	FOA	Rigid	Mondial Freezers Co.	HCFC-141b	Cyclopentane		Delay due political unrest during project implementation period (i.e., around 2011)
Egypt	UNIDO	FOA	Rigid	El Araby Company	HCFC-141b	Cyclopentane		Delay due political unrest during project implementation period (i.e., around 2011)
Egypt	UNIDO	FOA	Rigid	Bahgat	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	Everest	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	Fresh	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	Ocean	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	Siltal	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	Star	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	TopMaker	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Egypt	UNIDO	FOA	Rigid	Tredco	HCFC-141b	Cyclopentane		Commissioning delayed due to COVID-19 outbreak
Indonesia	UNDP	REF	Air-conditioning	PT Gita Mandiri Teknik	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Air-conditioning	PT Fata Sarana Makmur	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Air-conditioning	PT ITU Airconco	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Air-conditioning	PT Metropolitan Bayu Industri	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Sumo Elco Mandiri	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Rotaryana Prima	HCFC-22	HC-290	Delay due to non-availability and high price of HFC-32-based components	

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Indonesia	UNDP	REF	Commercial	PT Alpine Cool Utama	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Anekacool Citratama	HCFC-22	HFC-32	Delay due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Sabindo Refrigeration Technology	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Global Teknik	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Alpin Servis Triutama	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Aneka Froze Triutama	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Graha Cool Technic	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT United Refrigeration	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Gaya Tehnik Supply	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	PT Ilthabi Mandiri Technic	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Berkat Andijaya Elektrindo	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Cipta Karya Mandiri Insani	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Daikin Aircon	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Indonesia	UNDP	REF	Commercial	Jaya Teknik	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	LG Indonesia	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Maturnuwun Nusantara	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Planet Elektrindo	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Rodamas	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Sarana Aircon Utama	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Sarana Sumber Semesta	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Sekawan Abadi Jaya	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Seltech Utama	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Tata Solusi Pratama	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Trane Indonesia	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Waskita Prima Guna	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Indonesia	UNDP	REF	Commercial	Wira Kusuma Sejahtera	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Airtech Inti	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Jalur Sejuk	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Indo Prima Teknik	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Koronka Nusantara	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	ACR Kapuk	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Jasa Teknik	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Kulkasindo	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Intermas Pacific	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Pagoda Sakti Prima	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Rotaryana Engineering	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Indonesia	UNDP	REF	Commercial	Copel Andalan	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Indonesia	UNDP	REF	Commercial	Tegar Inti Sentosa	HCFC-22	HFC-32	Enterprise withdrew due to non-availability and high price of HFC-32-based components	
Iran (Islamic Republic of)	Germany	FOA	Rigid	Kian Panel Co.	HCFC-141b	Isopentane	Non-availability of suitable raw materials to meet performance standards and equipment supplier delays	
Iran (Islamic Republic of)	Germany	FOA	Rigid	Parlo Co.	HCFC-141b	Isopentane		Delay in obtaining enterprise counterpart funding
Iran (Islamic Republic of)	Germany	FOA	Rigid	Behdor Rangin Co.	HCFC-141b	Equipment modification		Enterprise stopped business operations; project cancelled and funds have been returned to MLF
Iran (Islamic Republic of)	Germany	FOA	INT	Zivar Khodro	HCFC-141b	Water-blown		Delay due to UN sanctions resulting in difficulties in supply of imported equipment for conversion and raw material
Iran (Islamic Republic of)	Germany	FOA	INT	Erish Khodro	HCFC-141b	Water-blown		Delay due to UN sanctions resulting in difficulties in supply of imported equipment for conversion and raw material
Iran (Islamic Republic of)	UNIDO	FOA	Rigid	Emersun	HCFC-141b	Cyclopentane		Delay due to UN sanctions resulting in financial restrictions affecting project implementation
Iran (Islamic Republic of)	UNIDO	FOA	Rigid	Parto Shiva Sanat	HCFC-141b	Cyclopentane		Delay due to UN sanctions resulting in high procurement costs for manufacturing equipment
Iran (Islamic Republic of)	UNIDO	FOA	Rigid	Javaheran Tehran	HCFC-141b	Cyclopentane		Delay due to UN sanctions resulting in high procurement costs for manufacturing equipment
Kuwait	UNIDO	FOA	Rigid	Kirby Building Systems	HCFC-141b	Cyclopentane		Delay due to lengthy process of issuing local regulations for implementing project and non-availability of standards for new product
Kuwait	UNIDO	FOA	Rigid	Kuwait Polyurethane Industry Co.	HCFC-141b	Cyclopentane		Delay due to the lengthy process of issuing local regulations for implementing project and non-availability of standards for new product

