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执行蒙特利尔议定书
多边基金执行委员会
第八十三次会议
2019 年 5 月 27 日至 31 日，蒙特利尔

现状报告及具有特定报告要求的项目报告

1. 本文件作为相关方向第八十二次会议提交的上一年度进展报告及财务报告[1]中所提出的问题之后续行动，以及在此前的会议上要求相关方提交具体报告的项目及活动之后续行动。

2. 该文件包含以下七个部分以及一项附录：

第一部分： 存在实施延迟且要求提供特别状态报告的项目
第二部分： 消耗臭氧层物质废弃物处置项目

第三部分： 在已核准的项目中临时使用高全球升温潜能值技术

第四部分： 氟氯烃逐步淘汰管理计划之相关报告

第五部分： 低全球升温潜能值的氟氯烃替代品示范项目与区域供冷可行性研究（第 72/40 号决定）

第六部分： 氟氯烃逐步淘汰管理计划第二阶段执行机构的变化以及对菲律宾逐步淘汰氢氟碳化合物的扶持活动

第七部分： 针对扶持活动的延期要求

附录 1： 由五部分组成的中国报告（UNEP / OzL.Pro / ExCom / 83/11 / Add.1）

3. 每个部分均包含简要的进度说明，以及秘书处的评论与建议。

[1] UNEP/OzL.Pro/ExCom/82/14-19.

第一部分：存在实施延迟且要求提供特别状态报告的项目

2018 年项目实施进度

4. 秘书处与相关双边机构及执行机构已就第八十二次会议要求提交状态报告的项目进行了讨论。继讨论之后，多项问题已得到圆满的解决。

5. 尚有未决问题的项目列于本文件附件一。

秘书处建议

6. 执行委员会可：

(a) 注意:

(i) 各双边机构和执行机构向第八十三次会议所提交的状态报告，报告载于 UNEP/OzL.Pro/ExCom/83/11 号文件；

(ii) 如本文件附件一所示，各双边机构和执行机构将向第八十四次会议就已建议增加状态报告的 54 个项目作出报告；以及

(b) 批准相关方就正在进行的项目所提的建议，这些项目均存在本文件附件一表格最后一栏所列出的具体问题。

具有特定报告要求的项目报告

7. 表 1 列出了本文件所涵盖的全部项目以及对相关问题的简要说明。

表 1. 相关方已向第八十三次会议提交的具有特定报告要求之项目报告

国家	项目名称	问题
二、消耗臭氧层物质废弃物处置项目		
古巴	消耗臭氧层物质废弃物管理及处置的试点示范项目——最终报告 附件二：最终报告	已完成。各机构需应要求酌情使用调查结果及建议
三、在已核准的项目中临时使用高全球升温潜能值（GWP）技术		
巴西	临时使用高全球升温潜能值的氢氟碳化合物多元醇系统（氟氯烃逐步淘汰管理计划第一阶段）	因尚未引入低全球升温潜能值技术，有待继续报告
古巴	已改用低全球升温潜能值技术（氟氯烃逐步淘汰管理计划第一阶段）的企业对高全球升温潜能值技术的临时应用	因尚未引入低全球升温潜能值技术，有待继续报告

国家	项目名称	问题
黎巴嫩	过渡期技术的应用——进度报告（氟氯烃逐步淘汰管理计划第二阶段）	因尚未引入低全球升温潜能值技术，有待继续报告
特立尼达和多巴哥	在企业中暂时使用高全球升温潜能值技术（氟氯烃逐步淘汰管理计划第一阶段）	因尚未引入低全球升温潜能值技术，有待继续报告。注意，在提交下一次付款申请之时，需要返还已取消项目所剩余的资金
四、氟氯烃逐步淘汰管理计划之相关报告		
巴哈马	氟氯烃逐步淘汰管理计划（第一阶段 - 探索试点改造项目最佳可选方案的研究报告）	敦促联合国环境规划署在第八十四次会议上就该项研究结果提供最新的最终报告
孟加拉国	氟氯烃逐步淘汰管理计划（第一阶段 - 最终进度报告）	已完成。要求在第八十四次会议之前返还剩余的资金
埃及	氟氯烃逐步淘汰管理计划（第一阶段 - 泡沫塑料行业及临时使用高全球升温潜能值技术的进度报告）	由于尚未引入低全球升温潜能值技术，有待继续报告泡沫塑料行业的进展情况，以及高全球升温潜能值技术的临时使用情况
赤道几内亚	氟氯烃逐步淘汰管理计划（第一阶段 - 协定签署情况报告）	已签署协定。无需再进一步报告
洪都拉斯	氟氯烃逐步淘汰管理计划（第一阶段 - 联合国环境规划署活动进度报告）	有待继续报告联合国环境规划署的活动和拨款情况
印度	氟氯烃逐步淘汰管理计划（第一阶段 - 最终财务报告）	已完成。已向第八十三次会议返还 83,405 美元以及 5,838 美元的机构支助费用
印度	氟氯烃逐步淘汰管理计划（第二阶段 - 泡沫塑料行业企业评估之进度报告）	相关方面要求的评估仍在进行当中。将在第八十四次会议上提交报告。
印度尼西亚	氟氯烃逐步淘汰管理计划（第一阶段——制冷和空调（制冷和空调）制造企业以及一系统公司 PT.TSG 化学公司（PT. TSG Chemical）的转换状态）	有待继续就制冷和空调制造企业的状态作出报告。请注意，PT.TSG 化学公司已退出氟氯烃逐步淘汰管理计划，且已向第八十三次会议返还 301,539 美元以及 22,616 美元的机构支助费用
伊朗伊斯兰共和国	氟氯烃逐步淘汰管理计划（第一阶段 - 最终进度报告）	待提交经修订的 PCR，包括最终拨款以及销毁基准设备的相关信息
约旦	氟氯烃逐步淘汰管理计划（第二阶段 - 五家企业停用 HFO 1233zd（E）发泡剂、转用环戊烷发泡剂的技术变革 ）	待批准该项技术变更，注意到企业将承担停用 HCFC 141b、转用环戊烷的任何额外费用
马尔代夫	氟氯烃逐步淘汰管理计划（渔业不含氟化氢的低全球升温潜能值制冷替代品示范项目）	有待向第八十四次会议提交最终报告

国家	项目名称	问题
北马其顿	氟氯烃逐步淘汰管理计划（第一阶段 - 泡沫塑料企业 Sileks 的转换进度报告）	注意：泡沫塑料企业 Sileks 已退出该计划，并且已向第八十三次会议返还 30,000 美元以及 2,250 美元的机构支持费用
苏里南	氟氯烃逐步淘汰管理计划（第一阶段 - 解决核查报告已明确的问题之进度报告）	留意报告
突尼斯	氟氯烃逐步淘汰管理计划（第一阶段 - 要求取消空调行业计划并更新协定 附件三：经修订的协定	有待注意取消空调行业计划；注意该协定的修订版；并要求各机构向第八十四次会议返还与空调行业计划相关的 900,489 美元
五、低全球升温潜能值氟氯烃替代品示范项目与区域冷却可行性研究		
埃及	关于聚氨酯泡沫在规模很小的用户群体中转换为非消耗臭氧层物质技术的低成本方案示范（进度报告，最终报告应于第八十三次会议上提交）	项目完成时间待延至 2019 年 7 月 31 日，在特殊情况下，注意迄今为止已取得的实质性进展，但有一项谅解，即相关方不再要求进一步延期，并要求联合国开发计划署在第八十四次会议之前提交最终报告。
欧洲与中亚（ECA）地区	建立一个区域级卓越中心，用于培训、认证以及低全球升温潜能值替代制冷剂示范（进度报告，最后报告应于第八十四次会议上提交）	项目完成时间待延至 2019 年 12 月 31 日，在特殊情况下，注意迄今为止已取得的实质性进展，但有一项谅解，即相关方不再要求进一步延期，并要求俄罗斯联邦政府在第八十五次会议之前提交最终报告
科威特	评估空调应用中不含氟氯烃和低全球升温潜能值技术性能的示范项目（进度报告）	该项目有待取消，并将要求联合国开发计划署向第八十四次会议返还 293,000 美元以及 20,510 美元的机构支助费用
摩洛哥	关于中小型聚氨酯泡沫塑料制造业企业采用低成本戊烷发泡技术转用非消耗臭氧层物质技术的示范项目（进度报告，最终报告应于第八十三次会议上提交）	项目完成日期待延至 2019 年 9 月 30 日，注意到若干第 5 条国家的项目执行进展情况以及对项目成果进行复制的潜在可能，并请联合国工发组织向第八十四次会议提交该项目的最终报告，并在第八十五次会议之前归还全部剩余资金
沙特阿拉伯	开发采用低全球升温潜能值制冷剂的窗式及柜式空调的空调制造商示范项目（最终报告） 附件四：最终报告	已完成。各机构在协助第 5 条国家筹备采用低全球升温潜能值制冷剂的柜式空调生产项目时，需应要求将最终报告考虑进去
沙特阿拉伯	在高环境温度的环境中为空调行业推广采用 HFO 的低全球升温潜能值制冷剂的示范项目（进度报告，最终报告应于第八十三次会议上提交）	项目完成时间待延至 2019 年 12 月 31 日，注意若干第 5 条国家的项目执行进展情况以及对项目成果进行复制的潜在可能，并要求联合国工发组织在第八十五次会议之前提交该项目的最终报告，并在第 86 次会议之前归还全部剩余资金
沙特阿拉伯	在高环境温度的环境中就喷雾泡沫应用采用 HFO 作为泡沫发泡剂逐步淘汰氟	项目完成时间待延至 2019 年 10 月 31 日，在特殊情况下，注意迄今为止已取得的实质性进展，但有一项谅解，即相关方不再要求进一步延期，并要求

国家	**项目名称**	**问题**
	氯烃的示范项目（进度报告，最终报告应于第八十三次会议上提交）	联合国工发组织在第八十四次会议之前提交该项目的最终报告
泰国	泰国泡沫系统公司采用低全球升温潜能值发泡剂配制用于喷涂式聚氨酯泡沫塑料应用的预混多元醇之示范项目（最终报告） 附件五：最终报告	已完成。各机构在协助第 5 条国家筹备使用 HFO 吹制泡沫的喷涂泡沫项目时，需应要求将最终报告考虑进去
西亚（地区）	在西亚地区高环境温度国家推广空调用制冷剂替代品示范项目 - PRAHA II（进度报告，最终报告应于第八十三次会议上提交）	项目完成日期待延至 2019 年 11 月 15 日，以便完成正在开展的活动，并要求联合国环境规划署和联合国工发组织在第八十四次会议之前提交最终报告，并在第八十五次会议之前归还全部剩余资金
科威特	比较三种不同的技术在中央空调应用之可行性研究（最终报告） 附件六：最终报告	已完成。有待提交 PCR，并将剩余的资金返还至第八十四次会议
六、要求就氟氯烃逐步淘汰管理计划第二阶段的执行变更执行机构		
菲律宾	氟氯烃逐步淘汰管理计划第二阶段及扶持活动（要求变更执行机构） 附件七：经修订之协定	注意世界银行已在第八十三次会议上返还 1,010,023 美元，加上氟氯烃逐步淘汰管理计划提供的机构支助费用 70,701 美元，以及 225,992 美元，加上就扶持活动提供的机构支助费用 15,819 美元；且有待批准将这些资金转给联合国工发组织。注意对氟氯烃逐步淘汰管理计划协定所作出的更新
七、**针对扶持活动的延期要求**		
多个国家	针对扶持活动的延期要求	表 15 中列出的三个国家的项目完成日期待延至 2019 年 12 月，48 个国家的项目完成日期待延至 2020 年 6 月，但有一项谅解，即相关方不再要求进一步延期，并且各机构将在项目完成期之后的六个月内提交最终报告

第二部分：消耗臭氧层物质废弃物处置**项目**

背景

8. 在第七十九次会议上，执行委员会除对其他事项作出要求之外，尤其要求各双边机构与执行机构提交除巴西和哥伦比亚以外的未完成的臭氧层消耗物质处置试点项目[2]的最终报告，并要求此前未向第八十次会议或第八十一次会议提交报告的项目向第八十二次会议返还项目剩余的资金（第 79/18 号决定项下第（d）条款）。在第八十二次会议上，执行委员会对所有业已完成的消耗臭氧层物质处置试点项目综合报告作出了审议。[3] 这不包括古巴的项目，因为当时最终报告尚未完成。在第八十二次会议上，执行委员会决定敦促联合国工发组织根据第 79/18（d）号决定，将欧洲及中亚地区（ECA）消耗臭氧层物质废弃物管理与处置区域项目的剩余资金返还至第八十三次会议；并就已于 2015 年完成的古巴消耗臭氧层物质废弃物管理与处置示范项目，敦促联合国开发计划署尽快在第八十三次会议之前提交该示范项目的最终报告（第 82/41 号决定项下第（c）及（ d）（ii）条款）。

古巴：消耗臭氧层物质废弃物管理与处置试点示范项目 – 最终报告（联合国开发计划署）

9. 联合国开发计划署作为指定的执行机构，根据第 82/41 号决定项下的（d）（ii）条款，已提交古巴消耗臭氧层物质废弃物管理与处置试点示范项目执行情况之最终报告。报告全文载于本文件附件二。

10. 古巴项目提议，对已根据政府能源计划收集的[4]45.3 公吨消耗臭氧层物质废弃物进行处置，[5] 并就采用水泥窑收集、储存和处置不需要的消耗臭氧层物质这一经济有效的方式进行展示。

11. 该项最终报告就下列工作提供了详细信息：项目执行情况；强化国家制冷剂收集系统，特别是强化收集及运输已回收的制冷剂之计划；以及制冷剂处置设施的设计与建造。

12. 该项目报告称，古巴已通过当地的工厂收集并汇总了消耗臭氧层物质的废弃物，经收集的消耗臭氧层物质已被送入市政中心，并由位于各大城市和省份的指定大型收集中心进行汇总，然后再将已回收的制冷剂进行称重、识别并分离为可回收的一次性材料。

13. 对于已确定进行处置的物质，相关方面使用专门的卡车运至储存中心并最终运至销毁设施，这种卡车具有适当的仪器（例如，带有安全阀、压力表、排油阀、用于清洁之用的检修孔；大容量制冷剂转移及回收器）设计与装备。整个过程均在授权工作记录中备有记录。

14. 选择用于销毁不需要的消耗臭氧层物质的技术，包含采用潮湿作业的旋转式水泥窑。该设施（Siguaney 水泥厂，“Siguaney Cement Plant”）必须进行改进，例如对使用现有水泥窑的天然气生产线实现自动化，安装新的控制面板以及空气、燃料和水的供应管线，以及安装工艺气进料口。相关方面已经进行土建工程施工，以就制冷剂气瓶和其他设备建立存储区域，并且安装了防火系统。该

[2]格鲁吉亚、加纳和尼泊尔的试点项目最终报告已提交至第七十九次会议，欧洲和中亚（ECA）地区和墨西哥的试点项目最终报告则已提交至第 80 次会议。
[3] UNEP/OzL.Pro/ExCom/82/21.
[4] UNEP/OzL.Pro/ExCom/62/28.
[5] 根据该能源计划，政府已要求平均寿命在 20 年至 60 年的 270 多万台冰箱和 276,000 台空调机组退役，并在 2005 年至 2010 年间更换为节能机组。

项目以科学、技术和环境部所颁发的环境许可为准。

15. 这项已经安装的设施名义销毁量为每年 10 吨。 2015 年至 2016 年间以及 2018 年，该项设施共销毁 1.745 公吨消耗臭氧层物质（即：0.268 公吨 CFC-11、1.262 公吨 CFC-12 以及 0.215 公吨 HCFC-22）; 2017 年没有销毁的消耗臭氧层物质。

16. 相关方面在项目实施过程中所发现的其中一项挑战在于，如何将已完成回收的制冷剂运往较大的收集中心以及该项销毁设施。这需要设计并购置具有特定特性的专用车辆（即：移动车间）。项目面临的其他挑战还包括：小型车间缺乏收集制冷剂的能力；延迟回收和运输制冷剂气体；延迟对销毁设施所需设备的进口及随后的安装工作；以及窑操作员需要接受额外培训，以适应新安装的组装处置系统之自动化控制措施。由于意外的工厂故障问题、该地区严重干旱造成的供水问题以及因缺少备件而造成的工厂故障，销毁过程当中也出现延误。

17. 项目执行期间吸取的经验教训包括下列各项工作的重要意义：协调参与项目的不同机构，监测各项工作进展以及解决尽快出现的问题，以避免项目执行过程中出现延误；就已收集的消耗臭氧层物质废弃物运往销毁设施的后勤安排提前作出规划；以及在选择老旧的现有工厂作为潜在的消耗臭氧层物质销毁设施时，应考虑可能存在的挑战和延误。

秘书处的评论

18. 该项目提议对通过政府能源计划（Energy Programme）收集的 45.3 公吨消耗臭氧层物质废弃物进行处置；然而，实际仅销毁 1.75 公吨。这是由于该销毁设施运作之初存在的难点等综合因素所致。此外，水泥厂的低生产水平，限制了可被销毁的消耗臭氧层物质废弃物的数量。[6] 该工厂目前正处于运营状态，且预计将继续销毁剩余的消耗臭氧层物质废弃物，这些废弃物系根据能源计划收集，目前储存于内贸部（Ministry of Internal Trade）仓库之内

19. 在阐明用于监测与核实该项设施所销毁的消耗臭氧层物质数量的方法时，联合国开发计划署解释称，相关方面没有开发新的监测系统，而是企业自己记录了放入水泥窑的消耗臭氧层物质废弃物的数量，并通过使用由此产生的水泥产量对其销毁量予以确认。相关方面已向国家臭氧机构（NOU）就这一数量进行报告用于记录。联合国开发计划署还阐明称，该项选定的处置设施的销毁去除率未经计算或核实。

20. 联合国开发计划署进一步解释称，相关方面没有进行水泥窑堆的排放测试，因为已经确定的、可以分析这些排放量的实验室要么不愿意在该国工作，要么由于经济封锁而无法在古巴开展业务。由于水泥窑寿命的缘故，水泥窑也没有安装采样平台，这使得样品采集非常困难。

21. 关于该试点项目对该国销毁消耗臭氧层物质的可持续性问题，联合国开发计划署报告称，该项目有助于终结消耗臭氧层物质的生命周期，就消耗臭氧层物质废弃物的处置而言，给予了该国一项环保型选择。该试点项目的成果显示，由于收集的废弃物量很少，难以在低消费量国家维持消耗臭氧层物质的销毁工作；然而，它们还为该国提供了一项机会，即让该国可在废弃物流可用时对水泥窑进行调整，让水泥窑今后可用于销毁消耗臭氧层物质之用。

[6] 每吨水泥最多可注入 0.1 千克，这可确保完全销毁气体。

建议

22. 执行委员会可：

(a) 留意由联合国开发计划署提交的古巴消耗臭氧层物质废弃物管理与处置试点示范项目的最终报告，该项报告载于文件 UNEP / OzL.Pro / ExCom / 83/11 当中；以及

(b) 要求各双边机构与执行机构酌情适用古巴消耗臭氧层物质废弃物管理与处置试点示范项目的调查结果及建议。

第三部分： 在核准的项目中暂时使用高全球升温潜能值技术

23. 如本节所述，双边和执行机构按照第 74/20 号决定，向第八十三次会议报告了巴西、古巴、黎巴嫩以及特立尼达和多巴哥临时使用高全球升温潜能值技术的情况。埃及和印度尼西亚也报告了暂时使用高全球升温潜能值的替代品，这将在第四部分，与他们的氟氯烃淘汰管理计划有关的其他问题一同讨论。

<u>巴西：暂时使用高全球升温潜能值氢氟碳化合物多元醇配方（氟氯烃淘汰管理计划第一阶段</u>）（开发计划署和德国政府）

背景

24. 在第八十次会议上，开发计划署提交了与巴西氟氯烃淘汰管理计划第五次付款相关工作方案执行情况的年进度报告。[7] [8] 开发计划署解释说，鉴于该国尚无商业规模的氢氟烯烃供应，两配方厂家（Shimtek 和 U-Tech）已要求暂时使用全球升温潜能值高的氢氟碳化合物多元醇配方。两配方厂都签署了一项承诺，即一旦可从市场获得氢氟烯烃，即停止暂时使用氢氟碳化合物混合物，同时两厂已进行了开发和优化，未增加多边基金费用。

25. 经过一次讨论后，执行委员会请开发计划署继续协助 Shimteck 和 U-Tech 两家企业保障已选定的替代技术的供应，但有一项谅解，在完全采用原本选择的替代技术或另一种低全球升温潜能值技术之前，不会支付任何增支经营费用。（第 80/12(e)号决定），还请开发计划署在每次会议上报告配方厂家所选择的临时技术使用情况，以及供应商提供在确保所选技术（包括相关组成部分）方面取得进展，已在国内商业供应的最新情况（第 81/9（b）号决定）。

26. 根据第 80/12(e)号决定和第 81/9(b)号决定，开发计划署报告说，Shimtek 已停止使用氢氟碳化合物，并选择使用水基技术取代使用氢氟烯烃进行柔性泡沫生产，使用自有资源对配方作出了必要调整。该企业报告称，国内市场氢氟烯烃的高成本，仍然是妨碍以有竞争力的价格生产配方的最大障碍。

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[7] 氟氯烃淘汰管理计划第一阶段的第五次和最后一次付款由第七十五次会议核准，总费用为 2,035,094 美元，其中包括 1,470,700 美元外加开发计划署 110,313 美元的机构支助费用，以及 409,091 美元外加 45,000 美元的德国的机构支助费用。

[8] UNEP/OzL.Pro/ExCom/80/34。

27. U-Tech 仍然在泡沫配方的生产中暂时使用 HFC-134a，因为使用低全球升温潜能值替代品的初步试验没有产生满意的结果，配方的稳定性和反应性持续存在问题。从 2018 年 3 月至 9 月等待交付 HFO-1234ze 样品进行补充测试之后，企业决定不经氢氟烯烃供应商调解，直接进口此类样品。目前，样品正在通关。U-Tech 报告称，获取样品的过程遇到重大困难，市场上仅有一家氢氟烯烃供应商。配方厂家还重申，气态氢氟烯烃成本的现况，使这一细分市场的替代对于该企业而言不可行。

秘书处的评论

28. 秘书处注意到开发计划署和两个配方厂家为确保供应低全球升温潜能值泡沫塑料发泡剂所作的努力。就 Shimtek 而言，秘书处注意到，该问题业已通过采用可用于柔性泡沫的水基技术解决，（Shimtek 在第一阶段提及的子行业）。配方调整的额外成本已由配方厂家承担。

29. 注意到 Shimtek 未能在第一阶段采用 HFO-1233zd（E），而在第二阶段，预计几个配方厂家（Shimtek，U-Tech，Comfibras，Basf 和 Dow）将在大量下游多个用户的多种用途中采用氢氟烯烃，秘书处询问如何解决这一问题。开发计划署说明，在第二阶段，若干配方厂家表示有兴趣使用多种技术选择（甲酸甲酯（甲醛），甲缩醛，氢氟烯烃和水基），以便更好地满足其客户的具体需求。开发计划署还预计，大规模消费氢氟烯烃将有助于实现更好的长期成本效益比。

30. 至于 U-Tech，开发计划署报告说，采购的 HFO-1234ze 样品的价格为 22.00 美元/千克，不包括直接进口和清关费用；这些费用可能使 U-Tech 不能继续参与这个细分市场（泡沫配方）。开发计划署与配方厂家继续对情况进行分析。

31. 为了更好了解这一问题，秘书处请开发计划署提供过去三年泡沫塑料用户其他发泡剂（即 HCFC-141b、HFC-245fa、HFC-134a 和 HFO-1233zd（E））的价格/千克（或样品成本，如果还没有商业化）。开发计划署表示没有这方面的信息因为国家臭氧机构没有，而配方厂家不愿意分享这方面的信息。

32. 开发计划署将继续根据第 80/12(e)号决定报告 U-Tech 的任何其他进展。

秘书处的建议

33. 执行委员会不妨：

(a) 表示赞赏地注意到 UNEP/Ozl.Pro/ExCom/ 83/11 号文件所载开发计划署提供的报告，以及为促进向氟氯烃淘汰管理计划第一阶段资助的巴西 Shimtek 和 U-Tech 配方厂家供应低全球升温潜能值的技术所做的努力；

(b) 表示注意到 Shimtek 配方厂家采用低全球升温潜能值技术；并

(c) 请开发计划署继续协助巴西政府确保向 U-Tech 配方厂家提供低全球升温潜能值替代技术，但有一项谅解，在完全采用原本选择的替代技术或另一种低全球升温潜能值技术之前，不会支付任何增支经营费用，并在完全采用原本选择的替代技术或另一种低全球升温潜能值技术之前，在执行委员会每次会议上提供关于其转换状况的报告，以及供应商在确保提供所选技术（包括相关

组成部分）方面取得进展，已在国内商业供应的最新情况。

古巴：暂时使用高全球升温潜能值技术的已转换为低全球升温潜能值技术的企业（氟氯烃淘汰管理计划第一阶段）（开发计划署）。

背景

34. 在第七十七次会议上，古巴政府提出批准其氟氯烃淘汰管理计划第一阶段第三次付款的申请，[9] 表示尽管两家聚氨酯泡沫塑料企业（即 Friarc 和 IDA）已获得转为水吹技术（低全球升温潜能值技术），但是他们目前暂时使用 HFC 365mfc 和 HFC 227ea（高全球升温潜能值技术）的混合物，因为得不到原本选择的技术，并且没有提供规定的绝缘性能。

35. 在审议该问题后，执行委员会请开发计划署继续协助古巴政府确保低全球升温潜能值技术的供应，并在最初选择的技术或另一项低全球升温潜能值技术全面采用、企业已转换之前，在每次会议上报告临时技术的使用情况（第 77/50(b)号决定），包括关于如果使用项目获得批准时所选择的以外的一种技术的增支资本成本和增支运营成本的详细分析，以及供应商提供在确保所选技术（包括相关组成部分）方面取得进展，已在国内商业供应的最新情况（第 81/10(b)号决定）。

36. 根据第 77/50(b)和第 81/10(b)号决定，开发计划署报告说，基于氢氟烯烃的配方由一个区域配方厂家提供，供两家企业于 2018 年 11 月进行试验。由于最初的一组试验结果不满意，该供应商最近访问了古巴，去进行第二组试验。至于 Friarc，该企业使用的异氰酸酯多于第一组试验中所需的异氰酸酯；然而， 2019 年 3 月 26 日，在供应商在场的情况下进行的第二组试验获得成功。至于 IDA，两组试验都不满意，是由于多元醇问题，多元醇似乎有稳定性问题。供应商将发送新样品再进行试验。与此同时，企业继续使用高全球升温潜能值的发泡剂。

秘书处的评论

37. 秘书处注意到开发计划署努力协助古巴的两家企业确保供应低全球升温潜能值的泡沫塑料发泡剂。秘书处询问了 HFO-1233zd（E）的供应和成本，指出，一旦替代品在技术上证明可行，它也应该可从商业获得而且负担得起；但是，目前还没有关于基于氢氟烯烃配方在古巴的价格的信息。秘书处还要求暂时使用的发泡剂（HFC-227ea / HFC-365mfc 混合物）的价格/千克，但在本文件印发时尚未收到该信息。