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Kuwait	UNIDO	FOA	XPS	Gulf	HCFC-22	Carbon dioxide/DME/ HFO		Delay due to the lengthy process of issuing local regulations for implementing project and non-availability of standards for new product
Kuwait	UNIDO	FOA	XPS	Isofoam	HCFC-22	Carbon dioxide/DME/ HFO		Delay due to the lengthy process of issuing local regulations for implementing project and non-availability of standards for new product
Lebanon	UNDP	FOA	Rigid	Iceberg S.A.L.	HCFC-141b	HFC-365mfc	Delay due to non-availability of HFOs	
Libya	UNIDO	FOA	Rigid	Al-Najah	HCFC-141b	Cyclopentane		Delay due to security situation in the country
Libya	UNIDO	FOA	Rigid	(Al-Amal Alkhadar) Al Najm	HCFC-141b	Cyclopentane		Delay due to security situation in the country
Libya	UNIDO	FOA	Rigid	Alyem Engineering	HCFC-141b	Cyclopentane		Delay due to security situation in the country
Mexico	UNDP	FOA	XPS	Termofoam	HCFC-142b	HFO-1234ze		Delay due to safety certification and commissioning of equipment
Nigeria	UNDP	FOA	Spray/Panel	Slavit Group	HCFC-141b	Cyclopentane/ Methyl formate		Delay in signing of project agreement with the Government
Nigeria	UNDP	FOA	Spray/Panel	Group project with 37 companies	HCFC-141b	Methyl formate		Delay in signing of project agreement with the Government
Nigeria	UNIDO	FOA	Multiple-subsectors	Group project for the conversions of foam manufacturing (75 enterprises)	HCFC-141b	Methyl formate/water		Delay due to financial difficulties faced by the beneficiaries resulting in delays in counter-part funding
Pakistan	UNIDO	FOA	Rigid	Shoaibee Industries	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Full Bright Plastic	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Asif Zubair & Co.,	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Tropical Plastic	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Unique Plastic	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Pakistan	UNIDO	FOA	Rigid	Delight Plastic	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Decent Plastic	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Informal Sector	HCFC-141b	Water/carbon dioxide		Delay in finalisation of implementation modalities with enterprise
Pakistan	UNIDO	FOA	Rigid	Pakistan Insulation (Pvt.) Ltd.,	HCFC-141b	Cyclopentane		Delay due to questions raised by NOU in assessment of eligibility of enterprise and eligibility of alternative technology
Pakistan	UNIDO	FOA	Rigid	PAECO	HCFC-141b	Cyclopentane		Delay due to questions raised by NOU in assessment of eligibility of enterprise and eligibility of alternative technology
Pakistan	UNIDO	FOA	Rigid	Foster Refrigerators (Pvt.) Ltd.,	HCFC-141b	Cyclopentane		Delay due to questions raised by NOU in assessment of eligibility of enterprise and eligibility of alternative technology
Pakistan	UNIDO	FOA	Rigid	Kold Kraft (Pvt.) Ltd.,	HCFC-141b	Cyclopentane		Delay due to questions raised by NOU in assessment of eligibility of enterprise and eligibility of alternative technology
Pakistan	UNIDO	FOA	Rigid	Informal Sector	HCFC-141b	Cyclopentane		Delay due to questions raised by NOU in assessment of eligibility of enterprise and eligibility of alternative technology
Philippines	UNIDO	REF	Air-conditioning	Panasonic	HCFC-22	HFC-32		Delay due to change of agency from World Bank to UNIDO and change in enterprises' business plans
Philippines	UNIDO	REF	Air-conditioning	Concepcion-Carrier	HCFC-22	HFC-32		Delay due to change of agency from World Bank to UNIDO, change in enterprises' business plans and financial issues faced by the enterprise
Philippines	UNIDO	REF	Air-conditioning	Hitachi	HCFC-22	HFC-32		Delay due to change of agency from World Bank to UNIDO and change in enterprises' business plans
Philippines	UNIDO	REF	Air-conditioning	Koppel	HCFC-22	HFC-32		Delay due to change of agency from World Bank to UNIDO, change in enterprises' business plans and financial issues faced by the enterprise
Qatar	UNIDO	FOA	Polystyrene/ polyethylene	Orient Insulation	HCFC-22	Carbon dioxide	Delay due to non-availability of equipment in manufacturing line resulting in delay	