秘书处的建议

38. 执行委员会不妨：

(a) 表示赞赏地注意到 UNEP/Ozl.Pro/ExCom /83/11 号文件所载开发计划署提供的报告，以及为促进向氟氯烃淘汰管理计划第一阶段资助的古巴企业 Friarc 和 IDA 供应低全球升温潜能值的技术而做的努力；并

(b) 请开发计划署继续协助古巴政府确保提供低全球升温潜能值替代技术，并向

[9] UNEP/OzL.Pro/ExCom/77/39。

第八十四次会议提交一份关于第（a）分段提及两个企业转换状况的报告，包括如果使用在项目批准时所选择的以外的一种技术时对增支资本成本和增支运营成本的详细分析，以及供应商在确保提供所选技术（包括相关组成部分）方面取得进展，已在国内商业供应的最新情况。

黎巴嫩：使用临时技术（氟氯烃淘汰管理计划第二阶段 – 进度报告）（开发计划署）

背景

39. 开发计划署作为指定执行机构，根据第 82/25(b)(i)[10] 和 (ii)[11] 号决定，代表黎巴嫩政府提交了一份关于在氟氯烃淘汰管理计划第二阶段中泡沫塑料、制冷和空调制造行业五家企业转换执行情况的进度报告。

进度报告

40. 开发计划署报告，Iceberg[12] and Frigo Liban[13] 的转换已经完成，结果淘汰了 1.61 ODP 吨的 HCFC-22 和 1.54 ODP 吨的 HCFC-141b。UNIC 转用 HFC-32 始于 2019 年 4 月，预计将于 2019 年 12 月完成，结果淘汰 0.88 ODP 吨的 HCFC-22。其他两家企业 CGI Halawany 和 ICR，正在与企业进行引进 HFC-32 技术的谈判。预计两家企业将于 2020 年底前转换。

41. 开发计划署进一步报告说，在核准氟氯烃淘汰管理计划第二阶段第二次付款时，空调和泡沫塑料企业供资拨款与提交八十一次会议的企业一级订正供资拨款相一致。黎巴嫩政府和开发计划署继续监测这些拨款以确保在商定的核准总供资范围内以有成本效益的方式转换整个部门，并确认在转换结束时剩余的任何资金将退还多边基金。

42. 氟氯烃淘汰管理计划第二阶段的泡沫塑料行业计划包括给 11 家中小型企业转换的技术援助，他们使用 37.9 公吨（4.17 ODP 吨）HCFC-141b 作为生产太阳能和电热水器的绝缘材料。开发计划署报告说，关于泡沫塑料转换，市场持续不供应氢氟烯烃配方仍然是一项挑战，尤其是对小企业而言。政府正在探索，能以具有成本效益和可持续的方式促进所有剩余泡沫应用/企业（SPEC，Prometal 和太阳能和电热水器行业）转换的其他低全球升温潜能值发泡剂。然而，鉴于 HCFC 141b 的禁令将于 2020 年 1 月生效，当地市场缺乏商用低全球升温潜能值替代品，迫使政府也考虑可能临时使用基于氢氟碳化合物的发泡剂，使剩下的泡沫塑料企业全部淘汰 HCFC-141b。在第八十一次会议上报告了类似情况，当时空调制造行业的一家企业使用 HFC-365mfc 作为发泡剂来转换泡沫成分。

[10] 请开发计划署继续协助黎巴嫩政府确保提供低全球升温潜能值替代技术，并在完全采用原本选择的替代技术或另一种低全球升温潜能值技术之前，在每次会议上提供关于 Iceberg SARL 和 CGI Halawany 转换状况的报告，以及供应商提供的在确保所选技术（包括相关组成部分）方面取得进展，已在国内商业供应的最新情况。

[11] 请开发计划署在第八十三次会议上报告其余企业实行转换进度和现况，包括资金分配：Frigo Liban，UNIC，CGI Halawany 和工业和商用冰箱。

[12] 该企业已淘汰 0.69 ODP 吨 HCFC-22 和 1.54 ODP 吨 HCFC-141b，并分别转换为 HFC-32 和 HFC-365mfc 的替代品，其中 HFC 365mfc 用作临时替代技术。

[13] 该企业已转用 HFC-32 并淘汰了 0.92 ODP 吨 HCFC-22 。

43.　黎巴嫩政府还对一旦获得供应，小型企业使用预混基于氢氟烯烃的配方表示关切，因为同泡沫专家的磋商表明，这些配方需要非常昂贵的特殊催化剂和稳定剂。

秘书处的评论

44.　秘书处注意到开发计划署努力协助剩余的泡沫塑料企业，特别是小型企业，在遇到持续存在难以获取氢氟烯烃的困难时，探索其他低全球升温潜能值的泡沫塑料替代品。请开发计划署确保在选择使用全球升温潜能值高（例如 HFC-245fa）时，应通知执行委员会。有人重申，由于从 2020 年 1 月开始禁止使用和进口 HCFC-141b，企业有义务尽快转用非消耗臭氧层物质技术。

45.　关于 Iceberg 在 2017 年完成转换，开发计划署报告说，它继续使用 HFC-365mfc 进行泡沫保温，这与当地市场缺乏氢氟烯烃配方的挑战相一致。开发计划署还确认，该企业已承诺在可以获得替代品时，使用自有资源转用氢氟烯烃配方或其他低全球升温潜能值的绝缘泡沫替代品。

46.　注意到开发计划署和黎巴嫩政府将继续监测每个企业的供资分配情况，将用第八十一次会议商定的订正企业一级拨款同企业达成协议。开发计划署确认，一旦这些企业完成转换，任何余额将根据第 81/50 号决定退还基金。

秘书处的建议

47.　执行委员会不妨：

(a)　表示注意到 UNEP/OzL.Pro/ExCom/83/11 号文件所载开发计划署和黎巴嫩政府提供的报告，描述了政府在寻找和获取商业上可获得的低全球升温潜能值（全球升温潜能值）替代品（即氢氟烯烃）方面所持续面临的挑战，以及黎巴嫩政府和开发计划署为促进向黎巴嫩氟氯烃淘汰管理计划第二阶段供资的企业提供低全球升温潜能值技术所作的努力；并

(b)　请开发计划署继续协助黎巴嫩政府确保提供低全球升温潜能值替代技术，向第八十四次会议，并在原本选择的技术或另一低全球升温潜能值的其他技术全部采用之前，在每次会议上报告泡沫和空调制造行业剩余受益企业的转换情况，包括小型泡沫塑料企业，以及供应商在确保提供所选技术（包括相关组成部分）方面取得进展，已在国内商业供应的最新情况。

- **特立尼达和多巴哥：氟氯烃淘汰管理计划（第一阶段 - 第四次付款）（开发计划署）**

背景

48.　在第八十一次会议上，开发计划署通报说，泡沫塑料部门的一家企业正在使用不同于执行委员会核准的发泡剂。随后，执行委员会请开发计划署向第八十二次会议提供一份关于使用甲酸甲酯 F 的情况，以及在氟氯烃淘汰管理计划第一阶段下多边基金援助的企业使用的替代发泡剂的报告（第 81/52(b)号决定）。在第八十二次会议上，开发计划署通报说，

由于无法安排专家任务，因此无法提供该企业的使用该物质的最新情况。有鉴于此，执行委员会敦促开发计划署在第八十三次会议上提出上述报告（第 82/26 号决定）。

49. 根据第 81/52(b)号和第 82/26 号决定，开发计划署代表特立尼达和多巴哥政府报告称，开发计划署访问了特立尼达和多巴哥，以审查项目执行情况。表 2 概述了泡沫塑料行业的企业清单和替代技术的采用情况；第一阶段的供资将导致全国完全淘汰该国剩余的 2.5 ODP 吨 HCFC-141b 合格消量。

表 2. 截止 2019 年 4 月特立尼达和多巴哥泡沫塑料企业转换概况

企业	核准资金 (美元)	技术选择	最新情况
Ice Con	43,900	甲酸甲酯	由于管理层的变化，企业决定退出该项目，并将停止其在泡沫塑料应用中的业务运营。 该项目将被取消，在完成行政和财务程序后，将返还估计为 20,000 美元的剩余资金
Ice Fab	31,900	甲酸甲酯	采购转换为甲酸甲酯技术的设备.
Seal Sprayed Solutions (Seal)	30,500	甲酸甲酯	使用甲酸甲酯/水，并将其作为标准配方提供给客户。 如果项目特别要求使用基于氢氟烯烃的发泡剂，则使用那些发泡剂
Tropical Marine	31,900	水	使用选定的替代品
Vetter	35,600	甲酸甲酯	使用选定的替代品
共计	**173,800**		

秘书处的评论

50. 秘书处请开发计划署将 Ice Con 未使用的余额（估计为 20,000 美元）退还给第八十三次会议，因为该项目拟被取消。但是，开发计划署提到，只有在完成行政和财务结算程序提交下一次付款申请后才能退还资金。

51. 秘书处关切地注意到 Seal 对特定项目使用基于氢氟碳化合物的发泡剂，并同开发计划署就某些订单中规定基于氢氟碳化合物的发泡剂的原因进行了讨论。开发计划署通报说，不完全了解有关采购要求规定特定吹跑剂的原因。企业必须提供符合消费者需求的产品，因此，当客户特别要求使用氢氟碳化合物发泡剂时，Seal 就使用该发泡剂。开发计划署还提到，基于氢氟碳化合物的配方可从国际配方厂家供应商处获得，适合市场上的喷涂泡沫应用。根据第 77/35(b)号决定，请开发计划署如有可能, 协助特立尼达和多巴哥政府考虑采取措施，协助在各部门和/或分部所涵盖的运用中采用低全球升温潜能值技术.

秘书处的建议

52. 执行委员会不妨：

(a) 表示注意到 UNEP/OzL.Pro/ExCom/83/11 号文件所载开发计划署关于特立尼达和多巴哥在氟氯烃阶段第一阶段管理计划期间获得援助的企业使用不同技术，以及在采用低全球升温潜能值发泡剂时所面临的挑战的情况报告；

(b) 还注意到，开发计划署在完成取消项目所需的行政和财务程序提交下一次付

款申请时，将退还 Ice Con 未使用的余额；并

(c) 请开发计划署继续协助特立尼达和多巴哥政府获取低全球升温潜能值替代技术的供应，并向第八十四次会议提供关于拟议技术转换情况的报告。

第四部分：与氟氯烃淘汰管理计划有关的报告

53. 本部分包括下列国家的氟氯烃淘汰管理计划第一阶段或第二阶段的进度报告：巴哈马、孟加拉国、埃及、赤道几内亚、洪都拉斯、印度、印度尼西亚、伊朗伊斯兰共和国、约旦、马尔代夫、北马其顿、苏里南和突尼斯。

巴哈马：氟氯烃淘汰管理计划（第一阶段 - 第三次付款）（环境署）

背景

54. 执行委员会在第 80 次会议上审议了关于巴哈马氟氯烃淘汰管理计划第一阶段第三次付款的申请。委员会指出，秘书处已提请注意与使用易燃制冷剂 R-22a 改装使用 HCFC-22 的器具相关的安全问题，环境署将开展一项研究，以探索最佳可行方案。有鉴于此，执行委员会要求环境规划署在第 82 次会议上提供关于该研究结果的最新情况，以探讨有关评估、监测和改装两套空调系统的试点项目的最佳备选方案（第 80/62 号决定（b））。由于环境署未在第 82 次会议上提供关于该研究的报告，执行委员会敦促环境规划署在第 83 次会议上，按照第 80/62 号决定（b）提供上述研究结果的最新情况（第 82/27 号决定）。

秘书处评论

55. 秘书处关切地注意到，研究结果的最新情况未能提供给第 83 次会议供审议。

56. 环境署解释说，于 2018 年确定了该顾问，并于 2019 年 2 月进行了视访；目前正在编写该文件的最终草案。一旦报告定稿后，将提交给秘书处。

秘书处建议

57. 敬请执行委员会敦促环境规划署，按照巴哈马氟氯烃淘汰管理计划第一阶段，在第 84 次会议上提供关于研究结果的最新最终报告，以探讨有关评估、监测和改造两套空调系统的试点项目的最佳备选方案。

孟加拉国[14]：氟氯烃淘汰管理计划（第一阶段 - 最后进度报告）（开发署和环境署）

58. 开发计划署作为牵头执行机构，按照第 82/28（b）号决定，代表孟加拉国政府提交了关于与氟氯烃淘汰管理计划第一阶段[15] 有关的工作方案执行情况的最后进度报告。

[14] 孟加拉国氟氯烃淘汰管理计划第一阶段在第 65 次会议上获得批准，总额为 1,556,074 美元，外加机构支助费用 136,231 美元，以在 2018 年将氟氯烃消费量减少 30%。

[15] 氟氯烃淘汰管理计划第一阶段的第三和第四次（最后）合并付款在第 80 次会议上得到核准，金额为 35,000 美元，外加环境规划署的机构支助费用 4,550 美元。

59. 第一阶段实施于 2019 年 3 月 31 日完成，并于 2019 年 4 月 1 日提交了项目完成报告；无需进一步报告。

氟氯烃消费量

60. 2018 年国家方案执行情况报告中报告的氟氯烃总消费量为 46.78 ODP 吨，比政府与执行委员会之间的协定规定的当年允许量 50.86 ODP 吨低 8%，比确定基准 72.65 ODP 吨低 35%。

进度报告

61. 氟氯烃淘汰管理计划第一阶段执行了以下活动：

(a) 2014 年修订了《消耗臭氧层物质管制规则》（2004 年），包括禁止进口和制造使用散装 HCFC-141b 的产品；建立氟氯烃许可证和配额制度；对 249 名海关和执法人员进行了氟氯烃进口管制和管理方面的培训；与五个邻国（不丹、中国、印度、缅甸和尼泊尔）的海关代表、国家臭氧机构和边境安全局，举办了有关监测和控制消耗臭氧层物质贸易问题的专题会议；向海关入境点提供五个制冷剂标记；

(b) 在 2014 年 Walton 高科技行业有限公司16 转换后，淘汰了用于制造冷冻设备绝缘泡沫的 20.20 ODP 吨（183.70 公吨）HCFC-141b。

(c) 与孟加拉国制冷和空调商协会（BRAMA）合作，培训 105 名培训师和 3,944 名技术人员，以掌握良好服务做法；通过与技术教育局和技术教育委员会合作，将与消耗臭氧层物质淘汰有关的技术问题纳入理工学院和职业机构的国家课程；以当地语言制作了良好服务做法的小册子和培训视频；和

(d) 提高认识活动，包括臭氧日庆祝活动，分发 7,500 项提高认识构建材料，包括海关快速工具和培训手册，环境署培训手册和两个宣传零 ODP，低全球升温潜能值替代制冷剂的视频。

62. 孟加拉国臭氧机构承担了责项目的执行和监测，该机构由环境部总干事主持。 臭氧机构的活动由国家臭氧消耗物质技术委员会进行监督。

资金发放水平

63. 截至 2019 年 3 月，在核准的 1,556,074 美元中，已发放了 1,545,405 美元，如表 3 所示。按照第 82/28（b）号决定，余额 11,856 美元（3,628 美元，外加开发计划署 272 美元机构支助费用，和 7,041 美元，加上环境规划署 915 美元的机构支助费用）将退还给第 84 次会议。

[16] 经第 62 次会议批准（第 62/31 号决定）并纳入氟氯烃淘汰管理计划第一阶段。

表 3. 孟加拉国氟氯烃淘汰管理计划第一阶段的财务报告

机构	核准（美元）	发放（美元）	发放率 (%)
开发计划署	1,201,074	1,197,446	99.7
环境规划署	355,000	347,959	98.0
合计	**1,556,074**	**1,545,405**	**99.3**

秘书处评论

64. 秘书处指出，开发计划署和环境规划署已按照第 82 次会议上提出的订订工作计划，完成了孟加拉国氟氯烃淘汰管理计划第一阶段计划的活动。孟加拉国氟氯烃淘汰管理计划第一阶段的完成淘汰了总计 24.53 ODP 吨的氟氯烃（即 Walton 高科技行业有限公司在制造绝缘泡沫塑料时转换的 20.20 ODP 吨 HCFC-141b；维修行业的 3.48 ODP 吨 HCFC-22，0.57 ODP 吨 HCFC-142b，0.21 ODP 吨 HCFC-123 和 0.07 ODP 吨 HCFC-124）。

65. 政府已经承诺通过自 2014 年以来禁止使用和进口 HCFC-141b，以及定期监测企业运营中对环戊烷的使用，确保 Walton 高科技工业有限公司转换所实现的淘汰的可持续性。关于技术人员和海关官员培训方案的可持续性，开发计划署通报，这些活动也正与 BRAMA 合作在氟氯烃淘汰管理计划第二阶段执行，BRAMA 是该国维修技术人员的主要培训合作伙伴。此外，国家臭氧机构还与教育部合作，以确保将所有培训课程纳入该国的职业教育方案。关于海关培训，培训单元已纳入海关总署定期培训课程。

秘书处的评论

66. 敬请执行委员会：

(a) 关注开发计划署提交并载于文件 UNEP/OzL.Pro/ExCom/83/11 中的孟加拉国氟氯烃淘汰管理计划第一阶段执行情况的最后进度报告； 和

(b) 要求孟加拉国政府和开发计划署按照第 82/28（b）号决定， 不迟于第 84 次会议，返还氟氯烃淘汰管理计划的第一阶段的余额 11,856 美元（美元 3,628 美元，加上开发计划署 272 美元的机构支助费用，以及 7,041 美元，加上美国环境规划署 915 美元的机构支助费用）。

<u>埃及：氟氯烃淘汰管理计划（第一阶段 - 第三次付款）</u>（开发计划署）

背景

67. 氟氯烃淘汰管理计划的第一阶段包括一个项目，将 81 个中小企业和 350 个微小用户转为 MF 或其他低全球升温潜能值技术（将在执行期间进行选择），并在其系统厂家和分销商的支持下，淘汰了 75.74 ODP 吨 HCFC-141b。资金被批准用于两个第 5 条拥有的系统公司的设备转换，并包括对所有系统公司和分销商的技术援助，以及中小企业的转换。

68. 在第 82 次会议上，据报告称，一个当地的系统公司（Technocom）和一个非第 5 条所有的（Dow）系统公司被转换。没有向 Dow 提供多边基金设备转换资金；但是，为下游用户采用替代泡沫发泡剂的技术援助得到了资助。一个系统公司退出项目（Obeigi），并且预计将与另一个公司

（Baalbaki）签署一份协议备忘录（协定书）[17]。共有 24 家下游用户获得了援助。其余 57 家下游用户的转换预计将于 2019 年底前完成。

69. 秘书处注意到，81 家中小企业和系统厂家 350 个微小用户的转换受到重大延迟，预计将于 2013 年 8 月前完成（即迄今为止仅转换了 24 家中小企业和两家系统厂家）。秘书处还指出，埃及政府自 2018 年 1 月 1 日起禁止进口预混多元醇中所含 HCFC-141b，并承诺在 2020 年 1 月 1 日之前，禁止进口、使用和出口散装 HCFC-141b 以及出口预混多元醇所含 HCFC-141b。

70. 在第 82 次会议上，据报告称，两个系统厂家（Dow 和 Technocom）正在开发低全球升温潜能值配方，这些含水和氢氟氢氟烯烃，还含有 HFC-245fa，HFC-365mfc 和 HFC-227ea，这些物质受到基加利修正案的管控。尽管预计使用高全球升温潜能值替代品是暂时的，并且其使用最迟在 2015 年之前已淘汰。开发计划署确认，对于在第一阶段已经获得援助的系统厂家项目下游用户，他们已经同意转用低全球升温潜能值技术，不会为其申请进一步的援助。

71. 在进行非正式磋商之后，并注意到埃及政府承诺将氟氯烃淘汰管理计划第一阶段的项目完成报告提交给 2020 年的第一次会议，并且委员会特别要求在 2020 年 12 月 31 日之前在财政上完成第一阶段，归还剩余的余额。（第 82/72（b）（i）和（iv）号决定）：

(b)(i) 埃及政府和开发计划署在每次会议完成第一阶段时，提交一份关于系统公司，81 家中小企业和 350 名微小用户的转换情况的报告，其中包括：系统-厂家转换状况，制定的配方和相关的付款发放；以所选技术最新转换的中小企业名单，相关付款发放和每个中小企业的承诺；以及有关微小用户数量的最新情况； 和

(b)(iv) 开发计划署在每次会议上向执行委员会报告埃及政府选定的临时技术的使用情况，直至按商定全面采用全球公认的全球升温潜能值低的技术，并附上供应商关于该国以商业方式提供可确保所选技术，包括相关组件，的进展的最新情况。

72. 执行委员会还要求开发计划署继续协助埃及政府，以确保为通过系统厂家改装 81 家中小企业而选择的替代技术的供应（第 82/72（b）（iii）号决定），并批准氟氯烃淘汰管理计划第一阶段的第三次和最后一次付款，其谅解是，即只有满足下列条件才能提交第二阶段第二次付款申请：已与 Baalbaki 系统公司签署了协定书；系统厂家项目第一阶段至少有 40 家中小企业已经改装；开发计划署至少从系统厂家项目的核准资金中发放了 350,000 美元，供给最后的泡沫塑料受益人（第 82/72（c）号决定）。

73. 开发计划署按照第 82/72（b）（i）和（iv）号决定，代表埃及政府提交了两份报告，说明系统厂家和下游用户的转换情况以及临时技术使用情况。

进度报告

74. 已经与 Baalbaki 签署了协定书，将转换八家客户，淘汰 53.7 公吨 HCFC-141b。已经编制了与 Technocom 的协定书增编，以转换另外 12 名客户，以淘汰 11.37 ODP 吨 HCFC-141b；预计协定书将于 2019 年 5 月签署。为 Balbaki 的替代技术包括水和 MF，而对 Technocom 则包括水基系统和

[17] 开发计划署的项目执行安排。

氢氟烯烃系统；在这两种情况下，预见临时均采用氢氟碳化合物。迄今为止，尚未转换任何微小用户；这些转换预计将在 2019 年下半年开始。

75. 关于技术使用情况，开发计划署报告说，Dow 和 Technocom 已经采用水基系统，并经客户同意用于某些应用；将向第 84 次会议提供关于引进 MF 的最新情况；并且需要进一步研究氢氟烯烃在多元醇中的绩效，因为一些系统厂家报告了准备系统中的一些问题，包括它们的稳定性。开发计划署继续监测相关局势，并计划于 2019 年 5 月与国家臭氧机构就引入低全球升温潜能值技术的障碍进行协商。

76. 自第 82 次会议以来又发放了 388,072 美元，使开发计划署的发放总额达到 2,407,924 美元（总额为 4,000,00 美元）。开发计划署确认，除非按照第 77/35（a）(vi)号决定，使用低全球升温潜能值技术，否则增量运营费用现在或将来也不会提供给客户。

秘书处评论

77. Dow 和 Technocom 的转换工作已经完成，包括将 24 个下游客户转换为水基氢氟碳化合物，临时转换为氢氟碳化合物，相关的 HCFC-141b 淘汰量分别为 4.44 ODP 吨和 13.09ODP 吨。虽然 24 个下游客户已经适当签署了停止使用氟氯烃系统的承诺，但由于临时过渡仍在进行中，因此没有提供停止使用氢氟碳化合物的类似承诺。虽然无法估计下游客户何时开始使用商定的低全球升温潜能值技术，但开发计划署预计能够在 2019 年 5 月所计划的任务组后提供更新情况。

78. 开发计划署未能提供由 Dow 和 Technocom 转换的下游客户临时使用的氢氟碳化合物与低全球升温潜能值发泡剂（即水和氢氟氢氟烯烃）的相对比例，因为其用量取决于具体的客户需求。同样，对于将由 Baalbaki 转换并置于 Technocom 的协定书附录的的另外 20 个下游用户，预计临时使用氢氟碳化合物的企业的相对比例将取决于客户的需求，因而无法获得。

79. 关于采用氢氟氢氟烯烃的挑战，开发计划署澄清说存在商业和技术两方面的挑战。虽然氢氟烯烃在埃及有售，但价格是客户在选择技术时考量的因素。开发计划署计划继续提供技术援助，以解决对基于氢氟氢氟烯烃系统的绩效的关切，包括通过 2019 年 5 月的任务组。

80. 开发计划署确认，政府仍致力于在 2019 年 12 月 31 日之前完成氟氯烃淘汰管理计划的第一阶段，并确定在 2020 年 1 月 1 日前禁止进口、使用和出口散装 HCFC-141b，以及禁止出口预混合多元醇所含 HCFC-141b。

秘书处建议

81. 敬请执行委员会:

(a) 关注开发计划署提交的关于系统公司，81 个中小型企业和 350 个微小用户的转换状况报告，以及关于埃及使用临时技术的情况报告 ，载于 UNEP/OzL.Pro/ExCom/83/11 号文件； 和

(b) 要求开发计划署继续协助埃及政府确保提供低全球升温潜能值替代技术，其谅解是：即在最初选择的技术或另一种低全球升温潜能值技术得到充分执行之前，不会发放增量营运费用，以及 在执行委员会每次会议上提交一份关于其转换情况的报告，直至最初选择的技术或另一项全球升温潜能值低的技术得到充分采用，以及供应商提供关于确保该国可以商业方式获得所选技术，包括相关组件，的最新进展情况 。

赤道几内亚：关于《协定》签署情况的报告（第 82/73（c）（i）号决定）（环境规划署）

背景

82. 在第 65 次会议上批准了赤道几内亚氟氯烃淘汰管理计划的第一阶段，以在 2020 年前使氟氯烃消费量减少 35%。第一次和第二次付款的执行被推迟，原因是社会动乱导致旅行限制，采购设备的海关的清关过程，以及由于该国的安全情况而难以完成核查报告。

83. 执行委员会第 82 次会议除其他外，特别核准了氟氯烃淘汰管理计划第一阶段第三和第四次合并付款，并要求环境规划署在 2019 年第一次会议上提供关于与赤道几内亚政府签署该协定情况的报告。（第 82/73（c）（i）号决定）。

84. 开发计划署报告说，赤道几内亚政府和环境规划署于 2019 年 3 月 4 日签署了一项小规模供资协议。除其他外，按照与第 82 次会议批准的付款执行计划，小规模供资协议还特别包括详细的活动，预算和执行时间表。执行期为 24 个月。

秘书处评论

85. 秘书处注意到赤道几内亚政府和环境规划署为避免进一步延误执行氟氯烃淘汰管理计划下的活动所作的努力。 随着小规模供资协议的签署，执行活动已经开始，预计最终付款将在 2020 年申请。环境规划署确认，它将通过其履约援助方案进一步支持赤道几内亚政府，并且按照第 82/73（c）（ii）号决定，提交关于在 2019 年第二次会议提供援助的报告。

秘书处建议

86. 敬请执行委员会关注，赤道几内亚政府和环境规划署签署了一项协定，以执行氟氯烃淘汰管理计划第一阶段第三和第四次合并付款。

洪都拉斯：氟氯烃淘汰管理计划（第一阶段 - 进度报告）（环境署）

87. 在第 81 次会议上，执行委员会核准了（在一揽子核准项目清单下）洪都拉斯氟氯烃淘汰管理计划第一阶段第四次付款，以及相应的 2018-2020 年付款执行计划，其谅解是：