Country	Agency	Sector	Sub-sector	Name	HCFC	Alternative	Delays due to availability of technology (decision 84/27)	Enterprises experiencing delays/changes in implementation plan (decision 84/42)
Sudan	UNIDO	FOA	Rigid	Mina Factory for Electrical and Home Appliances	HCFC-141b	Cyclopentane		Delay in finalisation of implementation modalities with enterprise
Sudan	UNIDO	FOA	Rigid	Target Group Factory for Insulation panels	HCFC-141b	Cyclopentane		Delay in finalisation of implementation modalities with enterprise
Syria Arab Republic	UNIDO	REF	Multiple-subsectors	Al Hafez Group	HCFC-22	HFC-410A		Delay due to security situation in the country
Trinidad and Tobago	UNDP	FOA	Multiple-subsectors	Seal Sprayed Solutions (TT) Ltd.	HCFC-141b	Methyl formate	Delay due to non-availability of methyl formate	
Tunisia	UNIDO	REF	Air-conditioning	Société Afrivision	HCFC-22	Propane (R-290)	Delay due to non-availability of alternative technology using R-290 in commercially attractive terms	
Tunisia	UNIDO	REF	Air-conditioning	Société Electrostar	HCFC-22	Propane (R-290)	Delay due to non-availability of alternative technology using R-290 in commercially attractive terms	
Tunisia	UNIDO	REF	Air-conditioning	Hachicha High World Wide (HHW)	HCFC-22	Propane (R-290)	Delay due to non-availability of alternative technology using R-290 in commercially attractive terms	
Tunisia	UNIDO	REF	Air-conditioning	Société Industrielle Mega	HCFC-22	Propane (R-290)	Delay due to non-availability of alternative technology using R-290 in commercially attractive terms	
Uruguay	UNDP	FOA	Multiple-subsectors	Group project (23 companies)	HCFC-141b	HFO-1234ze	Delay due to non-availability and high price of HFOs	
Zimbabwe	Germany	FOA	Rigid	Ref Air Ltd	HCFC-141b	Cyclopentane		Delay in procurement of raw materials by the enterprise
Zimbabwe	Germany	FOA	Rigid	Capri refrigeration Ltd	HCFC-141b	Cyclopentane		Delay in obtaining enterprise counterpart funding resulting in delays in installation of equipment

Annex IX

DETAILED INFORMATION ON HFC-RELATED INVESTMENT PROJECTS FUNDED UNDER ADDITIONAL CONTRIBUTIONS

<table>
<tr><td colspan="3">Country: Argentina</td><td colspan="3">Agency: UNIDO</td><td colspan="3">Meeting approved: 81st</td><td colspan="3">Status: Ongoing</td></tr>
<tr><td colspan="12">Project title and objective: Conversion project for replacement of HFC-134a with isobutane (R-600a)/propane (R-290)-based refrigerant in the manufacture of domestic and commercial refrigeration equipment at Briket, Bambi and Mabe-Kronen</td></tr>
<tr><td colspan="12">Sector/application: Domestic and commercial refrigeration</td></tr>
<tr><td colspan="2">HFC (s)</td><td colspan="2">Metric tonnes</td><td colspan="2">CO_2 eq mt</td><td colspan="2">Alternatives</td><td colspan="2">Metric tonnes</td><td colspan="2">CO_2 eq mt</td></tr>
<tr><td colspan="2">HFC-134a</td><td colspan="2">96.6</td><td colspan="2">138,138</td><td colspan="2">R-600a/R-290</td><td colspan="2">48.28</td><td colspan="2">145</td></tr>
<tr><td colspan="4">Funds approved (US $)</td><td colspan="4">Funds disbursed (US $)</td><td colspan="4">Date of completion</td></tr>
<tr><td colspan="4">1,840,755</td><td colspan="4">1,065,380</td><td colspan="4">December 2020</td></tr>
<tr><td colspan="12">Status of implementation: The project started in June 2018. Equipment is on site. Installation at the first company Bambi started in March 2019. All activities have to be suspended due to the COVID-19 pandemic. New appliances have been designed and tested.</td></tr>
<tr><td colspan="12">1. Signature of grant agreement (or equivalent)
UNIDO does not use grant agreements. After approval of the project in May 2018, UNIDO expert visited the site in June 2018, discussed and agreed with the Government and the enterprise the scope of activities and delineated the Multilateral Fund and counterpart inputs. Based on this, UNIDO prepared the terms of reference (TOR1) and received the counterparts' agreement to it (July 2018). TOR2 were prepared for the assistance and advice in redesign of appliances by a national expert (September 2018); the three counterparts agreed to redesign the equipment under the guidance of a national expert and cover all the related costs.</td></tr>
<tr><td colspan="12">2. Status of planning for procurement of equipment
The equipment bidding process was initiated in September 2018; bids were received in November 2018 and evaluated by UNIDO and the lowest priced, technically acceptable bid was selected. UNIDO's selection was discussed with the counterparts on the site and some adjustments were made. The purchase order was issued in February 2019; the supplier visited the counterpart to agree on the schedule of work. Minutes of meeting (MoM) were signed between the three counterparts and the supplier on June 2019. The supplier manufactured the equipment and delivered it to the site.</td></tr>
<tr><td colspan="12">3. Status of delivery and installation of equipment
The equipment was shipped from Europe, passed the customs in November 2019 and delivered to the three counterparts in December 2019. The installation started at Bambi in March 2020 but due to the COVID-19 all activities have been put on hold.</td></tr>
<tr><td colspan="12">4. Status of design of products using alternative technology
The counterparts have completed the design of the new appliances; additional details will be communicated upon resumption of the project.</td></tr>
<tr><td colspan="12">5. Status of commercial production of products using alternative technology
Not started yet on account of COVID-19.</td></tr>
<tr><td colspan="12">6. Energy efficiency performance
The details will be communicated to the Secretariat upon resumption of the project.</td></tr>
<tr><td colspan="12">7. Status of implementation of service sector component (as applicable)
N/A</td></tr>
<tr><td colspan="12">8. Key observations and lessons learnt relating to conversion
The details will be communicated upon completion of the project.</td></tr>
</table>

Country: Bangladesh		**Agency:** UNDP	**Meeting approved**: 80th		**Status:** Completed
Project title and objective: Conversion from HFC-134a to isobutane as refrigerant in manufacturing household refrigerator and of reciprocating compressor of HFC-134a to energy efficient compressor (isobutane) in Walton Hi-Tech Industries Limited					
Sector/application: Domestic refrigeration					
HFC (s)	**Metric tonnes**	**CO_2 eq mt**	**Alternatives**	**Metric tonnes**	**CO_2 eq mt**
HFC-134a	230.63	329,801	R-600a	143	429
Funds approved (US $)		**Funds disbursed (US $)**		**Date of completion**	
	3,131,610		3,126,415	December 2020	
Status of implementation: The project is completed. For details, please, refer to the final report being submitted separately to the 86th meeting.					
1. Signature of grant agreement (or equivalent) The project document is signed.					
2. Status of planning for procurement of equipment Done.					
3. Status of delivery and installation of equipment Done.					
4. Status of design of products using alternative technology Done.					
5. Status of commercial production of products using alternative technology Final report was submitted separately.					
6. Energy efficiency performance Final report was submitted separately.					
7. Status of implementation of service sector component (as applicable) Final report was submitted separately.					
8. Key observations and lessons learnt relating to conversion					

<table>
<tr><td colspan="3">Country: China</td><td colspan="3">Agency: UNDP</td><td colspan="3">Meeting approved: 82nd</td><td colspan="3">Status: Ongoing</td></tr>
<tr><td colspan="12">Project title and objective: Conversion from C5+HFC-245fa to C5+HFOs in a domestic refrigerator manufacturer (Hisense Kelon)</td></tr>
<tr><td colspan="12">Sector/application: Domestic refrigeration – insulation foam</td></tr>
<tr><td colspan="2">HFC (s)</td><td colspan="2">Metric tonnes</td><td colspan="2">CO_2 eq mt</td><td colspan="2">Alternatives</td><td colspan="2">Metric tonnes</td><td colspan="2">CO_2 eq mt</td></tr>
<tr><td colspan="2">Cyclopentane +HFC-245fa</td><td colspan="2">250</td><td colspan="2">257,500</td><td colspan="2">Cyclopentane +HFO-1233zd(E)</td><td colspan="2">750</td><td colspan="2">750</td></tr>
<tr><td colspan="4">Funds approved (US $)</td><td colspan="4">Funds disbursed (US $)</td><td colspan="4">Date of completion</td></tr>
<tr><td colspan="4">1,275,000</td><td colspan="4">380,000</td><td colspan="4">December 2020</td></tr>
<tr><td colspan="12">Status of implementation: Project document was signed in April 2019; total budget and work plan was signed in July 2019; the contract between FECO and Hisense-Kelon was signed in August 2019; and on-site verification for the CD line conversion was conducted in November 2019. Up to March 2020, Hisense-Kelon has completed the CD line conversion and started trial production in large scale.</td></tr>
<tr><td colspan="12">1. Signature of grant agreement (or equivalent)
Project document signed 30 April 2019 by FECO and UNDP; work plan for 2019 and 2020 was agreed and signed between UNDP and FECO on 24 July 2019; and the project agreement between FECO and Hisense-Kelon was signed 8 August 2019</td></tr>
<tr><td colspan="12">2. Status of planning for procurement of equipment
The planning for procurement related to modification of the seal rings in the pre-mix units, raw material storage tanks and pumps for converting to HFOs took place in August 2019</td></tr>
<tr><td colspan="12">3. Status of delivery and installation of equipment
The change/modification of the seal rings in the essential equipment took place during August to October 2019.</td></tr>
<tr><td colspan="12">4. Status of design of products using alternative technology
The capacity of the production manufacturing line is 1.2 million units per year. Details of testing of new blend is given in 5 below.</td></tr>
<tr><td colspan="12">5. Status of commercial production of products using alternative technology
Hisense-Kelon conducted trial production with cyclopentane/HFOs blend and sent samples for testing in October 2019. FECO contracted experts and undertook on-site visit to the beneficiary in November 2019, where it was reported that the beneficiary had gained the capacity of using the alternative technology for production.</td></tr>
<tr><td colspan="12">6. Energy efficiency performance
Since the enterprise manufactures various product models, additional time is needed for the energy efficiency performance testing. FECO will follow up on the progress.</td></tr>
<tr><td colspan="12">7. Status of implementation of service sector component (as applicable)
N/A</td></tr>
<tr><td colspan="12">8. Key observations and lessons learnt relating to conversion
The conversion required significant investment on equipment modification; besides the change of seal rings of essential equipment, the beneficiary enterprise had to modify the foam machines to enhance the control on metering of raw materials, temperature and other (the counterpart funding will be indicated in a future report). During onsite visits, it was reported that knowledge and experience was gained for other production lines that are not financially supported by the MLF.</td></tr>
</table>