(a) 环境规划署和洪都拉斯政府将加强努力，执行与氟氯烃淘汰管理计划第一阶段相关的制冷技术人员的培训活动；

(b) 环境规划署将向各次会议提交一份进度报告，说明与氟氯烃淘汰管理计划第一阶段有关的环境规划署各成分活动的执行情况，包括实现的发放付款情况，直到提交氟氯烃淘汰管理计划第一阶段第五次和最后一次付款；和

(c) 截至 2018 年 9 月 30 日，洪都拉斯氟氯烃淘汰管理计划第一阶段第一次付款，第二次付款和第三次付款环境规划署各成分核准的资金总额的发放目标为 50%，截至 2019 年 3 月 31 日为 80%，到 2019 年 12 月为 100%，第四次付款的环境规划署成分到 2019 年 3 月 31 日为 20%，到 2019 年 12 月为 50%。

88. 按照上述要求，环境规划署向第 83 次会议提交了关于环境规划署第一阶段活动执行情况的进度和财务报告。

氟氯烃淘汰管理计划第一阶段执行情况的进度报告

89. 自第 82 次会议以来，已经执行了以下活动：

(a) 环境规划署、国家臭氧机构（UTOH）、环境部和国家培训机构之间签署了谅解备忘录，以审查制冷和空调维修行业良好做法的培训和认证程序；

(b) 制定指南和培训课程，以指导教员和评估人员评估申请制冷和空调维修部门认证的技术人员的能力；

(c) 另外增加四个培训讲习班，共培训 287 名技术人员，掌握良好的制冷做法和安全处理易燃制冷剂；

(d) 提高认识视访 60 个制冷车间，和超市、酒店和食品行业的 28 家最终用户，以促进技术人员培训和认证方案，并提供制冷剂管理技术咨询，以遵守消耗臭氧层物质法规制定的法律规定；和

(e) 环境规划署与政府之间签署关于执行第四次付款和 2019 年 4 月预计的第一次现金预付款的协定。

资金发放水平

90. 截至 2019 年 4 月 25 日，核准用于环境规划署第一次、第二次和第三次付款的资金总额为 175,000 美元，其中已发放 118,520 美元（67.7％），如表 4 所示。环境规划署已向政府预付 7,952 美元，使第一，第二和第三次付款的预付款总额达到 126,472 美元（72.3％）。 尚未发放为批准供第四次付款的资金。

表 4. 洪都拉斯氟氯烃淘汰管理计划第一阶段的财务报告

付款	核准（美元）	UMOJA 记录的发放额 （美元）			实际发放率 (%)	目标发放率 (%)	预付额（美元）	预付率 (%)
		截止 30/9/2018	30/9/2018 至 25/4/2019	合计				
第一	75,000	37,047	30,000	67,047	89.4		7,952	100.0
第二	50,000	33,529	5,883	39,412	78.8			78.8
第三	50,000	6,272	5,789	12,061	24.1			24.1
小计	**175,000**	**76,848**	**41,672**	**118,520**	**67.7**	**80.0**	**126,472**	**72.3**
第四	50,000	0	0	0	0.0	20.0	0	0.0

氟氯烃淘汰管理计划第一阶段执行计划的最新情况

91. 计划在 2019 年 5 月至 10 月期间开展下列活动：

(a) 培训 31 个海关入境点的海关和执法人员，掌握控制氟氯烃和氟氯烃设备进口；

(b) 最终完成进口商、供应商和最终用户的电子注册系统，以及开发在线学习模块；

(c) 继续重新制定制冷技术员认证计划并促进其应用；修订技术标准，包括易燃制冷剂的安全措施；以及更新技术和公众意识信息材料； 和

(d) 为 400 名制冷技术员和 1 800 名制冷和空调学生，举办关于良好做法和安全处理消耗臭氧层物质替代品的培训讲习班。

秘书处评论

92. 秘书处指出，对于前三次付款，该国在 2019 年 3 月 31 日之前实现了 72％的发放率，而目标为 80％，而第四次付款则没有发放，目标是 20％。环境规划署解释说，前三次付款中的额外承付款 15,760 美元将在 2019 年 7 月之前记入发放款，使发放率达到 81％，第四次付款中的 12,500 美元将记录为 2019 年 7 月的发放款，使发放率达到 25％。

93. 尽管截至 2019 年 3 月 31 日尚未完成付款承诺，但秘书处指出，已加紧努力以执行与第一阶段有关的制冷技术人员的培训活动。去年共有 823 名技术员和制冷学员接受了培训，技术人员认证计划的建立继续取得进展。环境规划署解释说，正在接受培训的教员和评估人员将在哥伦比亚认证研究所获得国外认证，随后该系统将在全国范围内启动。预计将于 2019 年 12 月全面投入运作。

94. 秘书处建议环境规划署继续向该国提供援助，以完成在本报告期间预计将执行的其他活动，即培训额外的海关官员和开发氟氯烃进口商、供应商和最终用户的电子登记册。在第 81 次会议的讨论中，环境规划署解释说，UTOH 是一个担负大量责任的小团队。因此，环境规划署计划直接雇用三名专家，为 UTOH 提供技术支持，来执行计划的活动。其中一位专家已经在认证计划中工作，其余两位的招聘将于 2019 年 6 月完成。

95. 秘书处认为，提交第 84 四次会议的报告还应包括这些活动的进展情况和付款水平的最新情况，目的是按照第 81/34（a）号决定的要求，在 2019 年 12 月之前实现第一、第二和第三次付款的 100％，第四次付款的发放率为 50％。

秘书处建议

96. 敬请秘书处:

(a) 关注环境署提交的关于环境署与洪都拉斯氟氯烃淘汰管理计划第一阶段有关活动执行情况的进度报告，载于文件 UNEP/Ozl.Pro/ExCom/83/11；和

(b) 要求环境规划署在每次会议上继续提交关于与氟氯烃淘汰管理计划第一阶段有关的环境署成分所有活动，包括实现的发放，执行情况的进度报告 ，直到提出氟氯烃淘汰管理计划第一阶段第五和最后一次付款。

<u>印度：氟氯烃淘汰管理计划（第一阶段 - 最后财务报告）</u>（开发计划署，环境规划署和德国政府）

背景

97. 在第 82 次会议上，开发计划署代表印度政府，按照第 75/29（a）号决定，提交了氟氯烃淘汰管理计划第一阶段第三次和最后一次付款[18]有关的工作方案执行情况的最后进度报告。 第一阶段运作于 2017 年 12 月 31 日完成，项目完成报告于 2018 年 9 月 27 日提交，预计 2018 年 12 月 31 日完成项目财务。

[18] 氟氯烃淘汰管理计划第一阶段的第三次和最后一次付款在第 75 次会议上获得核准，总费用为 1,858,200 美元，包括 1,438,490 美元，加上开发计划署的机构支助费用 100,694 美元，和 86,160 美元，外加 10,478 美元的环境规划署机构支助费用，以及 199,440 美元，加上德国政府的机构支助费用 22,938 美元。

98. 执行委员会审议了该提案，除其他外，特别决定要求印度政府、开发计划署、环境规划署和德国政府向秘书处报告 2018 年 12 月 31 日对受益人的最后付款，并在第 83 次会议，返还截至同一日期的氟氯烃淘汰管理计划第一阶段剩余的任何余额（第 82/39 号决定）。

99. 因此，开发计划署向第 83 次会议提交了印度氟氯烃淘汰管理计划第一阶段的最后财务报告，指出未支出余额 83,405 美元，加上 5,838 美元的机构支助费用，将退还给基金。 其中，3,556 美元加上 249 美元的机构支助费用与第 71 次会议核准给开发计划署的第二次付款有关，79,849 美元加上机构支助费用 5,589 美元与在第 75 次会议上批准给开发计划署的第三次付款有关。

100. 借由本报告，印度氟氯烃淘汰管理计划第一阶段完成财务，无需进一步报告。

秘书处建议

101. 敬请执行委员会关注:

(a) 开发计划署提交的印度氟氯烃淘汰管理计划第一阶段的最后财务报告，载于 UNEP/OzL.Pro/ExCom/83/11 号文件； 和

(b) 开发计划署已在第 83 次会议上返还 3,556 美元，加上机构支助费用 249 美元，79,849 美元，加上机构支助费用 5,589 美元，与印度氟氯烃淘汰管理计划第一阶段第二和第三次付款的未用余额有关 。

<u>印度：氟氯烃淘汰管理计划（第二阶段 - 第二次付款）</u>（开发计划署、环境规划署和德国政府）

102. 在第 82 次会议上，开发计划署代表印度政府提交了关于氟氯烃淘汰管理计划第二阶段第二次付款的申请。该提案表明，截至 2015 年 1 月 1 日，印度政府已禁止在家用冰箱和连续夹板的制造中使用氟氯烃，包括纯净和预混多元醇含有的 HCFC-141b。但是，计划将三个连续夹板制造商纳入第一次付款，其中两家已与政府签署了协定书。有鉴于此，开发计划署澄清说，政府正在评估这些企业是否遵守了禁令。如果发现它们不合规，协定书将被终止，并且向两个企业发放的任何资金将返还给项目。

103. 因此，执行委员会除其他外，特别要求印度政府通过开发计划署在第 83 次会议上，就连续泡沫板制造企业是否遵守关于 HCFC-141b 的使用（第 82/74（b）（i）号决定）禁令，提供关于政府评估的最新情况，截至时间为 2015 年 1 月 1 日，指出如果印度政府确定连续发泡板制造企业没有遵守所提到的禁令，与该企业的协定书将被终止，按照第 77/43（d）（ii）号决定，任何已发放的资金将返还给该项目。委员会还指出，在执行委员会评估其资格（第 82/74（c）号决定）之前，不得将连续泡沫板制造企业列入第二阶段。

104. 截至编写本文件时，开发计划署报告说，按照第 82/74（b）（i）号决定进行的评估仍在进行中，并且一旦企业遵守禁令的情况确定后，则会通报。预计该评估可在第 83 次会议之前完成。

秘书处评论

105. 在提出澄清要求时，虽然没有具体理由说明在提交文件截止日期之前无法完成评估的原因，但开发计划署表示，评估可能在第 83 次会议之前完成。 根据第 82 次会议的商定，没有对这些企业进一步发款。 开发计划署还保证政府承诺执行第 82/74（b）（i）号决定；如果确定这两条连续生产线已违反连续板行业的 2015 年 1 月 1 日淘汰目标，则资金将返还给项目。

秘书处建议

106. 敬请执行委员会通过开发计划署请印度政府在第 84 次会议上，按照第 82/74（b）和（c）号决定，就政府对于自 2015 年 1 月 1 日以来连续泡沫板制造企业是否遵守使用 HCFC-141b 禁令提供评估。

<u>印度尼西亚：氟氯烃淘汰管理计划（第一阶段） - 制冷和空调制造企业和 PT. TSG 化工的转换状况</u>（开发计划署和世界银行）

107. 开发计划署作为牵头执行机构，代表印度尼西亚政府提交了一份报告，说明按照第 81/11（c）号决定，获得资金转换为低全球升温潜能值替代品但临时制造高全球升温潜能值制度的企业的状况，以及按照第 82/30（e）号决定提交 PT.TSG 化工系统厂家参与情况的报告。

制冷空调制造行业

108. 氟氯烃淘汰管理计划的第一阶段包括将制冷和空调制造业的 48 家企业转为低全球升温潜能值技术。但是，在执行过程中，28 家企业（16 家空调行业，12 家商用制冷行业）决定用自己的资源转换为高全球升温潜能值技术，并向多边基金返还 3,134,216 美元，加上机构支助费用。

109. 在其余 20 家企业中，只有一家（松下）目前正在制造基于 HFC-32 技术的空调。 8 家大中型企业生产基于 HFC-32 的原型设备，而 8 家小型企业是基于定制订单生产的装配商；迄今，尚未收到基于 HFC-32 设备的订单。另外三家制造企业仍在等待基于 HFC-32 的设备市场以进行改进后再进行转换。目前，19 家企业正在生产的设备基于全球升温潜能值（主要是 R-410A，R-404A 和 HFC-134a）制冷剂。

110. 19 家企业采用商定的技术转让和制造制冷和空调设备的延误原因是：以可承受的价格获得基于 HFC-32 的压缩机和部件的商业供应有限；HFC-32 设备在当地市场缺乏需求；与该国现有的其他设备相比，基于 HFC-32 设备的成本较高（例如基于 R-407C 制冷剂）。

第 82 次会议的报告和讨论

111. 据第 82 次会议报告，中国的压缩机制造商目前无法向印度尼西亚提供 HFC 32 压缩机，而泰国的压缩机制造商仅在 2019 年 2 月测试了其第一台原型。因此，决定制冷空调制造商的所需尺寸的 HFC-32 压缩机的供应链情景仍不清楚。 因此，执行委员会决定将制冷和空调制造业计划的完成时间延长至 2019 年 12 月 31 日，以便制造商能够测试最近研制的 HFC 32 压缩机，启动 HFC 32 设备的商业制造，并允许向制造商发放增量运营费用（第 82/30 号决定）。

第 82 次会议以来的进展

112. 中国压缩机制造商仍无法以与目前使用的 R-407C 压缩机相比而具有竞争力价格，提供印度尼西亚制造商所需的（相对较低）数量。 泰国的压缩机制造商尚未能够在印度尼西亚供应 HFC-32 压缩机，因为它仍在内部测试这些装置。 因此，自上次向第 82 次会议报告财务状况以来，没有向企业提供进一步的资金。

PU 泡沫行业

113. 据报告，在第 82 次会议上，一家系统公司（印度尼西亚 PT.Sutindo 化工）完成了转换，而另一家系统公司（PT.TSG 化工，资金配额为 301,539 美元，加上世界银行的机构支助费用 22,615 美元，仍在考虑是否退出该项目。 由于系统公司的火灾（与项目无关），PT. TSG 化工现已决定退出该项目； 与项目有关的资金配额将返还第 83 次会议。

秘书处评论

114. 尽管印度尼西亚政府在开发计划署、行业界和其他利益攸关方的支持下作出了努力，但在引进 HFC 32 技术方面进展有限，主要原因是缺乏印尼市场需要容量而具有价格竞争力的压缩机。虽然注意到政府和开发计划署在这方面的努力，但秘书处认为这两个因素本身不可能改变市场，特别是具有相当全球影响力的市场。为了产生可能使压缩机制造商与基于全球升温潜能值的设备竞争所必需的规模经济，可能需要对基于 HFC-32 的设备的大量市场需求，例如通过中国氟氯烃淘汰管理计划第二阶段所计划的转换。据此，按照第 82/30（g）（i）号决定，可以预期印度尼西亚氟氯烃淘汰管理计划第一阶段的进一步延展可提交第 84 次会议。

秘书处建议

115. 敬请执行委员会:

(a) 关注开发计划署和世界银行提交的关于印度尼西亚氟氯烃淘汰管理计划第一阶段制冷和空调制造企业及 PT.TSG 化工的转换状况的报告，载于 UNEP/OzL.Pro/ExCom/83/11 号文件； 和

(b) 关注 PT.TSG 化工已决定退出印度尼西亚氟氯烃淘汰管理计划第一阶段，以及与该企业有关的 301,539 美元加上机构支助费用 22,615 美元已经返还第 83 次会议。

<u>伊朗（伊斯兰共和国）：氟氯烃淘汰管理计划（第一阶段 - 最后进度报告）</u>（开发计划署、环境规划署、工发组织和德国政府）

背景

116. 开发计划署作为牵头执行机构代表伊朗伊斯兰共和国政府，按照第 74/43（b）号决定的，提交了该国氟氯烃淘汰管理计划第一阶段第四次和最后一次付款有关的工作方案执行情况的最后进度报告[19]和相关的在线项目完成报告。

氟氯烃消费量

117. 2018 年，伊朗伊斯兰共和国在其国家方案执行情况报告中，报告的消费量为 2,386.76 公吨（162.95 ODP 吨）氟氯烃。这一消费量比 2018 年《蒙特利尔议定书》氟氯烃消费量目标低 52%，

[19] 氟氯烃淘汰管理计划第一阶段第四次和最后一次付款在第 74 次会议上得到核准，总费用为 885,977 美元，其中包括 250,430 美元，加上开发计划署 18,872 美元的机构支助费用，274,827 美元，外加工发组织的机构支助费用 20,612 美元，和 288,582 美元，加上德国政府的机构支助费用 32,744 美元。

比政府与执行委员会之间协定规定的 2018 年（266.35 ODP 吨）年度消费量目标低 39%。氟氯烃进出口许可证和配额制度继续有效运作。

进度报告

118. 如下所报，伊朗伊斯兰共和国氟氯烃淘汰管理计划第一阶段的所有活动均已顺利完成。

监管措施

119. 国家臭氧机构继续颁发消耗臭氧层物质和含有消耗臭氧层物质设备的进口许可证。 海关署推出的新的在线系统加快了进口申请流程，提高了数据的准确性和可靠性，防止了非法贸易。 2018 年规定禁止进口含 HCFC-22 的住宅空调。

制造行业

120. 完成了以下活动:

(a) 将连续板材行业的七家聚氨酯泡沫塑料企业转换为碳氢化合物（HC）技术，淘汰 27.8 ODP 吨 HCFC-141b（德国政府）;[20]

(b) 将家用制冷和非连续板材中的 11 家硬质聚氨酯泡沫塑料企业改为碳氢化合物技术，淘汰 88.1 ODP 吨 HCFC-141b（工发组织）; 和

(c) 将一个空调制造企业转换为 R-410A，淘汰 29.3 ODP 吨 HCFC-22（开发计划署）

制冷和空调维修行业的活动（德国政府和环境署）

121. 制冷和空调维修行业的下列活动已经完成：400 多名海关和执法人员的氟氯烃法规和执法培训和提高认识讲习班; 为几个省的 750 多名技术人员提供了良好维修做法培训; 150 多名技术人员的能效和良好做法意识讲习班; 将制冷系统改为密封无泄漏系统; 调试和安装所述系统; 培训和监测两家连锁超市的结果; 为维修企业和超市管理日志的入门培训; 为利益攸关方制作和分发技术出版物。

资金发放水平

122. 截止至 2018 年 12 月，在核准的 9,994,338 美元中，已发放 9,760,317 美元，如表 5 所示。余额与工发组织完成的最后一次转换有关。 一旦 2019 年最后一笔付款发放，任何未用余额将退还给基金。

表 5. 伊朗伊斯兰共和国氟氯烃淘汰管理计划第一阶段财务报告

机构	核准 (美元)	发放 (美元)	发放率 (%)
联合国开发计划署	4,340,246	4,340,246	100
联合国工发组织	2,506,277	2,272,256	91
德国政府	2,885,815	2,885,815	100
联合国环境署	262,000	262,000	100

[20] 根据第 80/21 号决定， 另一家企业单独使用的 2.9 ODP 吨 HCFC-141b 自愿停止运作，相关资金将从氟氯烃淘汰管理计划第二阶段第二次付款中扣回多边基金。

机构	核准 (美元)	发放 (美元)	发放率 (%)
合计	**9,994,338**	**9,760,317**	**98**

秘书处的评论

123. 秘书处指出，剩下的第一阶段活动已经完成，许可和配额制度已通过在线系统得到执行和加强。 由于最后一家企业（Emersun）的调试仅在 2019 年 2 月才完成，因此应视为第一阶段的完成日期，而不是 2018 年 12 月 31 日。

124. 在审查项目完成报告时，秘书处指出，一旦工发组织完成与 Emersun 转换有关的剩余付款，就需要提交一份订订报告。 工发组织估计这些付款将在未来两个月内完成。 秘书处还指出，根据第 22/38（c）号决定，项目完成报告没有提供足够的信息，来说明为确保被替换的特定设备或部件实际上已被销毁或无法使用而采取的行动。 因此，秘书处要求修订后的项目完成报告包括所有已完成投资项目的此类信息。

秘书处建议

125. 敬请执行委员会:

(a) 关注开发计划署提交的关于伊朗伊斯兰共和国氟氯烃淘汰管理计划第一阶段第四次付款的工作方案执行情况的最后进度报告，载于文件 UNEP/OzL.Pro/ExCom/83/11；

(b) 要求伊朗伊斯兰共和国政府、开发计划署、工发组织、环境规划署和德国政府提交经修订的项目完成报告，包括:

(i) 氟氯烃淘汰管理计划第一阶段的最后付款以及退还给基金的任何余额; 和

(ii) 根据第 22/38（c）号决定，为确保替换的特定设备或部件实际上已被销毁或无法使用而采取的行动的详细资料。

<u>约旦：氟氯烃淘汰管理计划（第二阶段） - 五个企业 从氢氟烯烃-1233zd（E）转换到环戊烷基发泡剂的技术变化</u>（世界银行和工发组织）

背景

126. 在第 77 次会议上，执行委员会原则上核准了约旦[21]氟氯烃淘汰管理计划 2017 年至 2022 年第二阶段，以将氟氯烃消费量减少基准的 50%，金额为 3,289,919 美元，包括 2,075,236 美元，加上世界银行的机构支助费用 145,267 美元，以及 999,455 美元，加上工发组织的 69,961 美元的机构支持费用。在批准第二阶段时，执行委员会除其他外特别指出，约旦政府将灵活地利用为聚氨酯泡沫塑料行业核准的资金，按照与执行委员会的协定，实现顺利和有效淘汰 HCFC-141b（ 第 77/45（b）（iii）号决定）。

[21] UNEP/OzL.Pro/ExCom/77/51。

127. 氟氯烃淘汰管理计划第二阶段的聚氨酯泡沫塑料行业计划包括转换三家大型企业，约旦金属业先锋（ Jordan Pioneer ），钣金业的 Al Safa 和 Panel Co（Al Safa）以及约旦制造和服务解决方案（JMSS），43 家中小型企业（SME）和 6 家喷涂泡沫塑料应用企业。 泡沫塑料行业计划核准的淘汰总量为 33.07 ODP 吨。[22] 在这些企业中，Jordan Pioneer 同意将环戊烷转化为发泡剂; 其余的泡沫塑料企业同意转换为氢氟氢氟烯烃(氢氟烯烃)，因为这将涉及最低的增量资本费用; 由于 HCFC-141b 的供应量减少和相应的价格上涨，预计在不久的将来可以具有竞争力的价格提供减少基于氢氟烯烃的配方。 表 6 概述了这些企业的核准资金和相关淘汰 HCFC-141b 的情况。

表 6. 约旦第二阶段泡沫塑料行业氟氯烃淘汰核准的增量费用

细节	以美元计的增量费用	淘汰 ODP 吨
聚氨酯泡沫塑料（三大企业）	480,889	9.77
聚氨酯泡沫塑料 (43 家中小型企业[23])	799,794	14.61
喷涂泡沫 (六个企业)	411,212	8.69
合计	1,691,895	33.07

128. 在项目实施期间，生产板材和其他产品的 51 家聚氨酯泡沫塑料企业中有 5 家[24]，即 Al Safa、Shams Al-ram Tri、Yousef 金属工业车间、Al-Qanadeel 和预制建筑（Maani）已经要求从最初提议的氢氟烯烃 1233zd（E）转换到环戊烷的技术变更。由于企业认为环戊烷技术成熟并且与氢氟烯烃配方相比具有较低的运营成本，因此要求进行这种技术变革。在 2019 年 2 月进行的埃及考察期间，企业代表与系统公司、设备供应商和泡沫生产商进行了讨论，作为技术信息外延和经验分享的一部分。在考察期间，企业更好地了解了基于氢氟烯烃的多元醇体系的供应情况以及与使用环戊烷作为发泡剂相关的安全性方面，并决定采用环戊烷，因为基于氢氟烯烃的配方成本高，保质期短。这些企业还承诺投入所需的额外资金，以安全方式实施向环戊烷的转化。

129. 随后，按照约旦政府与执行委员会之间协定第 7（a）（vii）段，政府通过世界银行提交了五家企业从氢氟烯烃转换为基于环戊烷的泡沫发泡剂的改变技术请求 。

增量费用

130. 提交的五个企业转换为环戊烷的估计增量费用见表 7。批准的氢氟氢氟转换费用包括与技术援助、试验和测试有关的增量资本费用以及基于使用氢氟烯烃配方的成本。 转用环戊烷的资本成本较高，主要是由于投资额外的储存设备，更换泡沫分配器，在制造厂安装安全系统，以及安全审计和工作人员培训。与 HCFC-141b 相比，环戊烷制剂的使用成本较低，因此使用环戊烷可节省运营费用。

[22] 氟氯烃淘汰管理计划第二阶段将促成所有应用（包括家用和商用制冷）的 HCFC-141b 总淘汰量为 38.91 ODP 吨; 这包括散装的 27.6 ODP 吨 HCFC-141b 和进口预混多元醇中含有的 11.31 ODP 吨 HCFC-141b。

[23] 43 家中小企业中的一家企业，Enjaz 约旦钢结构，没有资格 。

[24] 提供了确认这一技术变革的信件，这些信件来自约旦环境部以及的五家企业，所有日期均为 2019 年 4 月 4 日 。 最初，有六家企业表示有兴趣采用环戊烷代替氢氟烯烃; 但是，在世界银行、政府和企业协商后，只有五家企业决定采用环戊烷。

表 7. 转化为环戊烷发泡剂的修订增量成本（美元）

企业	氢氟烯烃-1233zd(E)	环戊烷 *
Al Safa	205,000	383,283
Shams Al-ram Tri	130,077	391,063
Yousef 金属工业工厂	112,844	392,207
Al-Qanadeel	88,718	393,810
预制建筑 (Maani)	87,539	393,886
合计	**624,178**	**1,954,249**

* 如世界银行提案所述。

秘书处的评论

131. 秘书处指出，约旦政府与世界银行之间的协定已经签署，第二阶段的项目执行活动于 2018 年 1 月开始。

132. 秘书处要求澄清这一变化将如何影响该行业的其余转换项目。 世界银行澄清说，在泡沫塑料行业，其余企业的 HCFC-141b 消费量很小，而且现阶段它们并没有提出任何技术变革。 他们将在未来继续执行转换项目。

133. 关于环戊烷的供应情况，世界银行通报说，环戊烷可从当地供应商处获得，可从埃及和其他国家进口; 使用环戊烷的设备也可以从埃及和阿拉伯联合酋长国等邻国的供应商处获得。

134. 秘书处根据氟氯烃淘汰管理计划第二阶段商定的项目费用审查了转换为环戊烷的费用，用于约旦先锋转化为环戊烷，与这些企业的规模相当; 表 8 列出了经修订的增量成本。技术变革将导致订正增量成本 768,652 美元; 五家企业通过各自信件证实，他们将承担技术改革为环戊烷的额外费用。由于氢氟烯烃和环戊烷发泡剂都是低全球升温潜能值技术，预计温室气体影响可以忽略不计。

表 8. 转化为环戊烷发泡剂的修订增量成本（美元）

企业	HFO -1233zd(E)	环戊烷	差额
Al Safa	205,000	221,283	16,283
Shams Al-ram Tri	130,077	237,951	107,874
Yousef 金属工业工厂	112,844	240,402	127,558
Al-Qanadeel	88,718	243,834	155,116
预制建筑 (Maani)	87,539	244,002	156,463
合计	**624,178**	**1,187,472**	**563,294**

135. 最后，秘书处指出，技术变革将导致在这些企业的泡沫塑料应用中持续采用低全球升温潜能值技术，并将促进实现约旦的履约目标。

秘书处建议

136. 敬请执行委员会:

(a) 关注世界银行代表约旦政府提交的氟氯烃第二阶段将五个企业从氢氟烯烃-1233zd（E）转换为环戊烷基发泡剂的技术变革的请求， 约旦淘汰管理计划载于 UNEP/OzL.Pro/ExCom/83/11 号文件; 和

(b) 批准上文（a）分段提及的技术变革，并关注企业将为从 HCFC-141b 转换为环戊烷的技术变革将承担任何额外费用。

马尔代夫：氟氯烃淘汰管理计划（渔业制冷中无氟氯乙烯的低全球升温潜能值替代品示范项目）（环境规划署和开发计划署）

背景

137. 在第 76 次会议上，执行委员会核准了马尔代夫渔业部门的无氟氯乙烯的低全球升温潜能替代制冷剂的示范项目[25]，数额为 141,000 美元，外加机构支助费用 12,690 美元（第 76/34 号决定）。

138. 该项目获得批准，除其他外，特别要确定用于制冷设备的氟氯烃低全球升温潜能值替代技术，渔业部门收取 150 千克至 200 千克制冷剂，并转换三艘渔船设备基于 HCFC-22 的制冷剂，而采用低全球升温潜能值技术。

139. 在第 80 次会议上, [26] 开发计划署作为示范项目的执行机构，报告称政府选择了 R-448A，一种不易燃的氢氟氢氟烯烃(氢氟烯烃)-氢氟碳(HFC)化合物混合物[27]，其全球升温潜能值为 1,386，作为替代的选择。 开发计划署就该国是否可以使用这种替代方案进行示范项目寻求指导。 执行委员会要求开发计划署继续探索其他低全球升温潜能值替代品，并向第 81 次会议报告。

140. 在第 81 次会议上,[28] 开发计划署提交了关于示范项目的最后报告。该报告的结论是，R-448A 仍然是替代马尔代夫渔船使用的 HCFC-22 的最佳恰好替代制冷剂。执行委员会注意到示范项目的报告，并要求开发计划署在该国氟氯烃淘汰管理计划第一阶段执行情况的进度报告中列入关于在三艘捕捞船只中改装 HCFC-22 基制冷系统时所开展活动的详细资料, 并继续探索其他低全球升温潜能值替代品。

141. 环境规划署作为氟氯烃淘汰管理计划的牵头机构，向第 83 次会议提交了关于三艘渔船改装示范项目执行情况的进度报告。

142. 截止至 2019 年 3 月，采购了 R-448A 制冷剂、压缩机油和其他杂项材料，并按照 R-448A 制冷剂供应商提供的指导方针进行了改装。 除了在用 R-448A 替换 HCFC-22 之前更换压缩机油、垫圈、密封件和干燥过滤器之外，没有对制冷系统进行重大修改。 一艘渔船已成功改装至 R-448A。

143. 改装可以由常规制冷和空调技术人员进行，并在合理的时限内完成，而不会对船舶作业造成重大干扰。 已经观察到改装的渔船具有增强性能，因为改装的制冷系统将温度降低到零度比改装前的时间稍短。

[25] UNEP/OzL.Pro/ExCom/76/40。

[26] UNEP/OzL.Pro/ExCom/80/12。

[27] HFO-1234yf, HFO-1234ze, HFC-32, HFC-125 和 HFC-134a; 20/7/26/26/21 %。

[28] UNEP/OzL.Pro/ExCom/81/10。

144. 该报告还强调，R-448A 制冷剂目前尚未在马尔代夫市场上销售。 专门为示范项目购买的少量 R-448A 的价格为 55.31 美元/公斤，而 HCFC-22 的价格为 9 美元/公斤。这可能对在渔业行业采用新技术造成障碍。

秘书处评论

145. 当要求澄清时，开发计划署通知称，已经进行了详细的性能测量，包括吸入侧和排出侧的压力和温度测量。 数据显示改装船的性能略有改善，而且能效也略有改善（不显着）。在其他两艘改装船舶中将不断收集这些数据。 其余两艘船将于 2019 年 5 月进行改装，所取得的全部成果的最终报告以及改装三艘渔船的财务资料将提交第 84 次会议。

146. 秘书处指出，R-448A 制冷剂在马尔代夫市场上没有商业供应，而且该项目的进口量价格很高。 环境规划署解释说，一旦在亚洲市场上可获得足够数量的 R-448A 供应，制冷剂的成本就会降低。

147. 秘书处进一步询问了渔业部门的消费量，以及政府预计到 2020 年按照氟氯烃淘汰管理计划的规定实现减少 97.5％是否会有任何挑战。 环境规划署告知，大多数现有渔船仍在使用 HCFC-22，渔业部门约占 HCFC-22 消费量的 10％至 20％。 然而，从 2016 年起开始禁止使用氟氯烃设备，渔业部门的需求似乎在减少。马尔代夫政府重点关注提出低全球升温潜能值替代品和节能系统的解决方案; 因此，进口的新渔船和建立的设施将使用低全球升温潜能值制冷剂，这将有助于该国到 2020 年实现 97.5％的减排目标。

148. 一份财务报告表明，在为示范项目核准的 141,000 美元中，已发放了 94,378 美元（67％），剩余的 46,622 美元全部已经承诺发放。

秘书处建议

149. 敬请执行委员会:

(a) 赞赏地关注开发计划署提交的马尔代夫实施的渔业部门制冷氟氯烃低全球升温潜能值替代品示范项目的进度报告; 和

(b) 请开发计划署提交氟氯烃淘汰马尔代夫管理计划第一阶段执行情况的进度报告。

<u>北马其顿：氟氯烃淘汰管理计划（第一阶段 - 泡沫塑料企业 Sileks 转换的最新情况）</u>（工发组织）

背景

150. 执行委员会第 82 次会议审议了北马其顿氟氯烃淘汰管理计划的第八次付款。 工发组织解释说，在开始转换之前，在 2016 年一场大火毁了泡沫塑料企业 Sileks 的设施，但工发组织仅在 2018 年 9 月访问该国期间才获悉了这一情况。 没有决定该企业是否会继续其计划的转换或是否将退还资金。 随后，委员会核准了第八次付款，其谅解是，即根据有具体报告要求的项目报告，将向第 83 次会议提供泡沫塑料企业 Sileks 转换的最新情况（第 82/53（a）号决定）。

151. 工发组织代表北马其顿政府，按照第 82/53（a）号决定，提交了 Sileks 转换的最新情况。

更新

152. 工发组织继续与政府进行讨论，并对 Sileks 进行了视访。 火灾导致该企业完全被毁，无法承担额外的金融投资。 因此，工发组织和北马其顿政府商定取消该项目，并向多边基金返还 30,000 美元的相关资金，加上 2,250 美元的机构支助费用。

秘书处建议

153. 敬请执行委员会:

(a) 关注工发组织提供的转换泡沫塑料企业 Sileks 的最新情况，该转换是按 UNEP/OzL.Pro/ExCom/83/11 文件所载的北马其顿氟氯烃淘汰管理计划（氟氯烃淘汰管理计划）第一阶段供资的； 和

(b) 注意到泡沫塑料企业 Sileks 已决定退出北马其顿的氟氯烃淘汰管理计划，并且在第 83 次会议上已经退还了 30,000 美元，加上与该企业有关的工发组织 2,250 美元的机构支助费用。

苏里南：氟氯烃淘汰管理计划（第一阶段 - 第三次付款）（环境署）

背景

154. 在第 81 次会议上，执行委员会审议了苏里南氟氯烃淘汰管理计划第一阶段第三次付款的请求，并注意到秘书处提出对该国许可和监测系统的关切，涉及氟氯烃进口清关程序，按不同的统一制度（HS）编码记录氟氯烃，没有处罚或鼓励进口商遵守正确的程序报告氟氯烃的进口情况。随后，执行委员会除其他外，特别要求环境规划署在第 83 次会议上提供最新资料，说明苏里南政府为加强氟氯烃许可证和监测系统所采取的步骤，解决了秘书处氟氯烃核查报告审查中查明的问题（第 81/51（b）号决定）。委员会还决定，只有在苏里南政府处理了核查报告中确定的所有问题并执行相关行动，从而加强进出口许可证配额制度之后，才会考虑苏里南氟氯烃淘汰管理计划第一阶段的最后一次付款（第 81/51（c）（i）号决定）。

155. 响应第 81/51（b）号决定，环境规划署代表苏里南政府提供了一份报告，说明政府为加强氟氯烃许可证和监测系统所作的努力，概述如下:

(a) 国家臭氧机构于 2019 年 1 月开始讨论海关，贸易、工业和旅游部（MoTIT）以及公共卫生局等机构对氟氯烃进口无异议函[29] 的强制性要求的执行情况 ，这些机构涉及进出口交易的处理和监测。 作为一项临时措施，各政府实体同意，没有无异议函，海关不会发放行消耗臭氧层物质货物。 无异议函已作为强制要求，进口商必须向贸易、工业和旅游部 （MoTIT） 提交进口申请。 根据国家立法，运货检查只能由公共卫生局进行;

(b) 国家臭氧机构一直在与海关当局协商，对海关经纪人和官员进行氟氯烃及和统一制度编码产品说明的培训。 预计培训将在 2019 年 4 月至 9 月期间进行。此培训的合作伙伴将包括苏里南空调、制冷和通风协会（ARVAS）以及至少一家进口商;

(c) 自 2018 年 11 月以来，国家臭氧机构已开始实施在 2019 年 6 月之前建立的在线系统

[29] 无异议函是按配额制度进口氟氯烃的先决条件; 这是国家臭氧机构在进口氟氯烃之前向进口商发出的。

的运作，以处理进口许可申请。 贸易、工业和旅游部（MoTIT）还在建立一个包括消耗臭氧层物质的国家电子许可证制度; 这将允许在线交换进口数据和独立核实报告的制冷剂进口情况。为了监测氟氯烃的贸易和使用量，国家臭氧机构正在与贸易、工业和旅游部和苏里南空调、制冷和通风协会（ARVAS） 密切合作，以建立所有制冷剂采购的登记制度，这将作为贸易、工业和旅游部在线系统的一部分;

(d) 自 2018 年以来，海关和贸易、工业和旅游部正与国家臭氧机构分享所有制冷剂以及制冷和空调设备的进口数据。

秘书处评论

156. 秘书处赞赏地注意到苏里南政府为加强许可证制度所做的努力，并指出在氟氯烃淘汰期间需要密切监测这些努力。

157. 在要求澄清国家臭氧机构在进口核查过程中的作用时，环境规划署告知，根据国家立法，检查货物是公共卫生局的责任; 国家臭氧机构签发的进口无异议函对于允许进口氟氯烃是必要的，因此，国家臭氧机构在实施进口之前实际在控制进口过程。

158. 环境规划署通报说，为确保进口的单一行政文件（SADs）[30]中统一制度编码和产品说明在的准确性，建议就单一行政文件的数据输入对海关官员和经纪人，苏里南空调、制冷和通风协会和其他相关利益攸关方进行培训; 还将提供一个快速参考工具，以协助经纪人填写单一行政文件的正确数据。

159. 关于定期数据报告和数据维护问题，环境规划署告知，进口商每年根据无异议函提交数据; 正在进行讨论，要求进口商每年两次报告数据。 此外，国家臭氧机构计划在苏里南空调、制冷和通风协会的支持下与零售商讨论两年一次的销售报告流程。

160. 当要求澄清鼓励进口商遵循准确报告氟氯烃进口的正确程序的处罚或奖励措施时，环境规划署解释说， 按照贸易、工业和旅游部和海关规则，如果发现违反遵守程序行为，在进口商采取必要的纠正措施之前，不会处理进口请求。

161. 环境规划署还提及，其履约协助方案在与查明和预防非法贸易有关的问题方面，支持苏里南政府的政策及条例制定、审查和执行; 还向国家臭氧官员提供了的培训，掌握蒙特利尔议定书执行程序，包括监测和报告数据。

秘书处建议

162. 敬请执行委员会:

(a) 关注 UNEP/OzL.Pro/ExCom/83/11 号文件所载苏里南政府为环境规划署提交的加强氟氯烃许可证和监测系统而作出的努力的报告; 和

(b) 重申第 81/51（c）（i）号决定，执行委员会只有在苏里南政府解决了核查报告中确定的所有问题后，并实施了相关行动从而加强了进出口许可和配额制度之后，才会

[30] 进口氟氯烃的进口商需要填写单一行政文件（SAD），以便通过海关清关货物。

审议苏里南氟氯烃淘汰管理计划第一阶段最后一次付款的供资情况。

突尼斯：氟氯烃淘汰管理计划（第二阶段）- 要求取消空调行业计划和更新协定
(工发组织、环境规划署和法国政府)

163. 工发组织作为牵头执行机构并负责氟氯烃淘汰管理计划第一阶段的住宅空调行业计划[31]，已经代表突尼斯政府提出取消氟氯烃淘汰管理计划的行业计划并请求更新政府与执行委员会之间关于减少氟氯烃消费量的协定。

164. 突尼斯政府在给工发组织的信函中[32] 报告说，在评估了空调行业目前的情况后，它发现受益企业在转用商定的替代技术面（即 R-290）方遇到技术和财政困难。因此，它授权工发组织取消 1,108,275 美元，加上原则上为执行该行业计划而核准的机构支助费用，并返还与该行业计划有关的余额。 政府还要求将氟氯烃淘汰管理计划的执行期从 2018 年延长至 2020 年，以完成第一阶段的剩余活动。

165. 工发组织表示，突尼斯政府同意，与空调制造业相关的消费量为 79.3 公吨（4.36 ODP 吨）将被视为完全淘汰， 除根据初始协议与维修行业相关的消费量外，还将从剩余的符合条件的消费量中扣除。 表 9 显示了突尼斯目前的氟氯烃消费量。

表 9. 突尼斯的氟氯烃消费量（2014 - 2017 年第 7 条数据，2018 年国家计划数据）

HCFC	2014 年	2015 年	2016 年	2017 年	2018 年	基准
公吨						
HCFC-22	610.43	629.75	463.562	501.535	471.13	709.34
HCFC-141b	8.46	8.46	0	8.25	0	14.57
合计 (公吨)	618.89	638.21	464.062*	509.785	471.13	723.91
ODP 吨						
HCFC-22	33.57	34.63	25.50	25.78	25.91	39.01
HCFC-141b	0.93	0.93	0	0.91	0	1.61
合计 (ODP 吨)	34.5	35.56	25.50	28.49	25.91	40.62

* 2016 年报的告 HFC-123 (0.5 公吨)。

166. 工发组织进一步表示，空调行业计划的余额为 900,489 美元，包括 340,237 美元和相关的项目管理单位（PMU）费用 21,792 美元， 加上工发组织机构支助费用 25,342 美元，和 454,087 美元，加上法国政府的机构支助费用 59,031 美元，经核准作为氟氯烃淘汰管理计划第一阶段和第二阶段的一部分，将退还给第 84 次会议。

[31] 突尼斯氟氯烃淘汰管理计划第一阶段 2014 年至 2018 年期间将氟氯烃消费量按基准减少 15%，第 72 次会议原则上核准，数额为 1,966,209 美元，包括 1,100,195 美元，外加工发组织机构支助费用为 77,014 美元，以及 100,000 美元，加上 13,000 美元的环境署机构支助费用，和 600,000 美元，加上法国政府机构支助费用 76,000 美元（第 72/36（a）号决定）。

[32] 2019 年 3 月 15 日突尼斯国家环境保护局致工发组织的信函。

167. 工发组织为执行氟氯烃淘汰管理计划第一阶段的其余成分提供了一项订正计划，将于 2020 年定稿，具体如下:

(a) 最后通过附属法例，使新的认证制度符合欧洲 F-气体法规的要求;

(b) 完成溶剂行业其余企业的转换，并编写完成报告;

(c) 与维修行业的培训师共同，继续为海关当局和其他利益攸关方提供关于制冷剂识别专题的培训;

(d) 继续为职业学校的培训师开展培训活动，包括用于即将进行的技术人员培训的最新实用培训模块的所需要素，并继续进行技术人员培训;

(e) 继续执行设备更换的奖励方案，以鼓励为选定的最终用户使用新的替代制冷剂;和

(f) 继续开展持续的提高公众认识运动方案，涉及使用替代制冷剂的良好和安全维修做法和技能问题。

168. 正如表 10 所示，工发组织提议，在扣除对空调行业计划的供资并将协定从 2018 年延至 2020 年之后，分配第一阶段的供资。

表 10. 突尼斯氟氯烃淘汰管理计划第一阶段的订订付款分配

初始						
细节	**2014 年**	**2015 年**	**2016 年**	**2017 年**	**2018 年**	**合计**
牵头执行机构（工发组织）核准资金 (美元)	512,885	478,896	0	108,414	0	1,100,195
牵头执行机构的支助费用(美元)	35,902	33,523	0	7,589	0	77,014
合作执行机构 (环境署) 核准资金（ 美元 ）	30,000	55,000	0	15,000	0	100,000
合作执行机构的支助费用(环境署) (美元)	3,900	7,150	0	1,950	0	13,000
合作执行机构 (法国) 核准资金 (美元)	135,690	394,397	0	69,913	0	600,000
合作执行机构 的支助费用 (法国) (美元)*	17,187	49,957	0	8,856	0	76,000
核准资金总额 (美元)	678,575	928,293	0	193,327	0	1,800,195
机构支助费用总额 (美元)	56,989	90,630	0	18,395	0	166,014
核准费用总额 (美元)	735,564	1,018,923	0	211,722	0	1,966,209
订订后						
	2014 年	**2016 年**	**2018 年**	**2019 年**	**2020 年**	**合计**
牵头执行机构（工发组织）核准资金 (美元)	376,920	71,038	0	57,500	0	505,458
牵头执行机构的支助费用(美元)	26,384	4,973	0	4,025	0	35,382
合作执行机构 (环境署) 核准资金（ 美元 ）	30,000	55,000	0	15,000	0	100,000
合作执行机构的支助费用(环境署) (美元)	3,900	7,150	0	1,950	0	13,000
合作执行机构 (法国) 核准资金 (美元)	38,000	38,000		19,000		95,000
合作执行机构 的支助费用 (法国) (美元)**	4,940	4,940	0	2,470	0	12,350
核准资金总额 (美元)	444,920	164,038		91,500		700,458
机构支助费用 (美元)	35,224	17,063		8,445		60,732

初始						
细节	**2014年**	**2015年**	**2016年**	**2017年**	**2018年**	**合计**
核准费用总额 (美元)	480,144	181,101		99,945		761,190

* 根据初始项目总成本 600,000 美元计算
** 根据返还后修订的 95,000 美元资金计算为 13%。

秘书处评论

从第一阶段撤销空调行业计划

169. 在审查这一要求时，秘书处指出，在氟氯烃淘汰管理计划第一阶段的项目审查期间，因为市场上缺乏可用的低全球升温潜能值完全减少（CKD）试剂盒，这就要求这些项目仅在2016年开始，即氟氯烃淘汰管理计划批准后两年。由于第76次会议之时不能提供完全减少工具包，当第二次付款申请获得批准时，空调行业计划的执行进一步推迟。在进一步考虑这些工具包的可用性之后，四家空调企业自 2017 年以来用自己的资源，使用基于 R-410A 的完全减少工具包转换其业务，因此要求取消空调行业计划。

修订的氟氯烃淘汰管理计划第一阶段的行动计划和资金分配以及第三次付款的提交

170. 秘书处指出，工发组织提供的行动计划是作为第二次付款的一部分核准的活动的延续，包括将在最后一次付款中执行的活动。 这些活动将通过采用良好的维修做法，支持该国维持减少氟氯烃消费量。 工发组织将向第 84 次会议提交第一阶段第三次付款申请，以及氟氯烃淘汰管理计划第二阶段。 工发组织保证正在执行溶剂和制冷维修行业的活动; 在提交第三次和最后一次付款申请时，将进一步审查这些活动的进展情况。

修订氟氯烃淘汰管理计划协议

171. 鉴于氟氯烃淘汰管理计划第一阶段取消了空调行业计划和订订供资时间表，突尼斯政府与执行委员会之间的协定附录 2-A 和附录 8-A 已经更新， 增加了新的第 16 段，以表明更新协定取代本文件附件三所载第 72 次会议达成的协议。完整的更新协议将作为第 83 次会议最终报告的附录。

秘书处建议

172. 敬请执行委员会:

(a) 关注突尼斯政府要求取消 UNEP/OzL.Pro/ExCom/72/36 文件所载氟氯烃淘汰管理计划（HPMP）第一阶段由工发组织和法国政府执行的住宅空调行业计划，指出该行业计划纳入的所有企业已淘汰其 HCFC-22 的消费量（4.36 ODP 吨）;

(b) 进一步关注:

(i) 1,206,919 美元，包括 513,275 美元和相关项目管理单位（PMU）费用 81,462 美元，加上工发组织 41,632 美元的机构支助费用，和 505,000 美元， 加上原则上为氟氯烃淘汰管理计划第一阶段的空调行业计划核准的法国政府的机构支助费用 65,550 美元，将从突尼斯政府与执行委员会之间的协定中删除;

(ii) 氟氯烃淘汰管理计划第一阶段的制冷维修行业订订计划;

(iii) 基金秘书处更新了突尼斯政府与执行委员会之间的协定附录 2-A，载于 UNEP/OzL.Pro/ExCom/83/11 号文件附件三，以反映工发组织和法国政府执行的住宅空调行业计划的撤销和修订的供资时间表，并增加了新的第 16 段，表明更新后的协定取代第 72 次会议达成的协议，附录 8-A 已被删除; 和

(c) 请工发组织和法国政府向多边基金返还 900,489 美元，其中包括 340,737 美元和相关项目管理单位费用 21,792 美元，外加工发组织 25,342 美元的机构支助费用，和 454,087 美元加上法国政府的机构支助费用 59,031 美元，这些与作为 第 84 次会议 氟氯烃淘汰管理计划第一阶段和第二阶段的一部分而批准的空调行业计划有关。

第五部分: 氟氯烃的低全球升温潜能值替代品示范项目和区域制冷的可行性研究（第 72/40 号决定）

背景

173. 在第七十四、七十五和七十六次会议上，执行委员会根据第 XXV/5 号决定和第 72/40 号决定，核准了三项区域制冷可行性研究（多米尼加共和国、埃及和科威特）和 17 个低全球升温潜能值技术的示范项目，包括：制冷和空调及装配分行业的七个项目（中国、哥伦比亚、哥斯达黎加、科威特、沙特阿拉伯（2）、一个全球（阿根廷和突尼斯）和一个区域（西亚 [33]）项目；泡沫塑料行业五个（哥伦比亚、埃及、摩洛哥、沙特阿拉伯、南非和泰国）；制冷维修行业三个（马尔代夫、欧洲和中亚地区、以及一个东非和加勒比地区的全球项目）。

174. 截至第八十二次会议，多米尼加共和国和埃及 3 可行性研究中的 2 个，以及中国、哥伦比亚（2）、哥斯达黎加、马尔代夫和南非 17 个示范项目中的 6 个已完成，其最后报告已提交执行委员会。剩下的一项可行性研究和 11 个正在进行的示范项目中的 7 个的最后报告应于第八十三次会议上提交。

175. 双边和执行机构提交第八十三次会议审议的有：

(a) 沙特阿拉伯（空调，世界银行）和泰国示范项目的最后报告，以及科威特区域制冷可行性研究报告（报告全文作为本文件附件四、附件五和附件六附后）；和

(b) 9 个示范项目的执行情况进度报告。

176. 关于向第八十三次会议提交的示范项目进度报告，秘书处建议撤销一个项目（科威特），鉴于报告的埃及、欧洲和中亚、摩洛哥、沙特阿拉伯（2）和西亚的六个项目的进展情况和执行已达到后期阶段，延长其完成日期。

177. 每份报告的说明以及相应的秘书处的评论和建议如下。

[33]在高环境温度国家推广制冷剂替代品的西亚示范项目，称为 PRAHA-II。

埃及：小型用户转型为非消耗臭氧层物质技术聚氨酯泡沫塑料的低成本备选办法的示范（开发计划署）

背景

178. 在第七十六次会议上，执行委员会核准了一个优化埃及聚氨酯泡沫塑料行业的非消耗臭氧层物质技术示范项目。预计该项目将有助于扩大所述技术的供应，并为很小型用户（VSU）提供具有成本效益的淘汰选择，供资金额为 295,000 美元，外加给开发计划署的机构支助费用 20,650 美元。请埃及政府和开发计划署在项目核准后 12 个月内完成项目，并在项目完成后，迅速提交一份全面的最后报告（第 76/30 号决定）。

179. 在第八十次会议上，执行委员会将项目完成日期延长至 2018 年 12 月 31 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请开发计划署不晚于第八十三次会议提交最后报告（第 80/26(e)号决定）。

进度报告

180. 根据第 80/26(e)号决定，开发计划署代表埃及政府提交了示范项目的初步最后报告。虽然项目中的大部分活动已经完成，但是将在和选定的小型用户对配方厂家设备测试完成后向第八十四次会议提交最后报告。

181. 该项目分两部分实施：第一部分涉及设备选择（即制定设备规格，招标，投标审查和采购），第二部分是预包装发泡配方的优化（即，选择愿意使用这些配方的配方厂家，从供应商处采购预包装配方，和用选定设备同小型泡沫塑料用户对配方进行现场测试）。

182. 设备选择部分涉及采购流程，其中开发了供招标用的小型用户使用的小型移动设备的不同规格。在审查收到的报价后，选择并购买了三种类型的发泡机：一种是高压，一种是低压，另一种是用于整皮泡沫塑料的低压机。这些分发给三个配方厂家进行评估；但是，该项目的这一方面尚未完成。

183. 设备选择部分招标过程中获得的结果表明，可以用 5,350 美元而不是 10,000 美元的价格购买基本的底部灌注（PIP）泡沫塑料注入器；一个基本的喷塑/底部灌注注入器可以用 6,600 美元而不是 10,000 美元购得；并且可以用 18,480 美元而不是 25,000-30,000 美元的价格购买基本的整皮泡沫塑料注入器。

184. 该项目化学成分的目标是为不常用的很小型用户提供具有较长保质期的预包装泡沫塑料配方。这是通过寻找和访问至少一个此类配方的供应商以及对分销或开发类似产品感兴趣的本地配方厂家来进行的。由于所涉配方非常昂贵，配方厂家几乎没有兴趣。

185. 开发计划署表示，该项目的结果显示如下：

(a) 在明确确定规格的情况下，可能有较低价格的基本泡沫塑料注入器供应，因此可能降低多边基金今后为小型和很小型泡沫塑料制造商供资的泡沫塑料项目的设备成本；

(b) 对使用预包装化学品没有表现出任何兴趣，因为这些化学品是为狭窄专业应用（即电气支柱回填）而设计的，在第 5 条国家不常见，并且相关的投资成本非常高。

秘书处的评论

186. 秘书处要求澄清所选设备是如何评价的，指出该设备还未经过配方厂家也未经过选定的小型泡沫塑料用户的测试。开发计划署解释说，由于交付延迟，这项测试将于 2019 年 5 月底完成。已经向配方厂家提供了注入器的规格，以便有效地进行测试。一旦配方厂家完成此阶段，将在选定的一家小型用户对设备进行进一步评价。这些活动预计将于 2019 年 6 月完成。