Country: Lebanon	**Agency:** UNIDO	**Meeting approved**: 81st	**Status:** Ongoing		
Project title and objective: Conversion from HFC-134a and R-404A to R-600a and R-290 in domestic refrigeration at Lematic Industries					
Sector/application: Domestic refrigeration					
HFC (s)	**Metric tonnes**	**CO_2 eq mt**	**Alternatives**	**Metric tonnes**	**CO_2 eq mt**
HFC-134a	78.5	112,198	R-600a	33.5	101
R-404A	34.08	133,662	R-290	6.5	19.5
Funds approved (US $)		**Funds disbursed (US $)**		**Date of completion**	
1,053,858		842,975		July 2020	

Status of implementation: The Government endorsed the project for submission in April 2018. The project was approved at the 81st meeting (decision 81/63). The contract with Lematic was signed in December 2018 with an agreed date of completion of 30 December 2019; however, due to the security problems in October 2019, the completion date was extended to July 2020. The conversion is ongoing; procurement equipment and components required for the production line modification is ongoing, all equipment procured from overseas has been received and some items have been installed. While the completion of the project is expected in July 2020, the factory is currently closed due to the COVID-19, and all work is paused until further notice.

1. Signature of grant agreement (or equivalent)
   Agreement with the enterprise was signed in December 2018.
2. Status of planning for procurement of equipment
   Modifications to the storage and refrigerant supply system to make these explosion-proof by replacing the refrigerant supply pumps, refrigerant charging units, installation of a safety system (i.e., leak detectors, fire-fighting equipment, shut-off valves, pressure sensors, water sprinkler, smoke detectors, and ventilation system); and relevant certifications needed for implementing the project.
   For the assembly line modifications, the installation of helium charging/recycling unit to complement the existing helium sniffer, safety system that includes the installation of HC sensors and ventilation, ultrasonic welding equipment for sealing of the refrigeration system, hand-held HC leak detector for storage area, and addition of repair area on assembly lines with safe recovery of R-600a/R-290, are needed.
3. Status of delivery and installation of equipment
   All equipment procured was delivered to the enterprise in January-February 2020.
4. Status of design of products using alternative technology
   As for the product development using the alternative technology, the enterprise made all the necessary engineering and safety design modifications. Once all the equipment are installed the products (domestic refrigerator and freezer) for the different categories will be produced within a period of two weeks.
5. Status of commercial production of products using alternative technology
   Same as above
6. Energy efficiency performance
   Lematic efforts to switch to more efficient appliances are met by several obstacles, among which the switch to testing their equipment and customizing their laboratory according to the new IEC 62552:2015 standard. The current measurement and testing process at Lematic are done with an international instrument acquisition using data system to record refrigerator temperature, ambient temperature, humidity, voltage, amperage, power, and test period using lab-view.
   In order to perform the testing following IEC 62552:2015, commercial analyzing software is needed, to communicate with the current testing equipment and produce energy calculations and level rating. UNIDO under the K-CEP global project will support Lematic with this transformation, through the purchase of a technical and software support through the delivery of a software package, offering training, and providing support throughout the process.
7. Status of implementation of service sector component (as applicable)
   Lematic have their own crew of servicing workshops and technicians spread all over Lebanon. All the service workshops were equipped with necessary equipment and tools such as recovery machines, vacuum pumps, leak detectors, scales, and recovery cylinders.
   A team of 15 senior technicians including the technical director from Lematic were trained on dealing with flammable refrigerants, charging, safety, recovery, in the newly established RAC training center in Beirut in September 2019. In February 2020, a training session was conducted by HEAT team (Germany) and OTB Consults (Lebanon) for lab technician on energy efficiency standards and MEPS that are proposed to be established in Lebanon. Additional training on installation and commissioning of the equipment are also planned.