187. 秘书处根据提交的报告注意到以下情况：

(a) 虽然经过招标之后，开发计划署可确定能够提供低成本移动式发泡机的设备供应商，但这些机器的效用和效率尚未同很小型用户通过测试得到证实；并且

(b) 预包装的聚氨酯配方对于第 5 条国家来说不是商业上可行的选择，因为这些配方适用的用途在这些国家不常见，并且对于很小型用户来说，它们的成本非常高。

188. 秘书处指出，根据延长的项目完成日期（第 80/26(e)号决定），该项目没有在 2018 年 12 月完成。但是，完成低成本设备的测试和评估非常重要，因为它将为这种设备对小型用户的有用性提供技术结论。开发计划署表示，同三配方厂家和一些下游泡沫塑料用户对设备进行现场测试将于 2019 年 6 月完成。

189. 秘书处注意到设备的现场测试是剩余的唯一活动，建议延长该项目，以便在第八十四次会议上收到详细的最后报告。该报告应包含有关原始设备规格与优化的低成本设备单元规格的详细比较，设备在测试过程中的性能以及小型用户对实用性的建议。报告还应包括有关测试期间使用的泡沫塑料配方的信息，以及使用新的低成本设备的结果。根据项目的剩余活动，该项目应延长至 2019 年 7 月 31 日。

秘书处的建议

190. 执行委员会不妨：

(a) 表示注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件的由开发计划署提交的关于埃及很小型用户在聚氨酯泡沫塑料行业转用非消耗臭氧层物质技术的低成本方案的初步最后报告；

(b) 注意到迄今取得的实质性进展，作为特例，将上文(a)分段所述项目的完成日期进一步延长至 2019 年 7 月 31 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请开发计划署不迟于第八十四次会议提交最后报告；

(c) 请开发计划署确保将上文（a）分段所述项目的最后报告提交第八十四次会议，并将包含原始设备规格与优化的低成本设备单元规格的详细比较、设备在测试过程中的性能、包括测试期间使用的泡沫塑料配方、使用新设备的结果、及小型用户对实用性的建议。

欧洲和中亚（ECA）地区：建立欧洲和中亚低全球升温潜能值替代制冷剂培训、认证和示范区域英才中心（俄罗斯联邦）

背景

191. 根据第 82/22(f)号决定，俄罗斯联邦政府代表欧洲和中亚地区的国家提交了关于建立低全球升温潜能值替代制冷剂培训、认证和示范区域英才中心的进度报告 [34]。

192. 该项目的总体目标是提高东欧和中亚国家 [35] 制冷和空调行业的技术能力，克服采用低全球升温潜能值制冷剂的障碍，改善维修做法，降低现有制冷和空调设备的 F-气体排放水平，并为技师和设备制造商提供对家用、商用和工业用制冷和空调设备的节能设计和操作的理解。俄罗斯联邦政府要求工发组织协助执行该项目。

进度报告

193. 正通过自然保护部正在亚美尼亚建立区域英才中心，并将于 2019 年 9 月开放。该中心一旦全面运作，将向欧洲和中亚地区各国提供培训和咨询服务。

194. 正在执行以下活动:

(a) 建立一个网站（http://hvaccenter.am/），以播放该中心的服务，并提供远程在线培训的设置；

(b) 制定培训方案，认证计划和培训培训员；

(c) 制定关于制冷和空调的职业和学术研究通用课程，供各国实施，作为其氟氯烃淘汰管理计划活动的一部分（已完成）；和

(d) 将符合欧盟第 517/2014 号条例的 F-气体法规草案翻译成俄语，并制定关于 F-气体法规的简化技师认证制度，促进在每个欧洲和中亚国家启动认证制度（已完成）。

[34]第七十六次会议上，执行委员会根据第 72/40 号决定核准了该项目，供资金额为 591,600 美元，外加给俄罗斯联邦政府的机构支助费用 75,076 美元，并请俄罗斯联邦政府在该项目核准后 36 个月内完成，并在项目完成后迅速提交一份全面最后报告（第 76/35 号决定）。

[35]阿尔巴尼亚、亚美尼亚、波斯尼亚和黑塞哥维那、格鲁吉亚、吉尔吉斯共和国、黑山、北马其顿、摩尔多瓦共和国、塞尔维亚、土耳其和土库曼斯坦。

195. 俄罗斯联邦政府通过工发组织启动了执行使用低全球升温潜能值制冷剂和节能设计示范项目的招标程序。

资金发放情况

196. 截至 2019 年 4 月，在核准的 591,600 美元中，已发放 366,596 美元（62％）。

秘书处的评论

197. 秘书处澄清了项目完成日期，并指出该报告包括了将于 2019 年 11 月完成的活动，而项目完成日期为 2019 年 6 月。据解释，该项目于 2016 年获得核准，但资金到 2017 年 9 月才从俄罗斯联邦政府转移到工发组织。该项目预计将于 2019 年 12 月完成。

198. 回应秘书处通过该项目开展技术援助的澄清，俄罗斯联邦政府表示已启动以下活动：成立了受益国的国家制冷协会区域理事会；正在开发关于使用天然制冷剂和基于氨、二氧化碳和氢气的配方安全运行的学习模块，支持在线教育和培训；并将在线显示包括翻译版本在内的 e 学习模块的使用指南。

199. 秘书处注意到尽管经历了最初步的延误，但该项目的执行取得了实质性进展，并进一步注意到该项目将有助于加强欧洲和中亚地区的制冷和空调行业。

秘书处的评论

200. 执行委员会不妨：

(a) 表示注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件由俄罗斯联邦政府提交的关于建立欧洲和中亚低全球升温潜能值替代制冷剂培训、认证和示范区域英才中心的进度报告；

(b) 注意到迄今取得的实质性进展，作为特例，将项目完成日期延长至 2019 年 12 月 31 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请俄罗斯联邦政府不迟于第八十五次会议提交上文（a）分段所述项目的最后报告。

科威特：关于评价空调应用中无氟氯烃和低全球升温潜能值技术性能示范项目的报告（开发计划署）

背景

201. 在第七十六次会议上，执行委员会根据第 72/40 号决定，核准评价科威特空调应用中无 HCFC-22 和低全球升温潜能值技术性能的示范项目，[36] 供资金额为 293,000 美元，外加 20,510 美元的机构支助费用 。

202. 该项目的目的是示范目前可用于高环境温度（HAT）条件的两种类型的空调设备的性能：基于 HFC-32 容量 8 吨的空调系统；在科威特的四个选定地点安装了一台容量 40 吨使用 R-290 制冷剂的小型冷水机组。将考虑到压缩机、冷凝器、蒸发器、能效和能耗的性能，对设备的性能进行监测和评估，并将与使用 HCFC-22 和 R-410a 的相似尺寸和容量的设备进行比较。

203. 开发计划署代表科威特政府提交了一份示范项目报告。报告指出，尽管正在积极寻找拟议的 R-290 和 HFC-32 设备的供应商，开发计划署仍无法执行该项目，因为招标流程导致的费用为核准数额的三倍。因此，开发计划署和科威特政府正申请撤销该项目，并将余额退还第八十四次会议。

秘书处的评论

204. 要求开发计划署澄清在收到设备初始高投标时采取的行动，开发计划署解释说，经与国家臭氧机构和科威特科学研究所协商，决定将项目地点减少到两个，而不是四个，并开展第二次招标流程。第二次竞标被取消，因为只收到一份报价，设备成本报价为 650,000 美元。开发计划署表示，他们受到该组织的财务规则和条例的约束，这些规则和条例要求遵循招标程序，尽管只需要很少的几个单位，但从唯一供应商那里找不到采购这种设备的备选方案。

205. 秘书处对请求撤销表示关切，并指出项目提案经过了严格审查；开发计划署保证可以提供将要评估的设备。开发计划署解释说，在执行时，拟议设备的价格成为一项挑战，加之对以前没有使用过此类大容量设备以及标准尚不存在的国家运行安全的潜在担忧。由于这些原因，该项目无法完成，必须撤销并返还余额。提交的临时财务报告显示，未向该项目发放资金；开发计划署还澄清说，只有到第八十四次会议上才能返还，因为结束项目的程序需要开发计划署和科威特政府的签字。

[36] UNEP/OzL.Pro/ExCom/76/38。

秘书处的评论

206. 执行委员会不妨撤销评价科威特空调应用中无氟氯烃和低全球升温潜能值技术性能示范项目，并请开发计划署向第八十四次会议返还 293,000 美元，外加机构支助费用 20,510 美元。

摩洛哥：聚氨酯泡沫塑料制造行业中小型企业使用低成本戊烷发泡技术转换为非消耗臭氧层物质技术的示范项目（工发组织）

207. 在第七十五次会议上，执行委员会核准了摩洛哥聚氨酯泡沫塑料制造行业中小型企业使用低成本戊烷发泡技术转换为非消耗臭氧层物质技术的示范项目，[37] 供资金额为 280,500 美元，外加给工发组织的机构支助费用 19,635 美元（第 75/41 号决定）。

208. 该项目的目标是通过设计一个简单、标准化、易操作和小型的发泡机来探索降低初始资本成本的可能性，该发泡机能够使用易燃戊烷、设备和可移动通风系统，为几种产品提供服务。项目将在 16 个月内完成。

209. 在第八十次会议上，执行委员会同意将项目完成日期延长至 2018 年 12 月 31 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请工发组织不迟于第八十三次提交最后报告（第 80/26(f)号决定）。

210. 工发组织代表摩洛哥政府向第八十三次会议提交了示范项目的简要进度报告。提交的材料表明，发泡机和化学品的供应商均已确定；化学品和设备已购买并交付，设备业已安装；生产调试、启动、测试和培训将于 2019 年底完成。

秘书处的评论

211. 工发组织解释说，项目执行的重大延误是由于国家臭氧机构无法参与考察，以确定基于碳氢化合物预混多元醇和发泡设备的潜在供应商。此外，设备必须安装在工业区新建的厂房内，但在 2018 年设备交付时工业区尚未准备就绪。秘书处注意到已投入了大量工作，示范项目下规划的大部分活动已经完成，并且经费已经支出。完成项目并与所有其他第 5 条国家分享示范结果将是有益的。经与工发组织讨论后，商定该项目将于 2019 年 9 月完成，工发组织将向第八十四次会议提交示范项目的最后报告。

秘书处的建议

212. 执行委员会不妨：

(a) 表示注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件由工发组织提交的关于摩洛哥聚

[37] UNEP/OzL.Pro/ExCom/75/58。

氨酯泡沫塑料制造行业中小型企业使用低成本戊烷发泡技术转用非消耗臭氧层物质技术示范项目的进度报告；

(b) 指出执行取得很大进展，若干第 5 条国家可能复制其成果，将上文（a）分段所述项目的完成日期延长至 2019 年 9 月 30 日；

(c) 请工发组织向第八十四次会议提交上文（a）分段所述项目的最后报告，并在第八十五次前会议归还所有余额。

沙特阿拉伯：在高环境温度下空调行业推广基于氢氟烯烃的低全球升温潜能值制冷剂示范项目（工发组织）

背景

213. 工发组织代表沙特阿拉伯政府向第八十三次会议提交了关于在高环境温度下空调行业推广基于氢氟烯烃的低全球升温潜能值制冷剂示范项目的进度报告。

214. 该项目在第七十六次会议上获得核准，用于制造、测试和优化使用低全球升温潜能值氢氟烯烃/氢氟碳化合物混合物以及 R-290 的试验型空调机，以进行示范性生产运行和转换生产线。供资数额为 1,300,000 美元，外加给工发组织的机构支助费用 91,000 美元。

215. 在第八十次会议上，执行委员会同意将项目从 2018 年 5 月延长至 2018 年 12 月 31 日，但有一项谅解，即不得申请进一步延期，并请执行机构不迟于第八十三次会议提交最后报告（第 80/26(g)号决定）。随后，向第八十二次会议提交了一份简明的进度报告，记录了许多活动的重大进展，包括采购设备和交付部件（例如压缩机），生产设备的交付和第一批 R-290 装置的生产仍未完成。预计这些活动将于 2018 年 12 月完成。

进度报告

216. 在生产设备交付时，由于企业决定搬迁生产线，因此仍在等待安装。不过，企业计划初步安装设备，以便进行试运行和人员培训；该生产线将于 2019 年 9 月搬迁。这些设备需要进一步测试和优化。预计到 2019 年 12 月完成这些活动以及传播项目成果的讲习班。根据企业的测试以及 PRAHA-II 的结果，企业决定将其生产重点放在基于 R-290 的设备上，虽然并不排除未来使用氢氟烯烃和氢氟烯烃混合物。

秘书处的评论

217. 设备已采购并交付给企业；但是，到 2019 年 12 月底前还需要完成项目一些剩余的活动。鉴于项目实施处于后期阶段并且其结果可能对若干第 5 条国家产生影响，秘书处建议将项目延长至 2019 年 12 月 31 日， 要求向第八十五次会议提交最后报告，并到第八十六次会议归还所有余额。

秘书处的建议

218. 执行委员会不妨：

(a) 表示注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件由工发组织提交的关于在沙特阿拉伯高环境温度下空调行业推广基于氢氟烯烃的低全球升温潜能值制冷剂示范项目的进度报告；

(b) 注意到项目执行处于后期阶段并且其结果可能在若干第 5 条国家复制，将上文（a）分段所述项目的完成日期延长至 2019 年 12 月 31 日；并

(c) 请工发组织不迟于第八十五次会议提交上文（a）分段所述项目的最后报告，并到第八十六次会议归还所有余额。

沙特阿拉伯：空调制造商使用低全球升温潜能值制冷剂开发窗式空调和组合式空调示范项目- 最后报告（世界银行）

背景

219. 在第七十六次会议上，执行委员会核准了在沙特阿拉伯制造空调的两家企业的示范项目：沙特电器工厂有限公司（“SFEA”）和 Petra 工程工业有限公司（“Petra”），供资数额为 796,400 美元，外加给世界银行的机构支助费用 55,748 美元。在批准该项目时，执行委员会请沙特阿拉伯政府和世界银行在 2017 年 5 月之前完成该项目，并在项目完成后迅速提交一份全面最后报告（第 76/26(c)号决定）。

220. SFEA 将开发基于 HFC-32 和 R-290 的两种尺寸的窗式空调（1.5 至 2 制冷顿（TR）[38]），而 Petra 将开发包括冷却器和空气处理（11.4 至 28.4 制冷吨）的组合式空调系统， 使用相同的制冷剂。在该项目获得核准后，世界银行报告说，由于供应 60 赫兹压缩机的困难以及沙特阿拉伯窗式空调市场的缩减，SFEA 决定退出该项目。 因此， 220,000 美元加上世界银行的 15,400 美元的机构支助费用已返回第八十二次会议（第 82/22(b)(一)号决定）。

221. 在第八十次会议期间提供最新情况之后，执行委员会同意将项目完成日期延长至 2018 年 9 月 30 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请世界银行不迟于第八十二次会议提交上文（a）分段所述项目的最后报告（第 80/26(h)号决定）。在第八十二次会议上，执行委员会敦促世界银行尽快提交该项目的最后报告，以便在第八十三次会议上介绍（第 82/22(b)(二)号决定）。

[38] 1 制冷顿 等于 12,000 Btu/hr 或 3.5 千瓦。

222. 根据第 82/22(b)(二)号决定，世界银行代表沙特阿拉伯政府提交了关于空调制造商使用低全球升温潜能值的制冷剂开发窗式和组合空调示范项目的最后报告（ 作为本文件附件四附后）。

进度报告

223. Petra 设计、制造和测试了六个使用 HFC-32 和 R-290 制冷剂的商用风冷式制冷样机，制冷能力为 40 千瓦、70 千瓦和 100 千瓦。设备的设计符合 ISO-5149[39] 和 IEC-60335-2-40[40] 的安全要求。测试在 35℃、46℃和 52℃下进行。将结果与 R-410A 进行了比较，R-410A 是作为 HFC-32 的直接替代物进行测试的。在所有情况下，HFC-32 和 R-290 设备都显示出性能与 R-410A 相似或更好（效率和制冷能力）。但是，为降低使用 R-290 的风险所需的设计变更导致设备成本显着增加。在使用 HFC-32 时，成本增加很少。

224. 该项目显示，商用风冷式冷水机组可以设计为使用低全球升温潜能值制冷剂如 HFC-32 和 R-290 并运行，用于各种冷却能力和运行条件，包括高环境温度。由于冷水机组的应用和位置，现行国际安全标准的要求并未限制用于该项目的易燃制冷剂的数量。 但是，大多数商业应用的现行安全标准将严格限制使用 R-290 等易燃制冷剂，而 HFC-32 等轻度易燃制冷剂则不然。

秘书处的评论

范围和方法

225. 关于该项目的范围，世界银行澄清说，性能、收费和价格与基于 R-410A 的设备而不是基于 HCFC-22 的设备进行了比较，正如项目预期的那样，前者是市场标准。由于该项目已经完成，因此无法提供同基于 HCFC-22 设备的比较。秘书处回顾说，该项目是在全球升温潜能值低的氟氯烃替代品示范项目窗口下批准的，但同意基于 R-410A 的设备是目前市场上的主要技术选择。因此，示范项目的结果可能有益于第 5 条国家逐步减少氢氟碳化合物。

226. 该项目使用的方法没有将基于 R-410A 的设备的性能与为该项目制造的样机性能进行比较。而是将基于 HFC-32 和 R-290 的样机性能与使用 R-410A 的基于 HFC-32 的样机的性能进行了比较。这可能会产生有利于 HFC-32 性能的潜在偏差，因为参考模型对 HFC-32 进行了优化。

227. 世界银行提供了经优化 R-410A 的标准空调设备性能比较的额外信息，以与 HFC-32 样机使用的相同的两台压缩机，同以 R-410 为直接替代品的 HFC-32 样机和用 HFC-32 的进行性能比较。如表 11 所示， R-410A 标准空调机同以 R-410 为直接替代品的 HFC-32 样机在 35°C（T1）和 46°C（T3）条件下性能均低于 HFC-32 样机的性能。虽然在 T1 的情况下差异相对较小，但与 HFC-32 相比但

[39]国际标准组织（ISO）5149：制冷系统和热泵 - 安全和环境要求。可查阅 https://www.iso.org/standard/54979.html。

[40] 国际电工委员会（IEC）60335-2-40：家用和类似用途电器 - 安全可查阅 https://webstore.iec.ch/publication/31169。

在 T3 条件下，R-410A 的能效比（EER）和冷却能力均显著下降。在两种条件下，以 R-410A 作为直接替代品的 HFC-32 样机比 R-410A 标准设备性能更好。

表 11. R-410A 标准空调机和 HFC-32 样机的性能

设备	能效比 (Btu/Whr)		制冷能力(Btu/hr)	
	T1	T3	T1	T3
R-410A 标准设备	9.43	6.46	96.6	75.6
直接用 R-410A 作替代品的 HFC-32 样机	9.57	6.55	97.8	79.9
使用 HFC-32 的 HFC-32 样机	9.96	7.90	105.4	99.7

228. 关于项目的结果是否可能影响约旦独立的氢氟碳化合物投资项目的技术选择，[41] 以便将类似设备转换为第八十一次会议核准的 R-290（第 81/62 号决定），世界银行澄清说，虽然约旦 Petra 和沙特阿拉伯 Petra 的业主相同，但两者在财务、设计、人员、生产和工作范围各方面都是独立的企业；后者主要服务于沙特阿拉伯市场，制冷剂技术的选择取决于用户的不同应用，而前者则出口到具有不同规格和需求的 52 个国家。约旦 Petra 和沙特阿拉伯 Petra 计划继续研究和开发不同的 R-290 产品，供应市场。

229. 特定容量样机的主要区别在于压缩机的选择：对于 R-410A 和 HFC-32，它们是相同的定速涡旋压缩机，而固定速度的半封闭压缩机用于 R-290，可是找不到该项目所需容量压缩机的供应商（即 40 千瓦及以上）。世界银行指出，R-290 性能的差异部分归因于半封闭压缩机，一般来说，半封闭压缩机的效率不如使用 HFC-32 和 R-410A 的涡旋压缩机。

230. 该项目发现，大多数商业应用的当前安全标准将严格限制使用 R-290 等易燃制冷剂。 约旦项目预见到设备将包括多个独立的电路以保持在 5 千克/电路充电限制内，同时仍保持能量效率；当前项目下没有考虑这种方法。与使用单个较大制冷剂回路的设备相比，使用多个独立电路可能会增加制造成本；然而，并没有对需要增加多大作出估算。通过使用微通道热交换器也可以降低制冷剂的填充量， Industrias Thermotar Ltda 的示范项目即是一例。[42] 然而，Petra 更愿意在内部开发自己的翅片管式热交换器。

231. 根据设备容量，转换为 HFC-32 和 R-290 的制冷剂的填充量，相对于 R-410A，分别减少 15％至 25％和 23％至 33％。尽管填充量减少，冷凝器和蒸发器的成本在三种制冷剂之间没有变化，这与先前对此问题的研究相反。[43] 特别是，考虑到填充量减少，人们会预期用于制造冷凝器和蒸发器的材料会减少。此外，考虑到相对于 R-410A 和 HFC-32， R-290 的操作压力较低，可以在 R-290 热交换器中使用更薄的管道，这可以额外节省材料。世界银行澄清说，成本也取决于销售量，目前其销售量低于 Petra 使用直径较大的铜管的销量。此外，新的工具和机械需要额外的投资，因此，较小管径的制造成本也会更高。这样，对于具有标准和较小直径管的冷凝器，总成本相似。

232. 鉴于相对于 R-410A 而言，制冷剂填充量和制冷剂价格减少，比使用 HFC-32 的设备填充费用减少 50％至 57％，比使用 R-290 的则高 25％至 44％。使用 R-290 增加成本的原因是制冷剂的价

[41] UNEP/OzL.Pro/ExCom/81/40。

[42] http://www.multilateralfund.org/Our%20Work/DemonProject/Document%20Library/8110p2-4Colombia%20RAC%201.pdf。

[43] UNEP/OzL.Pro/ExCom/77/69。

格高（12.25 美元/千克），R-410A 的则是（6.55 美元/千克）。从 R-410A 过渡到 HFC-32，主要部件的成本略有增加，导致增加 11%至 13%，具体取决于设备的尺寸。HFC-32 和 R-290 之间大多数主要部件成本差异很小，压缩机除外，压缩机大约贵三倍，导致设备成本相对于 HFC-32 大幅增加。R-290 需要检漏仪，但 HFC-32 显然不需要，也造成这一差异。

233. 世界银行还提供了具有 ATEX[44] 组件的 R-290 单元的成本，大约是 HFC-32 设备的两倍。但是，秘书处并不清楚这种实质性的成本差异是否与大多数应用相关。特别是，ATEX 设备指令适用于具有潜在爆炸性环境中使用的设备。位于存在潜在爆炸性环境的危险区域的工业和商业空调和制冷系统必须满足 ATEX 要求，无论设备中使用的制冷剂是否易燃。世界银行提出，在制冷剂泄漏的情况下，使用碳氢化合物制冷剂的空调和制冷系统可能会被归类为危险区域，因此需要遵守 ATEX 指令。这种情况也适用于使用 A2L 制冷剂的系统；然而，由于这些制冷剂的可燃性极限较低，发生这种情况的频率也低。

234. Petra 还对其实验室进行了少量改动，以安全地处理和测试易燃制冷剂；改动成本在 15,000 美元到 20,000 美元之间。

秘书处的建议

235. 执行委员会不妨：

(a) 表示赞赏地注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件由世界银行提交的沙特阿拉伯空调制造商使用低全球升温潜能值制冷剂开发窗式空调和组合式空调示范项目的最后报告；并

(b) 邀请双边和执行机构在协助第 5 条国家编制使用全球升温潜能值低的制冷剂制造组合式空调的项目时，考虑到上文（a）分段所述的报告。

<u>沙特阿拉伯：高环境温度中喷涂泡沫塑料应用中利用氢氟烯烃作为发泡剂以淘汰氟氯烃的示范项目</u>（工发组织）

背景

236. 在第七十六次会议上，执行委员会核准沙特阿拉伯高环境温度中喷涂泡沫塑料应用中利用氢氟烯烃作为发泡剂以淘汰氟氯烃的示范项目，供资金额为 96,250 美元，外加给工发组织的机构支助费用 8,663 美元；请沙特阿拉伯政府和工发组织在该项目核准后 16 个月内完成，并在项目完成后迅速提交一份全面的最后报告（第 76/31 号决定）。

[44] ATEX 除其他外指定了具有爆炸性环境的环境中允许的设备。

237. 在第八十次会议上，执行委员会同意将项目完成日期延长至2018年12月31日，但有一项谅解，即不再进一步要求延长，并请工发组织不迟于第八十三次会议提交最后报告。（第 80/26（一）号决定）。

238. 该项目获得核准是为了示范在高环境温度（聚氨酯泡沫塑料行业）的喷涂泡沫塑料应用中使用 HFO-1233zd(E) 和 HFO-1336mzz(Z)加水共同发泡的益处、适用性和可复制性，以及评估通过使用泡沫密度较低和导热率较低的优化水/物理发泡剂与其他替代品相比，降低了多少资本和运营成本。

进度报告

239. 工发组织代表沙特阿拉伯政府提交了示范项目的详细进度报告。项目中的大部分活动已经完成，一旦完成实地规模测试和传播讲习班，即向第八十四次会议提交最后报告。

240. 该项目在 Sham Najd International 执行，Sham Najd International 是当地生产商，生产喷涂硬质聚氨酯（PUR）和异氰酸酯泡沫塑料（PIR），用于建筑工地和工业场所的墙壁、天花板、屋顶、吊顶和地板的隔热和防水。测试的唯一发泡剂是 HFO-1233zd(E)，因为不可能按全面的示范项目所需数量购买 HFO-1336mzz(Z)，原因是缺乏商业供应。

241. 根据测试结果，含有 HFO-1233zd(E)的喷涂雾泡沫塑料配方似乎很有潜力替代氟氯烃和氢氟碳化合物配方，因为它具有类似的技术和物理属性，并且全球升温潜能值低和消耗臭氧层物质为零。迄今为止示范项目的结论如下：

(a) HFO-1233zd(E)喷涂泡沫塑料的性能与 HCFC-141b-发泡的喷涂泡沫塑料的附着力、导热系数、尺寸稳定性、可涂性、总泡沫密度和抗压强度相匹配；

(b) 与基准泡沫塑料配方相比，聚氨酯作为产品的喷涂塑料表面显示出更多的针孔。尽管如此，它仍然符合客户的期望；

(c) 替代发泡剂不需要新的发泡设备。所有测试均使用 Sham Najd 的现有设备（Graco E-XP1 敷抹器）；

(d) 由于其沸点低（19.5℃），HFO-1233zd(E)应在低于 18℃，最好在 15℃的温度下在反应器中混合，以免在混合过程中损失发泡剂；

(e) 少量的 HFO-1233zd(E)可以在多元醇中混合，因为多元醇混合物的沸点也低于 HCFC-141b 的发泡沸点；

(f) 预混多元醇由配方厂家和最终用户储存总共五个月，未观察到反应性变化。由于 HFO-1233zd(E)的低沸点，混合物必须在最高 28℃下储存，这将导致化学品在较高温度下蒸发/沸腾。基于 HFO-1233zd(E)的泡沫塑料配方需要特殊的添加剂包（表面活化剂和催化剂）以避免多元醇共混物的劣化。催化剂包提供超过八个月的保质期；

(g) 基于 HFO-1233zd(E)的配方成本高于 HCFC-141b 的成本：根据提供的价格，增加的运营成本为 4.30 美元/ 千克。然而，包括用 HFO-1233zd(E)生产的泡沫塑料的导热率较低（更好的隔热性）和密度较低，得到的增量运营成本为 0.52 美元/ 千克。预计这些成本将在几年内降低，因为 HFO-1233zd(E)的价格下降而 HCFC-141b 的价格因供应量减少而增加。

秘书处的评论

附加测试

242. 鉴于该报告将供其他第 5 条国家制定和执行项目时参考，秘书处与工发组织讨论了应包括的其他细节。工发组织同意在实地试验中列入项目第一部分无法完成的若干试验，如粘附强度、吸水率、闭孔含量、耐热性和抗老化/降解的抗压强度等。所有上述测试均将依据 EN-14315（建筑物的隔热产品 - 原位成型喷涂异氰酸脂和聚氨酯泡沫塑料产品）进行。根据现有政策，最终报告还将包括独立的技术审查。

示范中使用制剂的供应

243. 在澄清用于测试 HFO-1233zd(E)的泡沫塑料配方制剂的来源以及这些制剂是否任何配方厂家都可获得时，工发组织表示，用于第一次测试的制剂完全由 Covestro 开发，不供应任何其他配方厂家。所有泡沫塑料制剂的细节都是配方厂家自己开发的，通常是保密的。然而，添加剂供应商（即 Evonik 和 Momentive）和发泡剂供应商（即 Honeywell 和 Chemours）积极为配方厂家的制剂人提供支持。这将使当地的配方厂家能够开发自己的制剂。

项目期限延长和最后报告

244. 秘书处指出，该项目未在 2018 年 12 月执行委员会同意的项目延长期限完成（第 80/26(一)号决定）。但是，所有实验室规模的测试都已取得实质性进展，并提供了一整套结果。至于剩下的两项活动（即实地规模测试和传播讲习班），工发组织澄清说后者将于 2019 年 5 月进行，一旦实地测试所购的其他材料于 5 月交付，即进行测试。测试将使用三种泡沫塑料配方制剂在 Sham Najd 进行。包括这些测试结果在内的最后报告将于 2019 年 10 月提供。

245. 秘书处注意到取得了很大进展，技术测试已获得结果，并获得可在高环境温度条件下，从现场测试中得到其他有价值的信息，秘书处支持延长该项目，以期在第八十四次会议获得详细的最后报告。根据编制报告时间的估计，秘书处建议将项目延长至 2019 年 10 月 31 日。

秘书处的建议

246. 执行委员会不妨：

(a) 表示注意到载于 UNEP/Ozl.Pro/ExCom/83/11 号文件由工发组织提交的关于沙特阿拉伯高环境温度中喷涂泡沫塑料应用中利用氢氟烯烃作为发泡剂以淘汰氟氯烃的示范项目执行情况的进度报告；并

(b) 注意到迄今取得的实质性进展，作为特例，将上文（a）分段所述项目的完成日期延长至 2019 年 10 月 31 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请工发组织不迟于第八十四次会议提交最后报告。

泰国：泰国利用低全球升温潜能值发泡剂配制喷涂聚氨酯泡沫塑料用途预混多元醇的配方厂家示范项目（世界银行）

背景

247. 在第七十六次会议上，执行委员会核准了泰国两个泡沫塑料配方厂家利用低全球升温潜能值发泡剂配制喷涂聚氨酯泡沫塑料用途预混多元醇的示范项目，总成本 352,550 美元，外加给世界银行的机构支助费用 24,679 美元（第 76/33 号决定）。

248. 该项目的目标是：

(a) 加强两个当地配方厂家使用氢氟烯烃（即, HFO-1233zd(E) 和 HFO-1336mzz(Z)）为聚氨酯喷涂泡沫塑料行业的中小企业配制、测试和生产预混多元醇的能力；

(b) 验证和优化为喷涂泡沫塑料的应用使用氢氟烯烃与二氧化碳共同发泡，以最小的增量运营成本实现同 HCFC-141b 类似的热性能，同时（将氢氟烯烃比率优化至 10％）；

(c) 编制不同氢氟烯烃减量制剂与基于 HCFC-141b 的制剂相比的成本分析；以及

(d) 向泰国和其他国家配方厂家传播评估结果。

249. 该项目在两个配方厂家执行，即曼谷综合贸易有限公司（BIT）和南城 Polychem 有限公司（SCP），他们向各种聚氨酯泡沫塑料，包括喷涂泡沫塑料应用的客户提供多元醇（主要使用 HCFC-141b）。

250. 世界银行代表泰国政府提交了示范项目的最后报告（作为本文件附件五附后）。示范项目的结论如下：

(a) BIT 和 SCP 对每一种氢氟烯烃(即分别为 HFO-1233zd(E)和 HFO-1336mzz(Z))的五种和

两种不同的减量制剂进行评估，并根据反应时间、粘附度和收缩性确定了最终制剂以进行详细评价。表 12 显示 BIT and SPC 用于最终测试的制剂细节，包括添加剂和其他成分：[45]

表 12.用于评价制剂占总配方的百分比（%）

	BIT			SCP		
详情	HCFC-141b	HFO-1233zd(E)	HFO-1336mzz(Z)	HCFC-141b	HFO-1233zd(E)	HFO-1336mzz(Z)
多元醇混合物	24.9	35.7	35.4	24.9	35.7	35.4
添加剂和催化剂	1.3	4.6	5.7	1.3	4.6	5.7
其他添加剂	6.0	6.7	5.4	6.0	6.7	5.4
发泡剂	10.0	4.7	4.7	10.0	4.7	4.7
异氰酸酯	57.8	48.3	48.8	57.8	48.3	48.8
共计	100	100	100	100	100	100

(b) 喷涂泡沫塑料配方所含氢氟烯烃发泡剂，相当于多元醇的 10%，并根据选定的多元醇作出调整，催化剂包能产生泰国喷涂泡沫塑料市场可接受的泡沫塑料性能。虽然 HFO-1233zd(E)制剂在配制中表现出不稳定性，但报告表示稳定性问题可以通过采用新的催化剂包来解决；

(c) 就粘附性和反应时间而言，用 HCFC-141b 发泡的喷涂泡沫塑料表现出的粘附性能和反应时间市场可接受。由减量氢氟烯烃制剂制成的喷涂泡沫塑料的密度略高于基准 HCFC-141b 制剂。还观察到抗压强度略微增加；

(d) 减量 HCFC-141b 制剂的初始 K 因子高于 HCFC-141b 制剂。氢氟烯烃发泡的泡沫塑料的所有性能随时间推移都相当稳定。报告还指出，增加的 K 因子在泰国市场可接受范围内；

(e) 两种氢氟烯烃制剂均通过了使用 ASTM [46] - 568 和 635 的防火性能测试；

(f) 在高达 35°C 以上的炎热夏季气候条件下，基于 HFO-1233zd(E)的配方可能需要可冷却配制的多元醇储存物的储存条件；

(g) 根据制剂，减量氢氟烯烃制剂（即 HFO-1233zd(E) 和 HFO-1336mzz(Z)）的价格分别

[45]选择配方时考虑的主要参数是反应性，收缩性和粘附性。

[46] 美国测试与材料协会。

比 BIT 公司的 HCFC-141b 制剂高约 22%至 38%，比 SCP 公司则分别高于 HCFC-141b 制剂的 42%至 46%。在 BIT 公司，基于 HCFC-141b 的配方为 1.93 美元/ 千克，在 SCP 公司则为 2.15 美元/ 千克，即基于氢氟烯烃的 SCP 公司制剂的价格上涨百分比仅比 BIT 公司高出约 5%；

(h) 参与示范的下游喷涂泡沫塑料用户对制剂在加工时间、粘附性能和与喷涂泡沫塑料相关的其他物理性质方面的整体性能感到满意。

251. 下面表 13 列出了预算为配方厂家采购的导热系数测试仪和喷涂泡沫塑料设备支付的实际成本。发泡机和导热系数测试仪的价格由各企业协商确定，因此供应给企业的设备存在差异。包括所有要素在内的项目财务报告将与项目完成报告一起提供。

表 13. 喷涂泡沫塑料设备和导热系数测试仪的成本

设备	BIT 公司		SCP 公司	
	核准额 (美元)	实际 (美元)	核准额 (美元)	实际(美元)
喷涂泡沫塑料机	40,000	43,675	40,000	41,692
导热系数测试仪	5,000	29,821	5,000	22,253

252. 两个示范项目的初步结果在世界银行于 2018 年 2 月在曼谷组织的第十二届区域消耗臭氧层物质讲习班上做了介绍，最后结果于 2019 年 2 月在曼谷举行的第十三届区域消耗臭氧层物质讲习班上介绍。每次讲习班有来自中国、印度尼西亚、约旦、马来西亚、菲律宾、泰国和越南的国家臭氧办公室和泡沫塑料行业的 80 余人参加。此外，在泰国又组织了三次讲习班，向政府官员、喷涂泡沫塑料企业、化学品供应商和设备供应商传播结果。参加研讨会的一些国家表示有兴趣使用这些结果并在其市场中使用氢氟烯烃开发制剂。

秘书处的评论

253. 秘书处指出，初步项目计划是在第七十九次会议上提交示范项目的调查结果，以便在评估泰国氟氯烃淘汰管理计划第二阶段时也可以使用该项目的结果；但是，结果没有按时提供。世界银行通报说，最初延迟的主要原因与获取氢氟烯烃供应和与受益企业的项目协议流程和管理模式有关。

254. 秘书处要求提供关于配方厂家开发低成本减量氢氟烯烃制剂技术能力的补充信息。世界银行告知，由于 BIT 公司的技术能力有限，氢氟烯烃制剂开发过程花费的时间比预期的要长；两配方厂家都对基于氢氟烯烃的喷涂泡沫塑料应用配方的整体性能表示满意。通过这个项目，他们获得了使用基于氢氟烯烃的喷雾泡沫塑料配方的信心，指出制剂开发和调整是一个持续的过程。世界银行还通报说，企业在为项目采购氢氟烯烃方面没有遇到重大挑战，也不预计氢氟烯烃的商业供应会有什么限制。

255. 秘书处要求提供更多信息，说明为什么 SCP 公司的异氰酸酯与多元醇的比例与 BIT 公司基于氟氯烃和氢氟烯烃的制剂不同。世界银行澄清说，BIT 公司和 SCP 公司在制剂中使用了不同的添加剂，结果多元醇与异氰酸酯的比例不同；两家企业都能够将这些制剂销售给客户并在市场上使用。秘书处还注意到， SCP 公司技术能力更好，能够为市场生产成本较低的制剂；并且，在该项目中，

通过一名国际专家提供技术支助，该专家对企业员工进行了与聚氨酯泡沫塑料技术理论和测试过程相关流程的培训。关于减量氢氟烯烃制剂的较高导热系数，世界银行告知，这是由于孔中二氧化碳的百分比较高；此外，泰国喷涂泡沫塑料市场的消费者可以接受导热系数的增加。

256. 关于每个企业中发泡剂、多元醇、其他添加剂和异氰酸酯之间的价格差异，世界银行告知，这是由于配方厂家与供应商之间个别企业谈判以及从供应商采购的添加剂类型；他们还澄清说，对于小型配方厂家，迄今不同化学品还没有优惠价格。

257. 关于热导系数测试仪的拟议成本和实际成本之间的巨大差异，世界银行澄清说，最初提案中低估了 K 值测试仪的成本，结果实际价格远远高于预算数额。测试泡沫塑料所需的设备规格没有变化。

258. 秘书处指出，最近的趋势表明 HCFC-141b 的价格在上涨，而且由于监管因素导致 HCFC-141b 的供应量减少，预计 HCFC-141b 的价格将继续上涨；在一些国家已经注意到了这种趋势。此外，报告的氢氟烯烃价格可能会不同，随着氢氟烯烃产量的增加，氢氟烯烃的价格可能会下降，尽管下降的时间尚不确定。此外，氢氟烯烃的价格显著下降加上 HCFC-141b 的价格上涨可能使基于氢氟烯烃的制剂的成本与 HCFC-141b 制剂相当。

秘书处的建议

259. 执行委员会不妨：

(a) 表示赞赏地注意到载于 UNEP/Ozl.Pro/ExCom/83/11 号文件由世界银行提交的泰国利用低全球升温潜能值发泡剂配制喷涂聚氨酯泡沫塑料用途预混多元醇的两配方厂家示范项目的最后报告；并

(b) 邀请双边和执行机构在协助第 5 条国家编制用氢氟烯烃发泡的喷涂泡沫塑料项目时，考虑到上文（a）分段中提到的最后报告。

<u>西亚地区：在西亚高环境温度国家推广空调替代制冷剂的示范项目 - 进度报告</u>（环境规划署和工发组织）

260. 环境规划署和工发组织代表参与该项目的西亚国家[47] 提交了一份关于在西亚高环境温度国家推广空调替代制冷剂的示范项目的进度报告，更出名的是 PRAHA-II。

[47]巴林、埃及、科威特、卡塔尔、阿曼、沙特阿拉伯和阿拉伯联合酋长国。没有为阿拉伯联合酋长国提供资金，当地工业自费建造样机并参加历次 PRAHA 会议。

261. 该项目由七十六次会议核准，目的是在西亚高环境温度国家推广空调替代制冷剂的示范项目（PRAHA-I）[48] 进展的基础上，提高高环境温度国家的利益攸关方在空调行业使用低全球升温潜能值制冷剂的能力。

262. 在第八十次会议上，执行委员会同意将最初预计于 2017 年 11 月完成的项目延长至 2018 年 12 月 31 日，但有一项谅解，即不得申请进一步延长项目的执行期限，并请执行机构不迟于第八十三次会议提交最后报告（第 80/26(l)号决定）。向第八十三次会议提交了一份简明的进度报告，记录了许多活动的重大进展；杰出的活动包括开发适合在高环境温度条件下使用模式的风险评估模型，预计将于 2018 年 10 月完成，使用 PRAHA-I 项目开发的样机进行测试和优化，预期将于 2018 年 11 月完成。

263. 西亚参与国、环境规划署和工发组织取得了实质性进展，完成了许多但不是全部项目计划的活动。特别是，该项目的第一个组成部分，建立当地工业利用全球升温潜能值较低的高效易燃制冷剂来设计和测试产品的能力已经完成。第二和第三部分也取得了实质性进展，即评价、优化为 PRAHA-I 建造的样机，并为高环境温度国家建立了风险评估模型。对于前者，PRAHA-I 样机的初步优化已经完成，并且评价了性能。根据结果，选择了三个样机进行额外的测试和评价；一个已建成，另外两个将分别于 2019 年 4 月和 5 月完成。这些单元的测试将于 2019 年 6 月完成，包括分析高滑移替代品泄漏补给的配方性能。至于后者，已收集该模型的必要数据；模型的测试和验证正在进行，将于 2019 年 9 月完成。

264. 由于同测试设施的合同难以最后确定，未完成的活动无法在预期时间范围内完成，因此只能向第八十三次会议提交初步进度报告。为此，环境规划署和工发组织申请将该项目进一步延长至 2019 年 11 月 15 日。

秘书处的评论

265. 尽管取得了进展，但该项目没有按照第 80/26(l) and 82/22(g)号决定完成。特别是，剩下的活动包括完成样机测试、审查和验证优化结果和为风险评估模型收集数据、以及一个传播项目结果的专题讨论会。前者预计将于 2019 年 6 月完成，后者计划于 2019 年 9 月或 10 月完成。

266. 根据迄今取得的进展以及项目完成后可能对高环温度环境国家提供的惠益，秘书处建议将项目延长期限至 2019 年 11 月 15 日，请将最后报告提交第八十四次会议，所有余额在第八十五次会议归还。

[48] 第六十九次会议核准，由开发计划署和工发组织执行(UNEP/OzL.Pro/ExCom/69/19）。该项目的最后报告可参阅 UNEP/OzL.Pro/ExCom/76/10 号文件。

秘书处的评论

267. 执行委员会不妨：

(a) 表示注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件由环境规划署和工发组织提交的关于在西亚高环境温度国家推广空调替代制冷剂的示范项目（PRAHA-II）的进度报告；并

(b) 将上文（a）分段所述项目的完成日期延长至 2019 年 11 月 15 日，以完成样机的测试，测试优化结果验证和风险评估模型和传播项目成果，并请环境规划署和工发组织不迟于第八十四次会议提交最后报告和在第八十五次会议归还所有余额。

区域制冷可行性研究

<u>科威特：比较供中央空调使用的三种非同类技术的可行性研究–最后报告</u>（环境规划署和工发组织）

268. 根据第 82/24(b)号决定，环境规划署和工发组织代表科威特政府提交了关于可行性研究的最后报告。报告全文作为附件六附于本文件后。

269. 该研究在两个地点（一所学校和一座清真寺）使用两级[49] “直接/间接”蒸发冷却（TSDI），证明了冷冻水系统和蒸发冷却相结合的中央空调系统的技术可行性。该技术是适合科威特气候条件的最佳选择。技术和财务研究基于学校所需 800 制冷顿和清真寺 81 制冷顿的装机容量。

270. 最后报告概述了以下结论：

(a) 为这两个地点安装混合非同类技术所需的资本成本比目前使用的同类技术高约 50％（即非同类技术成本为 1,600 美元/制冷顿而目前的同类技术为 750 美元/ 制冷顿）；

(b) 使用非同类技术表明，与目前的同类技术相比，这两个地点的能耗可节省约 46%；

[49]在第一阶段，热的外部空气进入热交换器内部，热交换器通过外部蒸发冷却。在初始冷却阶段期间，进入的空气流被冷却而不升高其湿度。在第二阶段，相同的气流通过浸水垫，再进一步冷却，空气则吸收一些额外的湿度。

(c) 根据对这两种技术的资本和运营成本的比较分析，该研究显示为学校安装非同类系统的额外资本成本（即 680,000 美元）的回收期为四年，内部收益率（IRR）为 31％；为清真寺的额外资本成本（68,850 美元）的回收期为两年，内部收益率为 35％；

(d) 该研究的结论是，与简单的传统电子同类系统相比，非同类技术辅助的非同类技术系统总体可节省约 52％左右，并且可能在其他用途中，使用该国的中央空调系统。

秘书处的评论

271. 在审查最后报告时，秘书处将其与提交第八十二次会议的初步报告进行了比较，并注意到它包含了有关那些待完成活动的更详细信息，特别是项目试验阶段的进展情况。报告介绍了从两个试点收集的数据，这些数据显示了有前途的结果。该报告还提供了评价该方法在技术和财务方面可行性的结果，因为试验阶段尚未完成，这没有在第八十二次会议上提供，并得出结论，这是该国有前途的替代品。

272. 根据两个试点的结果，科威特住房福利公共管理局（KPAHW）将考虑调整其未来公共建筑的投标程序，以转向两级直接/间接蒸发冷却系统。未来的发展计划将包括最早在 2020 年之前在其他选定的地点投资和执行这种非同类技术。

273. 工发组织和环境规划署还重申，即使在项目完成之后，科威特政府也将提供关于如何在科威特其他地点执行的最新情况.

秘书处的建议

274. 执行委员会不妨：

(a) 表示赞赏地注意到载于 UNEP/OzL.Pro/ExCom/83/11 号文件由环境规划署和工发组织提交的比较科威特中央空调使用的三种非同类技术的可比性研究最后报告；

(b) 重申环境规划署和工发组织将提交上文（a）分段所述可行性研究的项目完成报告，并将任何余额退还第八十四次会议；和

(c) 鼓励科威特政府通过环境规划署和工发组织向执行委员会未来的一次会议提供关于因为可行性研究结果而采取行动的最新资料。

第六部分： 菲律宾氟氯烃逐步淘汰管理计划第二阶段和逐步减少氢氟碳化合物扶持活动执行机构的改变

菲律宾：氟氯烃逐步淘汰管理计划第二阶段和扶持活动——要求改变执行机构(世界银行)

背　景

275. 在第 80 次会议上，执行委员会原则上批准了为菲律宾氟氯烃逐步淘汰管理计划第二阶段提供为数 2,750,057 美元，外加 192,504 美元的机构支助费用，[50,51]以及为氢氟碳化合物逐步减少的扶持活动提供金额为 250,000 美元，外加金额为 17,500 美元的机构支助费用，[52]这两项活动都将在世界银行的协助下执行。

276. 秘书处收到了菲律宾政府的一项请求，[53]请求将菲律宾氟氯烃逐步淘汰管理计划第二阶段和逐步减少氢氟碳化合物的扶持活动从世界银行移交给工发组织。

秘书处的评论

277. 针对菲律宾政府的来函，秘书处与世界银行进行了磋商，并要求其在第 83 次会议上将需返还的项目未用资金的价值转给多边基金和工发组织。世界银行通知秘书处，世界银行和菲律宾政府之间关于氟氯烃逐步淘汰管理计划第二阶段的协定并未签署；因此，将全数退还核准的金额。关于多边基金额外捐款下核准的扶持活动，世界银行报告说已支付 24,008 美元，外加机构支助费用。

278. 表 14 列出将返还多边基金并随后转给工发组织的资金。

表 14. 核准的资金以及原则上核准从世界银行转给工发组织的资金

项目名称	守　　则	第 80 次会议核准（美元）	截至 2019 年 4 月的余额（美元）		
			项目费用	支助费用	共　计
氟氯烃逐步淘汰管理计划（第二阶段第一次付款）	PHI/PHA/80/INV/103 号文件	736,129	736,129	51,528	787,657
	PHI/PHA/80/TAS/102 号文件	273,894	273,894	19,173	293,067
逐步减少氢氟碳化合物的扶持活动	PHI/SEV/80/TAS/01+ 号文件	250,000	225,992	15,819	241,811
余　额			**1,236,015**	**86,520**	**1,322,535**

[50] 第 80/60 号决定。
[51] 氟氯烃逐步淘汰管理计划第二阶段第一次付款获得批准，数额为 1,010,023 美元，外加世界银行的机构支助费用 70,701 美元(第 80/60(f)号决定)。
[52] 第 80/52 号决定。
[53] 2019 年 4 月 3 日菲律宾环境管理局给秘书处的信。

项目名称	守　　则	第 80 次会议核准（美元）	截至 2019 年 4 月的余额（美元）		
			项目费用	支助费用	共　计
原则上批准的第二阶段供资付款			1,740,034	121,802	1,861,836
总　　计			2,976,049	208,322	3,184,371

279.　秘书处指出，如本文件附件七所示，氟氯烃逐步淘汰管理计划第二阶段执行机构的改变需要更新该国政府与执行委员会之间的协定。完整的协定将附在第 83 次会议最后报告之后。

秘书处的建议：

280.　执行委员会不妨：

(a)　注意到菲律宾政府请求将氟氯烃逐步淘汰管理计划第二阶段中包括的所有逐步淘汰活动以及最初计划由世界银行执行的氢氟碳化合物逐步淘汰扶持活动移交给工发组织；

(b)　关于菲律宾氟氯烃逐步淘汰管理计划的第二阶段：

(i)　注意到世界银行已在第 83 次会议上向多边基金返还了 1,010,023 美元，加上与第一次付款(PHI/PHA/80/INV/103 号和 PHI/PHA/80/TAS/102 号文件)相关的机构支助费用 70,701 美元；

(ii)　核准：

向工发组织移交 1,010,023 美元，加上为世界银行核准的与第一次付款(PHI/PHA/80/INV/103 号文件和 PHI/PHA/80/TAS/102 号文件)相关的机构支助费用 70,701 美元；

从世界银行向工发组织移交 1,740,034 美元的资金，加上原则上核准与第二和第三次付款资金有关的 121,802 美元的机构支助费用；

(iii)　注意到基金秘书处更新了本文件附件七所载菲律宾政府与氟氯烃逐步淘汰管理计划执行委员会之间关于第二阶段的协定：特别是关于将世界银行的组成单元移交工发组织的第 9 段和附录 2−A；增加第 17 段是为了表明世界银行从第 83 次会议起不再是牵头执行机构，更新后的协定取代了第 80 次会议达成的文本；

(c)　关于多边基金额外捐款(PHI/SEV/80/TAS/01+号文件)下核准的氢氟碳化合物逐步淘汰扶持活动:

(i) 注意到世界银行已在第 83 次会议上返还了 225,992 美元的余额，以及 15,819 美元的机构支助费用；

(ii) 核准将 225,992 美元余额以及曾经为世界银行核准的 15,819 美元机构支助费用转给工发组织。

第七部分：关于延长扶持活动的请求

关于延长扶持活动的请求（开发署、环境署、工发组织和世界银行）

281. 在第 80 次会议上，执行委员会批准了 59 个第 5 条国家逐步减少氢氟碳化合物的扶持活动；[54]自批准之日起，项目期限为 18 个月。在第 81 次会议上，执行委员会决定根据第 79/46(d)(三)号决定，将此类项目的执行期保持在 18 个月，如有必要，在秘书处收到正式延期请求后，将此期限延长，但不超过 12 个月(自项目核准之日起共 30 个月)。[55]

282. 根据第 81/32(a)号决定，四个执行机构代表 51 个第 5 条国家提交了延长扶持活动的正式请求，预计完成日期为 2019 年 6 月，如表 15 所示。

表 15. 向第 83 次会议提交的延长氢氟碳化合物逐步淘汰扶持活动的请求

国　　家	牵头执行机构	要求延长的期限
安哥拉	环境署	12 个月
亚美尼亚	工发组织	12 个月
不丹	环境署	12 个月
波斯尼亚和黑塞哥维那	工发组织	12 个月
布基纳法索	工发组织	12 个月
喀麦隆	工发组织	12 个月
智利*	开发署	12 个月
中国**	开发署	12 个月
哥伦比亚	开发署	12 个月
刚果	工发组织	12 个月
哥斯达黎加	开发署	12 个月
多米尼克	环境署	12 个月
多米尼加共和国	环境署	12 个月
厄瓜多尔	环境署	12 个月
厄立特里亚	环境署	12 个月
斐济	开发署	12 个月
加蓬	环境署	12 个月
冈比亚	工发组织	12 个月
加纳	环境署	6 个月
危地马拉	环境署	12 个月
牙买加	开发署	12 个月
吉尔吉斯斯坦	环境署	12 个月

[54] 第 80/41 号决定。

[55] 第 81/32(a)号决定。

国　　家	牵头执行机构	要求延长的期限
黎巴嫩	开发署	12 个月
莱索托****	环境署	6 个月
马来西亚	世界银行	12 个月
马尔代夫****	环境署	12 个月
墨西哥**	工发组织	12 个月
蒙古	环境署	12 个月
纳米比亚	环境署	12 个月
尼日利亚	环境署	12 个月
北马其顿	工发组织	12 个月
帕劳	环境署	12 个月
秘鲁	开发署	12 个月
菲律宾	工发组织	12 个月
卢旺达****	环境署	12 个月
圣卢西亚岛	环境署	12 个月
圣文森特和格林纳丁斯	环境署	12 个月
塞内加尔	环境署	12 个月
塞尔维亚	工发组织	12 个月
索马里	工发组织	12 个月
苏丹***	环境署	12 个月
苏里南	环境署	12 个月
泰国	世界银行	12 个月
多哥	环境署	12 个月
特立尼达和多巴哥	开发署	12 个月
突尼斯****	工发组织	12 个月
土耳其	工发组织	12 个月
土库曼斯坦	环境署	12 个月
乌拉圭***	开发署	12 个月
赞比亚	环境署	12 个月
津巴布韦	环境署	6 个月