8.	Key observations and lessons learnt relating to conversion Lematic was keen to move fast in the conversion process mainly by offering their products to the international market. The project helped in building their technical capacities dealing with flammable refrigerants, updating their products to include energy efficiency standards. The conversion of their products using the alternative technologies including energy efficiency standards led to an increase in their cost of production by 10 per cent. This might lead according to the enterprise to a tough competition with imported products into the local market. The conversion process time based on BAU could be done in 14-16 months. The cost of the conversion is acceptable without any additional cost from the enterprise.

Country: Mexico	**Agency:** UNIDO	**Meeting approved**: 81st	**Status:** Ongoing

Project title and objective: Conversion of commercial refrigeration manufacturing in two facilities from the use of HFC-134a and R-404A as the refrigerants to propane (R-290) and isobutane (R-600a) at Imbera

Sector/application: Commercial refrigeration

HFC (s)	**Metric tonnes**	**CO_2 eq mt**	**Alternatives**	**Metric tonnes**	**CO_2 eq mt**
HFC-134a	51.73	73,974	R-600a/R-290	28.3	84.9
R-404A	4.31	16,904	R-290		

Funds approved (US $)	**Funds disbursed (US $)**	**Date of completion**
1,018,123	41	December 2020 (depending on the pandemic; UNIDO can provide update at the 86th meeting)

Status of implementation: The project started in July 2018. As at 20 March 2020, equipment required for the conversion was shipped from Europe in mid February 2020 and expected to arrive to Mexico in March 2020; new appliances have been designed and tested, but all other activities had to be suspended due to the COVID-19 pandemic.

1. Signature of grant agreement (or equivalent)
   UNIDO does not use grant agreements. After approval of the project, UNIDO expert visited the site, discussed and agreed with the Government and the enterprise the scope of activities and delineated the Multilateral Fund and counterpart inputs. Based on this, UNIDO prepared TOR and received the counterparts' agreement to it (October 2018). The counterpart agreed to implement all redesign work as counterpart input.
2. Status of planning for procurement of equipment
   The equipment bidding process was initiated by UNIDO in November 2018; the bids were received in March 2019 and evaluated by UNIDO, and the lowest priced technically acceptable bid was selected. UNIDO selection was discussed with the counterparts on the site where adjustments were made. UNIDO and the counterpart signed a MoM reflecting their agreement on 24 April 2019. The purchase order was issued in May 2019. The supplier visited the counterpart to agree on the schedule of work. A MoM was signed between the counterpart and the supplier on 31 July 2019. The supplier manufactured the equipment in 2019, but delivery was delayed until March 2020.
3. Status of delivery and installation of equipment
   The equipment was shipped from Europe in the second half of February 2020 and arrival to Mexico expected around 20 March 2020.
4. Status of design of products using alternative technology
   The counterpart has completed the design of the new appliances. The details will be communicated upon resumption of the project.
5. Status of commercial production of products using alternative technology
   This has not started yet due to suspension of the project.
6. Energy efficiency performance
   The details will be communicated upon resumption of the project.
7. Status of implementation of service sector component (as applicable)
   N/A
8. Key observations and lessons learnt relating to conversion
   The details will be communicated upon completion of the project.