* 环境署和工发组织作为合作执行机构
** 环境署作为合作执行机构
*** 工发组织作为合作执行机构
**** 意大利政府作为合作执行机构

秘书处的评论

283.　秘书处注意到，第 80 次会议批准了所有延长扶持活动的请求，预计都将于 2019 年 6 月完成。延期的主要原因除其他外包括需要完成计划的活动；延迟启动执行；国家臭氧机构和执行机构之间的协调困难。大多数国家要求延长 12 个月，而加纳、莱索托和津巴布韦则表示需要 6 个月来完成所有计划的活动。

秘书处的建议：

284. 执行委员会不妨：

(a) 注意并审议 UNEP/OzL.Pro/ExCom/83/11 号文件表 15 所列 51 个第 5 条国家的各自执行机构提交的关于延长氢氟碳化合物逐步减少扶持活动的请求；和

(b) 将加纳、莱索托和津巴布韦氢氟碳化合物逐步淘汰扶持活动的完成日期延长至 2019 年 12 月，将安哥拉、亚美尼亚、不丹、波斯尼亚和黑塞哥维那、布基纳法索、喀麦隆、智利、中国、哥伦比亚、刚果、哥斯达黎加、多米尼克、多米尼加共和国、厄瓜多尔、厄立特里亚、斐济、加蓬、冈比亚、危地马拉、牙买加、吉尔吉斯斯坦、黎巴嫩、马来西亚、马尔代夫、墨西哥、蒙古、纳米比亚、尼日利亚、北马其顿、帕劳、秘鲁、菲律宾、卢旺达、圣卢西亚、圣文森特和格林纳丁斯、塞内加尔、塞尔维亚、索马里、苏丹、苏里南、泰国、多哥、特立尼达和多巴哥、突尼斯、土耳其、土库曼斯坦、乌拉圭和赞比亚延长至 2020 年 6 月，但有一项谅解，即不再要求延期，双边和执行机构将在项目完成之日起六个月内提交根据第 81/32(b)号决定完成的扶持活动最后报告。

附件一

需向第八十四次会议另行提交状况报告的项目

国家	编号	机构	项目名称	建议
安地卡及巴布达	ANT/PHA/73/PRP/17	联合国环境规划署	制定氟氯烃淘汰管理计划（第二阶段）	要求向第八十四次会议就执行情况提交状态报告
安地卡及巴布达	ANT/SEV/73/INS/16	联合国环境规划署	延长体制强化项目（第五阶段：2015 年 1 月-2016 年 12 月）	要求向第八十四次会议就执行情况提交状态报告
巴林	BAH/PHA/68/INV/27	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第一次拨款）（Awal Gulf 的制造企业在生产中央空调及窗式空调的过程中逐步淘汰 HCFC-22）	要求向第八十四次会议就执行情况提交状态报告
中非共和国	CAF/SEV/68/INS/23	联合国环境规划署	延长体制强化项目（第六阶段：2013 年 1 月-2014 年 12 月）	要求向第八十四次会议就执行情况及资金拨付水平提交状况报告
智利	CHI/PHA/76/TAS/191	联合国环境规划署	氟氯烃淘汰管理计划（第二阶段第一次拨款）（制冷维修行业）	要求向第八十四次会议就执行情况及资金拨付水平提交状况报告
朝鲜民主主义人民共和国	DRK/PHA/73/INV/59	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第一次拨款）（逐步淘汰平壤松邦及普弘建材厂聚氨酯泡沫塑料行业使用的 HCFC-141b）	就包含恢复活动的最新进展在内的项目执 行情况，要求向第八十四次会议提交状况报告
朝鲜民主主义人民共和国	DRK/PHA/73/TAS/60	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第一次拨款）（制冷维修与监测）	就包含恢复活动的最新进展在内的项目执 行情况，要求向第八十四次会议提交状况报告
朝鲜民主主义人民共和国	DRK/PHA/75/INV/62	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）（逐步淘汰平壤松邦及普弘建材厂聚氨酯泡沫塑料行业使用的 HCFC-141b）	就包含恢复活动的最新进展在内的项目执 行情况，要求向第八十四次会议提交状况报告
朝鲜民主主义人民共和国	DRK/PHA/75/TAS/63	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）（政策、制冷维修及监测）	就包含恢复活动的最新进展在内的项目执 行情况，要求向第八十四次会议提交状况报告
朝鲜民主主义人民共和国	DRK/PHA/77/INV/64	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第三次拨款）（政策、制冷维修及监测）	就包含恢复活动的最新进展在内的项目执 行情况，要求向第八十四次会议提交状况报告
朝鲜民主主义人民共和国	DRK/SEV/68/INS/57	联合国环境规划署	延长体制强化项目（第六阶段和第七阶段：2010 年 1 月- 2013 年 12 日）	就包含恢复活动的最新进展在内的项目执 行情况，要求向第八十四次会议提交状况报告

国家	编号	机构	项目名称	建议
刚果民主共和国	DRC/PHA/79/PRP/42	联合国开发计划署	制定氟氯烃淘汰管理计划（第二阶段）	就包含第二阶段提交的最新情况在内的资金拨付水平，要求向第八十四次会议提交状况报告
刚果民主共和国	DRC/PHA/79/PRP/43	联合国环境规划署	制定氟氯烃淘汰管理计划（第二阶段）	就包含第二阶段提交的最新情况在内的资金拨付水平，要求向第八十四次会议提交状况报告
多米尼加	DMI/SEV/80/INS/23	联合国环境规划署	用于强化体制的其他紧急援助	要求向第八十四次会议就第81/36 号决定所述战略及行动计划的执行情况提交状况报告
埃塞俄比亚	ETH/PHA/77/INV/28	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）	要求向第八十四次会议就项目取得的进展和资金拨付水平提交状况报告
埃塞俄比亚	ETH/PHA/77/TAS/27	联合国环境规划署	氟氯烃淘汰管理计划（第一阶段第二次拨款）	要求向第八十四次会议就执行情况及资金拨付水平提交状况报告
埃塞俄比亚	ETH/SEV/77/INS/26	联合国环境规划署	延长体制强化项目（第七阶段 2017 年 1 月- 2018 年 12 月）	要求向第八十四次会议就执行情况及资金拨付水平提交状况报告
危地马拉	GUA/PHA/75/TAS/50	联合国环境规划署	氟氯烃淘汰管理计划（第一阶段第三次拨款）	要求向第八十四次会议就执行情况及资金拨付水平提交状况报告
海地	HAI/PHA/76/INV/22	联合国开发计划署	氟氯烃淘汰管理计划（第一阶段第二次拨款）	就资金拨付水平、与联合国开发计划署达成协定的最后定稿以及为加快项目活动实施提供援助的联合国环境规划署履约协助方案，要求向第八十四次会议提交状况报告
海地	HAI/SEV/75/INS/20	联合国环境规划署	延长体制强化项目（第四阶段：2015 年 11 月- 2017 年 10 月）	要求就执行情况及资金拨付水平向第八十四次会议提交状况报告
印度	IND/SEV/76/INS/467	联合国开发计划署	延长体制强化项目（第十阶段：2016 年 4 月- 2018 年 3 月）	要求向第八十四次会议就资金拨付水平提交状况报告
伊朗（伊斯兰共和国）	IRA/PHA/77/INV/226	联合国开发计划署	氟氯烃淘汰管理计划（第二阶段第一次拨款）（泡沫塑料行业）	要求就资金拨付水平向第八十四次会议提交状况报告
伊拉克	IRQ/PHA/74/INV/23	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）（制冷维修行业）	要求就资金拨付水平向第八十四次会议提交状况报告
卡塔尔	QAT/PHA/65/INV/18	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第一次拨款）（制冷维修行业）	要求就项目执行情况向第八十四次会议提交状况报告，注意项目将于 2019 年 7 月 1 日前完成，并将于 2019 年 12 月 31 日之前返还剩余资金

国家	编号	机构	项目名称	建议
卡塔尔	QAT/PHA/65/TAS/17	联合国环境规划署	氟氯烃淘汰管理计划（第一阶段第一次拨款）（制冷维修行业）	要求就项目执行情况向第八十四次会议提交状况报告，注意项目将于 2019 年 7 月 1 日前完成，并将于 2019 年 12 月 31 日之前返还剩余资金
卡塔尔	QAT/PHA/73/PRP/20	联合国环境规划署	制定氟氯烃淘汰管理计划（第二阶段）	要求就第二阶段提交的信息向第八十四次会议提交状况报告，注意已经延迟提交
卡塔尔	QAT/PHA/73/PRP/21	联合国工发组织	制定氟氯烃淘汰管理计划（第二阶段）	要求就第二阶段提交的信息向第八十四次会议提交状况报告，注意已经延迟提交
卡塔尔	QAT/SEV/79/INS/22	联合国工发组织	更新体制强化项目（第四阶段：2017 年 8 月- 2019 年 7 月）	要求就执行情况及资金拨付水平向第八十四次会议提交状况报告
沙特阿拉伯	SAU/FOA/62/INV/13	联合国工发组织	从 Al Watania Plastics 的挤塑聚苯板制造中逐步淘汰 HCFC-22 和 HCFC 142b	要求就包括此前已经采购、目前需要出售之设备的拍卖最新情况的执行情况，向第八十四次会议提交状况报告
沙特阿拉伯	SAU/PHA/68/INV/17	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第一次拨款）（制冷维修与监测）	要求就执行情况向第八十四次会议提交状况报告
沙特阿拉伯	SAU/PHA/72/INV/20	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）（制冷维修与监测）	要求就执行情况向第八十四次会议提交状况报告
沙特阿拉伯	SAU/PHA/75/INV/24	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第三次拨款）（聚氨酯泡沫塑料行业计划）	要求就执行情况向第八十四次会议提交状况报告
沙特阿拉伯	SAU/PHA/75/INV/25	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第三次拨款）（制冷维修与监测）	要求就执行情况向第八十四次会议提交状况报告
沙特阿拉伯	SAU/PHA/77/INV/31	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第四次拨款）（聚氨酯泡沫塑料行业计划）	要求就执行情况及已拨付的资金水平向第八十四次会议提交状况报告
沙特阿拉伯	SAU/PHA/77/TAS/32	联合国环境规划署	氟氯烃淘汰管理计划（第一阶段，第四次拨款）（制冷维修、海关培训与监测）	要求就执行情况及资金拨付水平向第八十四次会议提交状况报告
沙特阿拉伯	SAU/SEV/67/INS/15	联合国环境规划署	延长体制强化项目（第二阶段：2012 年 7 月至 2014 年 6 月）	要求就执行情况向第八十四次会议提交状况报告
索马里	SOM/PHA/77/INV/12	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）（制冷维修行业）	要求就执行情况向第八十四次会议提交状况报告

国家	编号	机构	项目名称	建议
索马里	SOM/PHA/77/TAS/13	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第二次拨款）（附加担保）	要求就执行情况向第八十四次会议提交状况报告
南苏丹	SSD/PHA/77/TAS/04	联合国环境规划署	氟氯烃淘汰管理计划（第一阶段第一次拨款）	要求就执行情况及资金拨付水平向第八十四次会议提交状况报告
南苏丹	SSD/SEV/76/INS/03	联合国环境规划署	体制强化项目（第一阶段： 2016 年 5 月- 2018 年 4 月）	要求就执行情况及资金拨付水平向第八十四次会议提交状况报告
苏里南	SUR/PHA/74/TAS/22	联合国环境规划署	氟氯烃淘汰管理计划（第一阶段第二次拨款）	要求就资金拨付水平向第八十四次会议提交状况报告
苏里南	SUR/SEV/77/INS/25	联合国环境规划署	延长体制强化项目（第六阶段：2016 年 12 月- 2018 年 11 月）	要求就执行情况及资金拨付水平向第八十四次会议提交状况报告
阿拉伯叙利亚共和国	SYR/FOA/61/PRP/102	联合国工发组织	氟氯烃淘汰投资活动的筹备工作（泡沫塑料行业）	要求就执行情况以及对第一阶段提交的信息之监测，向第八十四次会议提交状况报告
阿拉伯叙利亚共和国	SYR/PHA/55/PRP/97	联合国工发组织	制定氟氯烃淘汰管理计划	要求就执行情况以及对第一阶段提交的信息之监测，向第八十四次会议提交状况报告
阿拉伯叙利亚共和国	SYR/REF/62/INV/103	联合国工发组织	Al Hafez 集团从整组式空调设备和硬质聚氨酯保温板的制造中逐步淘汰 HCFC-22 和 HCFC 141b	要求就执行情况向第八十四次会议提交状况报告
阿拉伯叙利亚共和国	SYR/SEV/73/INS/104	联合国工发组织	延长体制强化（第五阶段：2015 年 1 月- 2016 年 12 月）	要求就执行情况向第八十四次会议提交状况报告
突尼斯	TUN/FOA/77/PRP/72	联合国工发组织	氟氯烃淘汰投资活动的筹备工作（第二阶段）（聚氨酯泡沫塑料行业）	要求就包括第二阶段提交的最新情况在内的资金拨付水平，向第八十四次会议提交状况报告
突尼斯	TUN/PHA/77/PRP/71	联合国工发组织	制定氟氯烃淘汰管理计划（第二阶段）	要求就包括第二阶段提交的最新情况在内的资金拨付水平，向第八十四次会议提交状况报告
土耳其	TUR/PHA/74/PRP/105	联合国工发组织	制定氟氯烃淘汰管理计划（第二阶段）	要求就包括第二阶段提交的最新情况在内的资金拨付水平，向第八十四次会议提交状况报告
也门	YEM/SEV/73/INS/43	联合国环境规划署	延长体制强化项目（第八阶段：2015 年 1 月- 2016 年 12 月）	要求就执行情况和资金拨付水平，向第八十四次会议提交状况报告
赞比亚	ZAM/PHA/77/INV/33	联合国工发组织	氟氯烃淘汰管理计划（第一阶段第三次拨款）	要求就执行情况和资金拨付水平，向第八十四次会议提交状况报告

Annex II

Government of Cuba

Pilot Demonstration Project on ODS-Waste Management and Disposal

Final report

Prepared by
Ozone Technical Office (OTOZ)

Implemented with assistance of the United Nations Development Programme - UNDP

Funded by the Multilateral Fund (MLF) for the Implementation of the Montreal Protocol

December 2nd, 2018

Contents

1. **Summary of the project details as per the approval.**

COUNTRY:	Cuba
IMPLEMENTING AGENCY:	UNDP
PROJECT TITLE:	Pilot Demonstration Project on ODS-Waste Management and Disposal
SECTOR:	ODS-Waste
Sub-Sector:	Refrigeration Servicing Sector
Date of Approval:	April 2011
PROJECT IMPACT:	8.8 Metric Tons of CFC-12
PROJECT DURATION:	36 months
LOCAL OWNERSHIP:	100 %
EXPORT COMPONENT:	0 %
REQUESTED MLF GRANT:	US$ 525,200
IMPLEMENTING AGENCY SUPPORT COST:	US$ 39,390 (7.5 %)
TOTAL COST OF PROJECT TO MLF:	US$ 564,590
COST-EFFECTIVENESS:	US$ 3.95/kg ODS (metric) based on complete destruction of recovered ODS Waste in Cuba. Not all will be destroyed during the 3-year demonstration project.
NATIONAL COORDINATING AGENCY:	Technical Ozone Office: Ministry of Science, Technology and the Environment.

2. **Background**

In 2006, Cuba introduced the *Energy Revolution Year* where one important component was to promote the complete substitution of old energy inefficient domestic refrigerators and air-conditioning units. The programme was actively supported by the National Ozone Unit (NOU) to ensure that the Ozone depleting substances (ODS) contained in those refrigerators were properly recovered, following best refrigeration practices. With this Energy Programme, between 2005 and 2010 over 2.757 million refrigerators and 276,000 air-conditioning units, on average 20 to 60 years old, were de-manufactured and replaced with energy efficient units at a cost of over 700 million US dollars to the government of Cuba which funded the complete recollection, substitution and de-manufacturing programme.

At the 62nd meeting of the Executive Committee of the Multilateral fund, a Pilot demonstration project on ODS waste management and disposal, with UNDP as implementing agency; The funds provided by the Multilateral Fund were US$ 525,200. The project sought to demonstrate a cost-effective way for the collection, storage and disposal unwanted ODS using a cement kiln.

3. Implementation of the project

The project worked in two aspects, 1) Strengthening the national system for refrigerant collection, and 2) Design and construction of a refrigerant disposal facility.

The project started in March 2011 with participation of the Ministry of Science, Technology and Environment (CITMA), Ministry of Construction (MINCON), Ministry of Internal Commerce (MINCIN), led by the Ozone Technical Office (OTOZ). Each of the involved entities designate a participant that supported the implementation of the project.

4. Description of the collection, storage and destruction

4.1 Recovery and collection of ODS

All refrigeration servicing workshops and maintenance brigades in the country, belonging to any of the organisms (OACE – Organismo de Administracion Central del Estado) are required to avoid the release to the atmosphere of refrigerant from equipment being serviced, repaired, substituted or dismantled and must recover this, store it in equipment loaned to them, and hand it over to the municipal workshops of the Ministry of Interior Commerce (MINCIN), Industrial Equipment and Services Enterprise (Empresa Industrial de Equipos y Servicios - EIESA) or others as previously agreed with the MINCIN. EIASA's workshops as well as the municipal MINCIN approved workshops are responsible for adequate handling and storage of ODS received.

The system is structured around 1,000 local level workshops. As there are 169 municipalities, one of the above mentioned 1,000 workshops acts as a municipal level center. The ODS recovered by the 1,000 workshops thus feeds into 169 municipal level workshops. There are 6 territorial workshops that serve as collection centers which cover the entire country, located in the main cities and provinces: Havana, Villa Clara, Santi Espíritu, Camagüey, Holguín and Santiago de Cuba.

The ODS refrigerants comes from all the service workshops regardless of the governmental sector where it comes from. The service workshops are responsible for taking and delivering the gas to the municipal collection centers, which inform the collection centers when they have significant quantities.

In the territorial workshops (collection centers), the cylinders brought by the service workshops are weighted, the gas they contain is then identified, and transferred to cylinders of greater capacity that exists in every collection center.

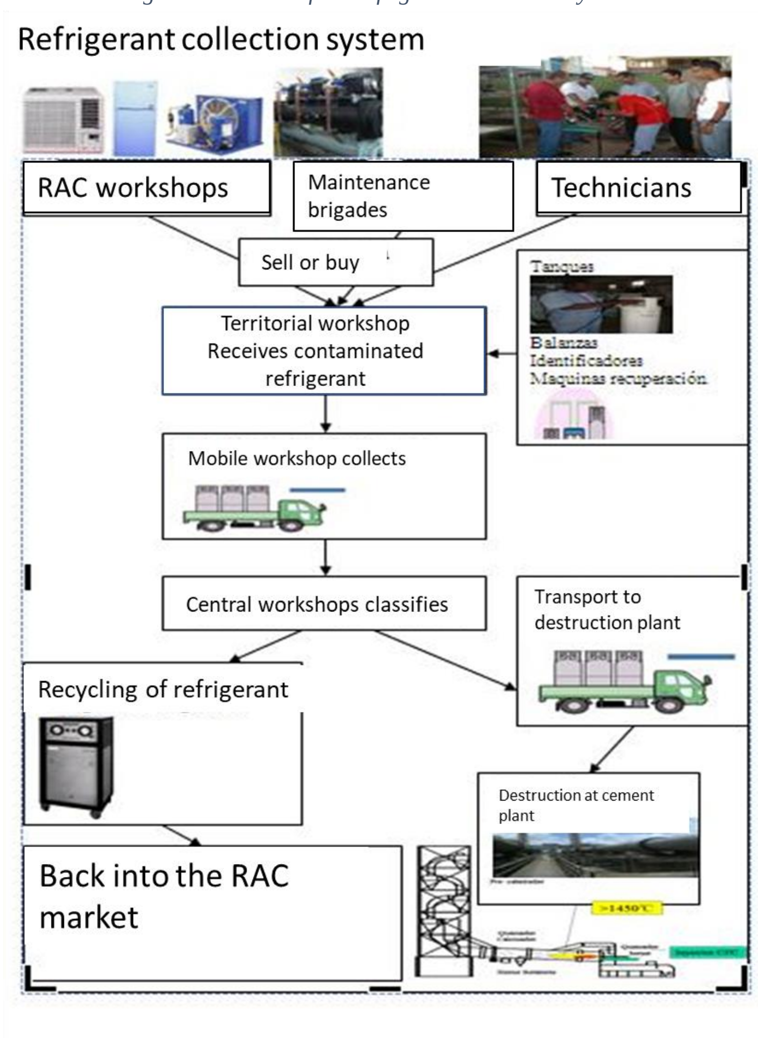
Once the recovered refrigerant is in the collection center, it is identified and its concentration measured, if its reading yields more than 98%, it is further recycled and cleaned in a refrigerant recycling machine, otherwise it will be destroyed in the cement plant.

All this process is registered in authorization books kept for this purpose where type of gas, quantity, origin and destination are registered.

All gases are transported independently of the origin and destination in a specialized vehicle designed for this purpose. The workshops inform the central warehouse when they have significant quantities for the change to collect the stored material.

A scheme of the refrigerant collection system is show below in figure 1.

Figure 1. Scheme of the refrigerant collection system.



4.2 Transport of the recovered refrigerant

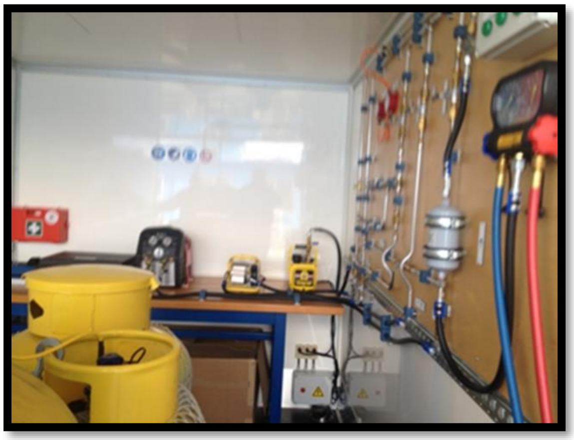
One of the main challenges identified during the design of the project was the transport of the recovered refrigerant to the collection centers and to the destruction facility. To overcome this challenge the project team, led by OTOZ, and with support of the Spanish firm in charge of the design and installation of the destruction facility, MIESA EXPORTACIÓN SL, designed and acquire a specialized vehicle (mobile workshop).

The description and main characteristics of the vehicle for transfer of refrigerants are:

- Type of truck: Single cabin and short bed, closed, adjusted to the size of the equipment that is mounted, without free spaces or storage area.
- There has a rigid structure where the machines for transferring and recovering refrigerants, hose adapters and all electrical connections are mounted.
- Three (3) tanks: a) One (1) of 1-tonne for contaminated refrigerant, b) One (1) of 500 kg and c) One of 200 kg for recovered refrigerants are incorporated into the truck, with safety valve, pressure gauges, manhole for cleaning, oil drain valve, level of volumetric liquid and two (2) half-inch valves of liquid and steam with a maximum working pressure 30 Bar.
- Digital Balance 115v. Heavy, robust, anti-vibration work incorporated into the truck for weighing tanks and cylinders in transport equipment with capacity. 0-150 Kg Precision 0.1 kg.
- High capacity refrigerant transfer machine; Liquid 300 l/min, 110-volt, 3/8-inch sockets. Electric connection.
- High capacity Recovery Machine: Vapor 300 g/min. Liquid 7,500 g/min. 110-volt, 3/8-inch intakes. Electric connection.
- 8 flexible 3m hoses for extra strong high-pressure coolant and 3/8-inch ball valves on one end, SAE 1/2.
- 8 flexible hoses of 3/8 inch alternating red and blue specialized for refrigerants. Maximum operating pressure 600 PSIG.
- 3 flexible hoses of 15 cm. for extra strong high-pressure refrigerant and ½-inch ball valves on one male end and female connection, SAE 3/8.
- 3 flexible hoses of 15 cm. for extra strong high-pressure refrigerant and 3/8-inch ball valves on one end, and both female connections, SAE 1/2.
- With ample space to handle tanks from which the refrigerant is extracted or filled: 30 lb (13.6 Kg); 50 lb (22.5 Kg) and 60 Kg.
- Specifications standards: European standard for the transport and storage of refrigerants.

In the pictures below, an interior view of the mobile workshop can be seen.

Picture 1. Interior of the mobile workshop.



Picture 2. General view of the mobile workshop (Source: OTOZ).

Picture 3. Instruments inside the mobile workshop. (Source: OTOZ).

5. Description of the destruction process

5.1 Selection of the destruction technology

The technology chosen for the destruction of ODS in the demonstration project in Cuba was rotary cement kilns, this is one of the destruction and disposal technologies approved by the parties of the Montreal Protocol (Decision XIV/6, Annex VI: Approved destruction processes)[1].

During the initial phase of the project, a technical team of Cuba visited the Akoh cement plant, part of the group Sumitomo Osaka Cement Co. Ltd. in Japan to analyze the technology. This plant uses as feedstock waste and fuel alternative such as waste plastics, wood, sludge waste treatment plants, urban waste, waste oil, coal ash, used tires and CFCs.

After the visit, the technical team found that it was suitable for the country to adopt this approach for the disposal of ODS, as there were several cement kilns with dry and humid process, and that other technologies were not present in the country requiring high capital costs to set them up.

Rotary cement kilns provide an excellent technical option for the destruction of ODS given specific characteristics such as:

- High flame temperatures which can reach 1800-2000 Cº;
- Long residence times, as a consequence of large kiln size and volumes, which can reach 6 seconds in the kiln per-se;
- No residues are generated in the form of either ashes or scoria.

Given the high temperatures and long residence times, these kilns are ideal media to destroy organic compounds of a high chemical stability such as CFCs and HCFCs. One of the main problems with their destruction is the emissions of acid gases, such as HCl and HF, but they can react with the calcium salts present in the feedstock, coming to form $CaCl_2$ and CaF_2 which become part of the clinker.

On the other hand, chlorine contained in these gases constitutes the main problem given that it can, not only affect the quality of the cement, but also the kiln itself. It is important to have a control ratio to avoid excesses of this gas in the hot gas flux of the kiln, as it could contribute to the unlimited thickening of the crust that adheres to the refractory coating, affecting the interior of the kiln, which can lead to reduced productivity. This effect is significantly more marked in dry process kilns, as they require installations for the development of the calcination stages and synthesis, which contribute to the gases recirculation inside the kiln and therefore they spend more time in direct contact with the solid and cause the volatile elements to increase their concentration as time passes; therefore, the negative effect created by the presence of Cl- and F- becomes increasingly marked.

So, to minimize this effect a cement kiln with a humid process was chosen for the demonstration project.

[1] https://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/976

5.2 Designated local facility

In Cuba there is just one (1) cement plant that uses humid process in its manufacture. This facility, known as the Siguaney Cement Plant of the Grupo Empresarial del Cemento (Cement Business Group) under the Ministry of Construction, is located in the town of Siguaney located in the province of Sancti Spiritus, approximately 300 km to the South-East of Havana.