<table>
<tr><td colspan="2">Country: Thailand</td><td colspan="2">Agency: IBRD</td><td>Meeting approved: 82nd</td><td>Status: Ongoing</td></tr>
<tr><td colspan="6">Project title and objective: Conversion from HFC to propane (R-290) and isobutene (R-600a) as a refrigerant in manufacturing commercial refrigeration appliances in Pattana Intercool Co. Ltd.</td></tr>
<tr><td colspan="6">Sector / application: Commercial refrigeration</td></tr>
<tr><td>HFC (s)</td><td>Metric tonnes</td><td>CO_2 eq mt</td><td>Alternatives</td><td>Metric tonnes</td><td>CO_2 eq mt</td></tr>
<tr><td>HFC-134a</td><td>8.78</td><td>12,555</td><td>R-600a</td><td>3.95</td><td>12</td></tr>
<tr><td colspan="2">Funds approved (US $)</td><td colspan="2">Funds disbursed (US $)</td><td colspan="2">Date of completion</td></tr>
<tr><td colspan="2">183,514</td><td colspan="2">Not available; retroactive payment after sub-grant agreement signature</td><td colspan="2">December 2020</td></tr>
<tr><td colspan="6">Status of implementation:</td></tr>
<tr><td colspan="6">1. Signature of grant agreement (or equivalent)
The grant agreement between the Government and the World Bank has been presented to the Cabinet for its approval. Once the grant Agreement is approved, sub-grant agreement with Pattana Intercool will be processed. The company has already completed preparation of a safety plan focusing on occupational health and safety that meets the local authority’s requirement. The plan has been reviewed and endorsed by the Bank.</td></tr>
<tr><td colspan="6">2. Status of planning for procurement of equipment
Pattana Intercool has developed specifications of equipment items to be financed by the Fund and confirmed its counterpart funding. The procurement process started in September 2019. Any expenditures incurred prior to the signing of the grant agreement will be reimbursed by the Bank through the retroactive financing provision agreed earlier by Department of Industrial Works (DIW) and the Bank. Key equipment includes vacuum pumps, charging machine, leak detectors, and safety equipment (ventilation system and sensor alarm system).</td></tr>
<tr><td colspan="6">3. Status of delivery and installation of equipment
Not all equipment has arrived. Due to COVID-19, the enterprise is not able to estimate when all equipment can be installed yet.</td></tr>
<tr><td colspan="6">4. Status of design of products using alternative technology
Not yet started.</td></tr>
<tr><td colspan="6">5. Status of commercial production of products using alternative technology
Not yet started.</td></tr>
<tr><td colspan="6">6. Energy efficiency performance
Not available.</td></tr>
<tr><td colspan="6">7. Status of implementation of service sector component (as applicable)
Not applicable.</td></tr>
<tr><td colspan="6">8. Key observations and lessons learnt relating to conversion
Not yet available.</td></tr>
</table>

Annex X

LIST OF COUNTRIES WITH ENABLING ACTIVITIES FUNDED UNDER ADDITIONAL CONTRIBUTIONS

Country	Agency	Date approved	Funds approved (US $)
Afghanistan	UNEP	Jun-2018	150,000
Albania	UNIDO	Nov-2017	94,978
Angola	UNEP	Nov-2017	150,000
Argentina	UNIDO	Jun-2018	250,000
Armenia	UNIDO	Nov-2017	150,000
Bahamas	UNEP	Dec-2018	95,000
Benin	UNEP	Jun-2018	150,000
Bhutan	UNEP	Nov-2017	50,000
Bolivia (Plurinational State of)	UNEP	Dec-2018	150,000
Bosnia and Herzegovina	UNIDO	Nov-2017	95,000
Botswana	UNEP	Jun-2018	150,000
Brunei Darussalam	UNEP	Dec-2018	150,000
Burkina Faso	UNIDO	Nov-2017	150,000
Cambodia	UNEP	Nov-2017	150,000
Cameroon	UNIDO	Nov-2017	150,000
Cabo Verde	UNEP	Dec-2018	95,000
Chad	UNEP	Jun-2018	150,000
Chile	UNIDO	Nov-2017	86,000
Chile	UNDP	Nov-2017	33,000
Chile	UNEP	Nov-2017	31,000
China	UNEP	Nov-2017	85,000
China	UNDP	Nov-2017	165,000
Colombia	UNDP	Nov-2017	250,000
Comoros	UNEP	Jun-2018	50,000
Congo	UNIDO	Nov-2017	150,000
Cook Islands	UNEP	Dec-2018	50,000
Costa Rica	UNDP	Nov-2017	150,000
Cote d'Ivoire	UNEP	Jun-2018	150,000
Democratic Republic of the Congo	UNEP	Jun-2018	150,000
Djibouti	UNEP	Jun-2018	50,000
Dominica	UNEP	Nov-2017	50,000
Dominican Republic	UNEP	Nov-2017	150,000
Ecuador	UNEP	Nov-2017	150,000
Egypt	UNIDO	Jun-2018	105,000
Egypt	UNEP	Jun-2018	145,000
Equatorial Guinea	UNEP	Jun-2018	150,000
Eritrea	UNEP	Nov-2017	95,000
Eswatini	UNEP	Jun-2018	95,000
Ethiopia	UNEP	Jun-2018	95,000
Fiji	UNDP	Nov-2017	150,000
Gabon	UNEP	Nov-2017	150,000
Gambia	UNIDO	Nov-2017	95,000
Georgia	UNEP	Jun-2018	95,000
Ghana	UNEP	Nov-2017	150,000
Grenada	UNIDO	Jun-2018	50,000
Guatemala	UNEP	Nov-2017	150,000
Guinea-Bissau	UNEP	Jun-2018	95,000

Country	Agency	Date approved	Funds approved (US $)
Guyana	UNEP	Jun-2018	95,000
Honduras	UNEP	Jun-2018	150,000
Indonesia	IBRD	Jun-2018	250,000
Jamaica	UNDP	Nov-2017	150,000
Kenya	UNEP	Jun-2018	150,000
Kiribati	UNEP	Jun-2018	50,000
Kyrgyzstan	UNEP	Nov-2017	95,000
Lao People's Democratic Republic	UNEP	Jun-2018	95,000
Lebanon	UNDP	Nov-2017	150,000
Lesotho	UNEP	Nov-2017	55,000
Lesotho	Italy	Nov-2017	40,000
Liberia	Germany	Nov-2017	95,000
Libya	UNIDO	Jun-2018	150,000
Madagascar	UNEP	Jun-2018	150,000
Malawi	UNEP	Jun-2018	150,000
Malaysia	IBRD	Nov-2017	250,000
Maldives	UNEP	Nov-2017	55,000
Maldives	Italy	Nov-2017	40,000
Mali	UNEP	Jun-2018	150,000
Marshall Islands	UNEP	Jun-2018	50,000
Mauritania	UNEP	Jun-2018	150,000
Mexico	UNIDO	Nov-2017	220,000
Mexico	UNEP	Nov-2017	30,000
Micronesia (Federated States of)	UNEP	Jun-2018	50,000
Mongolia	UNEP	Nov-2017	95,000
Montenegro	UNIDO	Nov-2017	49,973
Morocco	UNIDO	Jun-2018	150,000
Mozambique	UNEP	Jun-2018	150,000
Myanmar	UNEP	Jun-2018	95,000
Namibia	UNEP	Nov-2017	150,000
Nauru	UNEP	Jun-2018	50,000
Nepal	UNEP	Jun-2018	95,000
Nicaragua	UNIDO	Jun-2018	150,000
Niger	UNIDO	Jun-2018	150,000
Nigeria	UNEP	Nov-2017	250,000
Niue	UNEP	Jun-2018	50,000
North Macedonia	UNIDO	Nov-2017	95,000
Palau	UNEP	Nov-2017	50,000
Papua New Guinea	Germany	Nov-2017	95,000
Paraguay	UNDP	Jun-2018	75,000
Paraguay	UNEP	Jun-2018	75,000
Peru	UNDP	Nov-2017	150,000
Philippines	UNIDO	Nov-2017	225,992
Philippines	IBRD	Nov-2017	24,008
Rwanda	UNEP	Nov-2017	55,000
Rwanda	Italy	Nov-2017	40,000
Saint Kitts and Nevis	UNEP	Jun-2018	50,000
Saint Lucia	UNEP	Nov-2017	95,000
Saint Vincent and the Grenadines	UNEP	Nov-2017	50,000
Samoa	UNEP	Jun-2018	50,000
Sao Tome and Principe	UNEP	Jun-2018	95,000
Senegal	UNEP	Nov-2017	150,000
Serbia	UNIDO	Nov-2017	150,000

Country	Agency	Date approved	Funds approved (US $)
Seychelles	Germany	Nov-2017	95,000
Sierra Leone	UNEP	Jun-2018	95,000
Solomon Islands	UNEP	Jun-2018	95,000
Somalia	UNIDO	Nov-2017	150,000
South Africa	UNIDO	Dec-2018	240,000
South Sudan	UNEP	Jun-2018	95,000
Sri Lanka	UNEP	Jun-2018	150,000
Sudan	UNIDO	Nov-2017	75,000
Sudan	UNEP	Nov-2017	75,000
Suriname	UNEP	Nov-2017	95,000
Syrian Arab Republic	UNEP	May-2019	250,000
Thailand	IBRD	Nov-2017	250,000
Togo	UNEP	Nov-2017	150,000
Tonga	UNEP	Nov-2017	50,000
Trinidad and Tobago	UNDP	Nov-2017	150,000
Tunisia	Italy	Nov-2017	75,000
Tunisia	UNIDO	Nov-2017	75,000
Turkey	UNIDO	Nov-2017	250,000
Turkmenistan	UNEP	Nov-2017	150,000
Tuvalu	UNEP	Jun-2018	50,000
Uganda	UNEP	Jun-2018	50,000
United Republic of Tanzania	UNEP	Jun-2018	95,000
Uruguay	UNIDO	Nov-2017	50,000
Uruguay	UNDP	Nov-2017	100,000
Vanuatu	UNEP	Jun-2018	50,000
Venezuela (Bolivarian Republic of)	UNIDO	Jun-2018	250,000
Viet Nam	UNIDO	Nov-2017	250,000
Zambia	UNEP	Nov-2017	95,000
Zimbabwe	UNEP	Nov-2017	150,000
Total			**15,184,951**