The cement kiln is 126 m long by 4 m diameter. With a production capacity of 500 ton of Clinker/day, using oil as fuel. The temperatures of operation are 1800-2000 °C in the freeboard and 6 seconds of gasses residence time, under alkaline atmosphere. Chlorine contents are present in the fuel and raw materials. Kiln has not an emission control. Other wastes processed at the kiln are used oils, sludge and obsolete medicines.

6. Construction of the destruction facility

6.1 Selection process of technology supplier

The acquisition of the equipment was contracted to a Spanish company and the assembly was executed by the Cuban part; the start-up was conducted by the Cuban part with support of the Spanish company.

The Company MIESA EXPORTACIÓN SL with address C / San Vicente, 8-48001 Bilbao (BIZKAIA), Spain, was hire as supplier of the project, with the objective of providing engineering, assembly and maintenance services of the equipment and automatic systems needed for the ODS destruction in the cement kiln.

The selection process was conducted by the Cuban Importing Company (EMED) according to the local regulations and processes. During the bidding process, EMED selected the Spanish company as it was the only one that comply with the technical requirements, offered the automatic system requested and agreed to adjust the automation of the gas burning line with the existing kiln in a joint work with designers from the Cuban counterparts as this one was a requirement made by the authorities.

The supplier provided the control panel (automatic cabinets, brand Siemens) and the PLC for the kiln with the whole installation and its accessories, automation of the gas burning line, supply lines (water, energy, air) and sanitary material for the swimming pool area.

In addition, all the necessary equipment for the transfer of stored gas, recovery machines, refrigerant gas identifiers, gas cylinder to recover, scales for weighing the gas and other supplies and accessories, were provided by the supplier.

6.2 Civil work at the cement plant.

It was necessary a building annexed to the area of the kiln automatic controls to locate the acquired equipment, the pool area of the cylinders, and a reception and storage area for the full and empty refrigerant cylinders.

It is also necessary to point out that in Cuba, the Environmental Law 81 of the Ministry of Science, Technology and Environment (CITMA) requires for this type of project the request for an environmental license during its execution, start-up and operation. This license mentions actions and activities of mandatory compliance.

It was also necessary to install a fire prevention system and certify it according to the Cuban norms for this type of installation; it is also part of the aforementioned conditions of the environmental license granted.

The construction process of the civil work is show in the pictures below.

Picture 4.Project team during the construction of the ODS disposal plant. (Source: OTOZ)

Picture 5. Construction of the ODS disposal plant (Source: OTOZ).

Picture 6. Installation of the control panels. (Source: OTOZ)

Picture 7. Assembly of supply lines (Source: OTOZ)

Picture 8. Storage area for cylinders (Source: OTOZ).

Picture 9. General view of the civil works of the disposal plant. (Source: OTOZ).

7. Description of the destruction process

7.1 Reception, storage and handling of ODS cylinders.

The cylinders with unwanted ODS arrive at the plant from two points:

- The stored ones of the Energy Program in Havana City.
- From the collection centers of the different part of the country.

The cylinders of CFCs and HCFCs are received in the plant and stored in a covered area destined for this purpose, at room temperature. There is a scale for the weighing of the same is identified the substance contained, as well as wheelbarrow to transport them.

All these processes are enabled in a registry to keep track of the amount and kind of ODS destroyed.

7.2 Station for preparing and injecting the ODS from the cylinders to the cement kilns.

As mentioned before, it is very important to control the injection ration of ODS into the cement kiln. The injection is control through an automatic process that was designed for the destruction of CFC and HCFC and its parameters are adjusted automatically in the control cabinet after deciding the destruction of one or the other.

In ODS dosing station, the cylinders are placed inside a pool at a temperature of 30°C, in order to facilitate the extraction of the vapor phase from the cylinder; then the cylinders are connected by threaded hoses and their corresponding valves to a manifold that allows the simultaneous coupling of several bullets to the kiln feeding system, to achieve the strict control of the dosing of the gas to the kiln. There is a regulating valve for pressure and flow. It also has an emergency valve for the automatic disconnection of the supply to the kiln in case of unexpected stops or failures in the operation.

In the case of CFC-11 (which is liquid at room temperature), air is injected into the cylinders and heated at its base to achieve evaporation and in this phase (gas) is introduced into the kiln.

The installation is equipped with a vacuum pump that is used sporadically to extract the gases from

the cylinders when they have little content. There is a filter to separate the oil that may come with the gas, with the aim of not embedding in the pipes, the latter are coated with insulating material to maintain the temperature. In addition, it consists of a vaporizer to heat the water of the pool when the temperature is below 30°C, controlled by a temperature sensor facilitating the gas output of the cylinders.

The gas injection system has a complex system of valves to ensure that the quantities that are injected into the kiln are correct. The CFCs or HCFCs are injected at the entrance of the primary air fan of the kiln burner, by means of a 0.5-inch pipe. It is important to bear in mind that the feeding of CFCs, or HCFCs to the kiln, is only done when the cement is being produced and when this process is stable.

For each type of refrigerant, a kiln dosage is guaranteed, as it is key to maintain the quality of the cement so the quantities of ODS to be destroyed are according to the calculation of the production load of the cement kiln. Due to the age of the kiln a maximum amount of 0.1 kg per tonne of cement is injected, which guarantees the complete destruction of the gases.

The installed system has a nominal destruction capacity of 10 tons/year, being the destruction capacity related to the production of cement.

8. Start-up and operation of the destruction plant

The destruction plant in Siguaney cement plant started in October 2015, but even before the commissioning of the disposal plant, it has faced different challenges that has delayed its start-up and limited its operation which has impacted the CFC and HCFC destroyed.

Among the challenges faced were:

a) Delay in the approval of the environmental license: CFC and HCFC were two new type of waste to be treated in the cement kiln.
b) Delay in the commissioning of the civil works and importation process of the system.
c) Requirement to wait for a maintenance window in the kiln to conduct the trials and start the system.
d) Breakage of parts of the technological process of cement manufacturing, such as valves, the mills, refractory bricks from the kilns. This goes through lengthy import procedures into the country.
e) Problems with the supply chain of the raw material, for the types of cement that it produces.
f) Problems in the country with the supply of fuel.
g) Problems with the supply of water to the factory, due to the drought in that area of the country.
h) Extension of technological breaks more than the time foreseen by the schedule.

9. Amount of ODS destroyed

The amount of ODS destroyed is presented in the next table; The low quantities destroyed respond to problems listed before and to the low production level of the plant, which is in line with the economic activity of the country.

Table 1. Amount destroyed by the ODS disposal plant.

Year	ODS destroyed	Amount (ton)
2015	R-12	0.308
	R-22	0.215

Year	ODS destroyed	Amount (ton)
2016	R-11	0.268
	R-12	0.259
2017		0.000
2018	R-12	0.695
total		**1.745**

During the end of 2016 and 2017, there were a severe drought in the area, so the complete operation of the cement plant stopped as it is based in a humid process; as the destruction of ODS is linked to the manufacture of cement, there was not destruction of ODS in 2017.

Currently the disposal plant is in operation and it is expected that continues destroying the collected ODS under Energy Programme and the implementation of the HCFC phase out management plan. OTOZ estimates that more than 80 tonnes of refrigerant are stored in a warehouse in Havana, guarded by the Ministry of Internal Trade (MINCIN), who is responsible for its storage, transportation and destruction in the factory.

10. Operation of the collection system

A refrigerant recovery and collection systems is in place, it is in charge of the Ministry of Internal Commerce (MINCIN), which coordinates the operation of the municipal and territorial workshops that conform the system. The MINCIN is also in charge of the mobile workshop used to transport the collected refrigerants between the different centers and the disposal plant.

In Cuba, transportation is a challenge, so the mobile workshops designed and acquired by the project is a key tool to complete the sound management of refrigerant within the country.

However, the collection system faces some challenges, such as:

- The smaller workshops do not deliver the amounts collected to the provincial centers.
- Many of the smaller workshops do not have the appropriate equipment for the collection of refrigerants.
- Limit the mixture of refrigerants at the time of recovery.
- The destruction of refrigerant involves a payment for its disposal to the cement plant. The cement company calculated the cost of destruction of $ 6 per kilo.

11. Challenges and lesson learnt during project implementation

11.1 Challenges

Some of the challenges faced by the project during its implementation were:

- Lack of installed capacity in the smaller workshops to collect refrigerant.

- The installed controls of the cement kiln were quite old, so it was required additional training to kiln operators and to adapt solutions to make it work between the obsolete technology of the cement plant and the state-of-the-art technology of the automatic controls of the assembled disposal system.
- Breakage of parts of the plant that was necessary to import during the project that stopped the start-up process extending the project implementation time.
- Times of delay in the fuel supply of the plant due to country problems.
- Delay caused by the water supply in the territory caused by a severe drought. Other sectors of the industry and the population were prioritized for the water supply.
- Delay in the hiring and importation of resources by the Importing Company, resulting in delays in the physical and financial execution of the project not foreseen in the work plan.
- Delay by the Entity responsible for the recovery and transportation of refrigerant gases in implementing its technical and financial execution plan.
- Difficulties in the identification of laboratories available in Cuba for conducting a dioxins and furans analysis and difficulties in identifying laboratories abroad for contracting the analysis of these samples (There is no laboratory in Cuba for the analysis of this type). There are not the necessary sample collection points in the discharge chimney for the collection of the sample.

11.2 Lesson learnt.

The implementation of the project left some valuable lessons, such as:

- The selected technology of destruction of gases in cement plant depends on industrial processes, (these gases are injected into the kiln in the process of making cement, when this process is stopped, the destruction of gases is stopped and the scheduled schedule.
- It takes time for the necessary training of the specialists who receive the new technology.
- The coordination between the different parties or institutions involved in the project is complex and requires a lot of time. It is needed to be systematically checked, to resolve the difficulties that arise during execution and to monitor the progress of the tasks.
- The part that receives the new technology, in this case the cement plant, sometimes due to breakage, due to the non-existence of raw material in time and/or due to an increase in the number of unplanned technological breaks, lengthens the project implementation schedule, resulting in delays of the planned activities.
- Even if there is collected ODS waste in the country, the logistical arrangements for its transportation to the destruction plant are as important as the destruction plan itself.
- To adapt new controls and devises to an existing plant, especially to one with several years in operation, carries difficulties and delays. It is important to consider this parameter when selecting the location of a destruction facility.

附件三

突尼斯政府与多边基金执行委员会就减少氟氯烃消费量所达成的最新协定当中将包含的文本
（为便于参考，相关变更部分以黑体显示）

16. 本项最新协定取代突尼斯政府与执行委员会在执行委员会第七十二次会议上所达成的协定。

附录 **2-A**：目标及供资

行	细目	2014 年	2015 年	2016 年	2017 年	2018 年	2019 年	2020 年	总量
1.1	《蒙特利尔议定书》附件 C 第一类物质的削减时间表（ODP 吨）	40.70	36.63	36.63	36.63	36.63	36.63	36.63	暂缺
1.2	附件 C 第一类物质的最大允许消费总量（ODP 吨）	40.70	36.63	36.63	36.63	34.60	34.60	34.60	暂缺
2.1	牵头执行机构（联合国工业发展组织）商定供资额（美元）	**376,920**	**0**	**71,038**	**0**	**0**	**57,500**	**0**	**505,458**
2.2	牵头执行机构的支持费用（美元）	**26,384**	**0**	**4,973**	**0**	**0**	**4,025**	**0**	**35,382**
2.3	合作执行机构（联合国环境规划署）商定供资额（美元）	**30,000**	**0**	**55,000**	**0**	**0**	**15,000**	**0**	**100,000**
2.4	合作执行机构的支持费用（联合国环境规划署，美元）	**3,900**	**0**	**7,150**	**0**	**0**	**1,950**	**0**	**13,000**
2.5	合作执行机构（法国）商定供资额（美元）	**38,000**	**0**	**38,000**	**0**	**0**	**19,000**	**0**	**95,000**
2.6	合作执行机构的支持费用（法国，美元）	**4,940**	**0**	**4,940**	**0**	**0**	**2,470**	**0**	**12,350**
3.1	商定供资总额（美元）	**444,920**	**0**	**164,038**	**0**	**0**	**91,500**	**0**	**700,458**
3.2	支持费用总计（美元）	**35,224**	**0**	**17,063**	**0**	**0**	**8,445**	**0**	**60,732**
3.3	商定费用总计（美元）*	**480,144**	**0**	**181,101**	**0**	**0**	**99,945**	**0**	**761,190**
4.1.1	根据本协定商定实现逐步淘汰的 HCFC-22 总量（ODP 吨）								9.26
4.1.2	先前核准的项目中实现逐步淘汰的 HCFC-22 量（ODP 吨）								0
4.1.3	符合资助条件的 HCFC-22 剩余消费量（ODP 吨）								29.75
4.2.1	根据本协定商定实现逐步淘汰的 HCFC-141b 总量（ODP 吨）								1.34
4.2.2	在先前核准的项目中实现逐步淘汰的 HCFC-141b 量（ODP 吨）								0
4.2.3	符合资助条件的 HCFC-141b 剩余消费量（ODP 吨）								0.27
4.3.1	根据本协定商定实现逐步淘汰的 HCFC-142b 总量（ODP 吨）								0
4.3.2	在先前核准的项目中实现逐步淘汰的 HCFC-142b 量（ODP 吨）								0
4.3.3	符合资助条件的 HCFC142b 剩余消费量（ODP 吨）								0.04
4.4.1	根据本协定商定实现逐步淘汰进口预混多元醇中所含 HCFC-141b 的总量（ODP 吨）								0
4.4.2	将在先前核准的项目中实现逐步淘汰进口预混多元醇中所含的 HCFC-141b 量（ODP 吨）								0
4.4.3	符合资助条件的进口预混多元醇中所含的 HCFC-141b 剩余消费量（ODP 吨）								5.02

* 继撤销空调行业计划以及相关项目管理和机构支持费用（包括机构支助费用在内的 1,206,919 美元）之后，在第八十三次会议上作出了修订。

Annex IV

DEMONSTRATION PROJECT TO DEVELOP WINDOW AND PACKAGED AIR-CONDITIONERS USING LOWER-GWP REFRIGERANT IN SAUDI ARABIA

FINAL REPORT

Submitted by:

The World Bank

February 2019

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Executive Summary

This demonstration project was conducted in response to decision 76/26 of the Executive Committee of the Multilateral Fund (May 2016 meeting), asking for the development of window and packaged air-conditioners in Saudi Arabia using alternative refrigerants with lower global warming potential (GWP). The Multilateral Fund allocated US $796,400 to two companies: Saudi Factory for Electrical Appliances Co. Ltd. would develop window AC prototypes while PETRA Engineering Industries (KSA) Co., Ltd would develop packaged air-conditioners. The window AC component was later withdrawn from the project after approval.

The project was carried out at PETRA Engineering Industries Company Saudi Arabia and consisted of designing, manufacturing and testing commercial air-cooled chillers using low GWP refrigerants R-32 and R-290. A total of six units were built (3 for R-290 and 3 for R-32) with cooling capacities of 40 kW, 70 kW and 100 kW. The design of the products was in accordance with the safety requirements of ISO-5149 and IEC-60335-2-40, given that both R-32 and R-290 are flammable refrigerants.

The air-cooled chillers were tested at a standard ambient condition of 35^{o}C as well as at high ambient temperatures of 46^{o}C and 52^{o}C. Results were compared to the baseline refrigerant R-410A, which for this project was tested as a drop-in to R-32. In all cases, both R-32 and R-290 units showed similar or better performance (efficiency and cooling capacity) than R-410A. However, design changes necessary to mitigate the risk of using R-290 (highly flammable refrigerant) resulted in a significant increase in the cost of the chillers. The cost increase was minimal in the case of the mildly flammable refrigerant R-32.

The project demonstrated that commercial air-cooled chillers can be successfully designed and operated with low GWP alternative refrigerants such as R-32 and R-290 for a variety of cooling capacities and operating conditions (including high ambient temperatures). Requirements of current international safety standards did not limit the amount of flammable refrigerants used for this particular project because of the specific application and location of the chillers. However, it should be noted that in most commercial applications, the use of highly flammable refrigerants such as R-290 is severely restricted by current safety standards, which is not the case for mildly flammable refrigerants like R-32.

It is believed that findings from this project will help developing countries with high ambient temperature conditions accelerate their adoption and implementation of the Kigali Amendment.

I. Introduction

In 2007, the Parties to the Montreal Protocol agreed to accelerate the phase-out schedule for hydrocholorofluorocarbons (HCFCs) in developing countries. More specifically, the Parties agreed to a freeze consumption in 2013 (based on average consumption of 2009-2010) followed by reductions of the baseline by 10%, 35%, 67.5% and 97.5% for years 2015, 2020, 2025 and 2030 respectively allowing 2.5% to continue during the period 2030 - 2040 as a service tail and a complete phase out by 2040.

The Article 5 parties, especially those in high-ambient conditions, face serious challenges in finding out suitable lower-GWP alternatives to replace HCFC-22 in air-conditioning applications while maintaining minimum energy performance standards. Although the Executive Committee has funded demonstration project to promote low-GWP alternatives for the A/C industry in high-ambient countries, there are gaps in testing lower-GWP refrigerants: R-32 and R-290 in window and packaged air-conditioners.

To address this gap, the Executive Committee of the Multilateral Fund (MLF)[1] at its 76th meeting in May 2016 approved a demonstration project in Saudi Arabia to develop window and packaged air-conditioners using low GWP alternative refrigerants. The MLF allocated US $796,400, plus agency support costs of US $55,748 for the World Bank. Funding from the Multilateral Fund has been specifically allocated to the two air-conditioning manufacturers in Saudi Arabia. Saudi Factory for Electrical Appliances Co. Ltd. would develop window AC prototypes while PETRA Engineering Industries (KSA) Co., Ltd would develop packaged air-conditioners.

After the approval of the project, Saudi Factory for Electrical Appliances Co. Ltd. did not participate in the development of window AC prototypes without providing any official explanation. The fund[2] related to the development cost of window AC prototypes has been returned to MLF at the 82nd meeting. The development of window AC using lower GWP refrigerant is expected to be covered by one of AC manufacturers as indicated by UNIDO at the 76th meeting.

PETRA Engineering Industries Company Saudi Arabia (hereinafter referred to as "PETRA") confirmed its commitment to develop the packaged air-conditioners.

Objectives

The main objective of the demonstration project was to design, develop and test the performance of air-cooled chillers (integrated chiller and air-handling unit) using low GWP refrigerants R-32 and R-290 at 3 cooling capacities: 40 kW, 70kW, and 100 kW.

Both R-32 and R-290 are environmentally friendly refrigerants, with zero ozone depletion potential (ODP) and low GWP. Both refrigerants have excellent thermophysical properties and are considered good alternatives to R-410A (and R-22). However, both are flammable and

[1] Decision 76/26, May 24, 2016
[2] US $220,000 plus agency support costs of US $15,400

necessitate design modifications of the baseline R-410A product. Some properties of R-32, R-290 and R-410A are summarized in Table 1 below.

In order to achieve the project's objectives, PETRA conducted the following tasks:

- Review R-32 and R-290 refrigerant properties.
- Integrate the refrigerant properties in the design software simulation model.
- Use the software simulation model to design the evaporator and condenser coils including circuiting, number of rows, tube diameters and fin spacing.
- Validate the simulation results through actual tests, before producing the prototypes.
- Select the main components (evaporator, condenser, fans and compressor) to achieve similar or better performance than the baseline R-410A unit. The design took into account specific characteristics of each refrigerant such as higher operating pressures and discharge temperatures of R-32.
- Address safety measures by considering the risk associated with the flammability of both R-32 (mildly flammable) and R-290 (highly flammable). The design of the units was consistent with the requirements of ISO-5149 for refrigerant quantities and IEC-60335-2-40 for electrical components and markings.

Table 1: Properties of R-32, R-290 and R-410A

Parameters	R-32	R-290	R-410A
Chemical name	Difluoromethane	Propane	-
Chemical formula or mass composition	CH_2F_2	$CH_3CH_2CH_3$	R-32/R-125 (50%/50%)
Safety group (ASHRAE 34)	A2L	A3	A1
Lower Flammability Limit (Kg/m^3)	0.307	0.038	-
Boiling point (°C)	-51.65	-42.11	-51.44
Critical Temperature (°C)	78.11	96.74	71.36
ODP	0	0	0
GWP $_{(AR4)}$	675	3	2,088

In total, six prototype units were manufactured: three with R-32 (at cooling capacities of 40 kW, 70 kW and 100 kW), and three with R-290. The units were tested at a standard ambient condition of 35°C as well as at high ambient temperatures of 46°C and 52°C. The results were compared to the baseline R-410A which was tested as a drop-in refrigerant to R-32.

II. Project Implementation

The project consisted of three phases: (1) software development; (2) design and fabrication of the prototypes; and (3) testing.

1. Software Development

New software was developed to simulate the performance of the R-32 and R-290 units. PETRA developed the software in 6 different stages as described below:

a. **Data acquisition** – This stage consisted of acquiring scientific information by reviewing the latest scientific research papers, case studies, etc.
b. **Design** – This is the most critical stage where the evaporator and condenser heat exchanger models are developed. The system's coefficient of performance can be evaluated as a function of the heat exchanger design and various two-phase flow heat transfer and pressure drop for both R-32 and R-290 are investigated.
c. **Implementation** – After the completion of the design phase, the algorithms are developed and translated into programming code language.
d. **Testing** – This is a critical stage in the software development stage. The software is tested to assess if it meets its intended purpose and does what it is supposed to do. Errors are identified and corrected until the software is ready for operational use.
e. **Deployment** – After completing the testing phase, the software is deployed to the technical/application team where it is used by engineers to design products. Any problem when operating the software is recorded and passed on to the support and maintenance team for appropriate action.
f. **Support and Maintenance** – This is the last stage in the life cycle process where modifications are made to the software to correct faults, improve performance or adapt the software to a modified environment.

Finally, the software makes use of a user-friendly interface as shown in Figure 1.

2. Design and Manufacturing of Prototypes

The design of the prototype units presented unique challenges as both R-32 and R-290 are flammable refrigerants. According to ASHRAE 34 [1] or ISO 817 [2], the group safety classification for R-32 is A2L, where "A" stands for lower toxicity and "2L" for lower flammability (i.e. refrigerants with a burning velocity less or equal than 10 cm/s). On the other hand, R-290 has a safety classification A3, where "3" stands for higher flammability.

Several safety features had to be taken into consideration to limit the risk of using flammable refrigerants as described below.

ISO 5149

First, the refrigerant quantities used in the chillers had to be consistent with the requirements of ISO 5149 [3]. This refrigerant charge limit depends on the type of occupancy where the chillers will be installed (i.e. general, supervised or authorized occupancy), the safety classification of the refrigerant, the air conditioning system classification (direct, indirect etc.) and where the refrigerant containing components (i.e. compressors, heat exchangers etc.) are located (outdoor, mechanical room etc.).

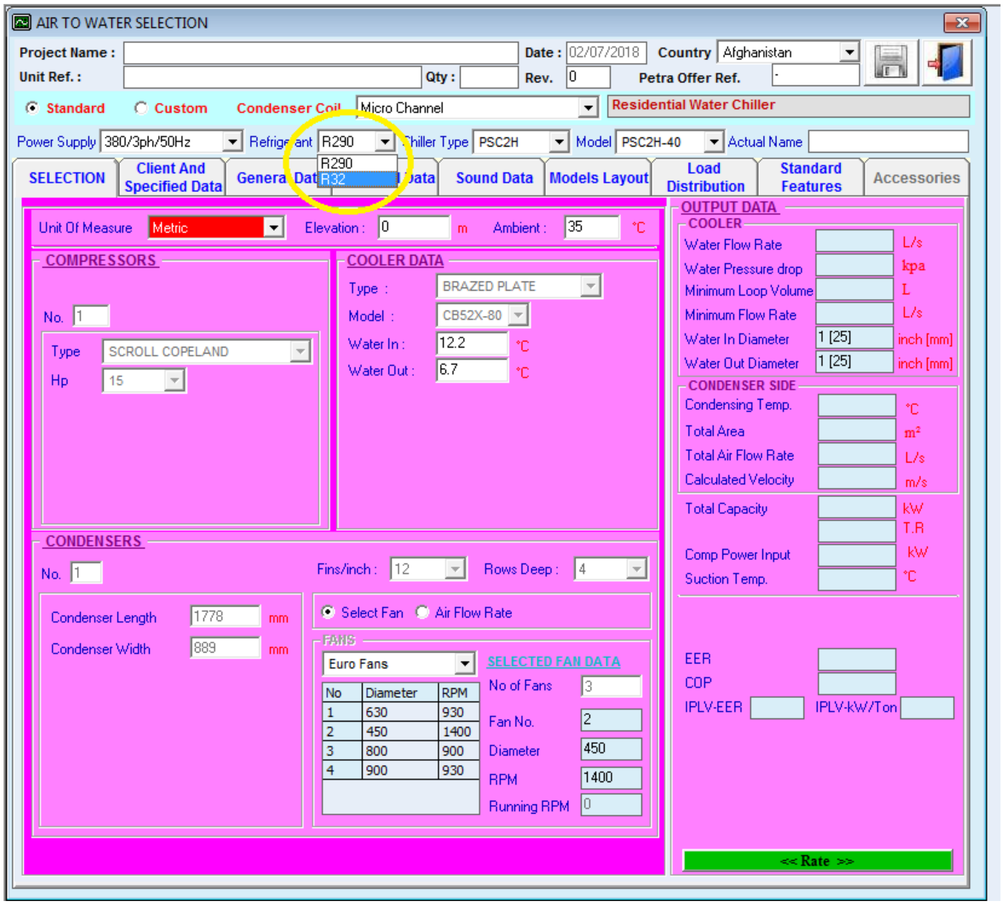


Figure 1: Software User Interface

During product development and testing, the air-cooled chillers were located in PETRA's manufacturing facility (i.e. authorized occupancy). Consequently, according to ISO 5149 there were no refrigerant charge restrictions for both R-32 and R-290. However, had the intended use of the chillers be for general occupancies (such as hospitals, schools etc.), or supervised occupancies (such as office buildings etc.), the amount of flammable refrigerant would have been severely restricted for R-290 because of its highly flammable classification (i.e. "3"), to a point where the chillers would not be able to operate properly.

Based on ISO 5149 and refrigerant charges ranging from 4 – 5.5 kg per circuit (Table 4), the R-290 air-cooled chiller could be used for applications other than human comfort in supervised or authorized occupancies and when the equipment is located in an above ground machinery room. If the charge could be reduced to less than 5 kg per refrigeration circuit, they could be also used in all occupancy categories if the equipment is located in open air such as on the roof top.

On the other hand, the charge limit restriction would have been less constraining for R-32 because of its mildly flammable classification (i.e. "2L"). The following tables show possible applications for each occupancy category and location classification.

Table 2: Possible Applications of R-290 Prototypes

<table>
<tr><th colspan="2" rowspan="2">Occupancy category</th><th></th><th colspan="4">Location classification</th></tr>
<tr><th></th><th>I[3]</th><th>II[4]</th><th>III[5]</th><th>IV[6]</th></tr>
<tr><td rowspan="3">General occupancy “a”: hotels, schools, restaurant</td><td colspan="2">Human comfort</td><td colspan="2">No (charge > 1 kg)</td><td>No[7]</td><td rowspan="9">Yes[8] (charge < 5 kg)</td></tr>
<tr><td>Other applications</td><td>Below ground</td><td colspan="2">No (charge > 1 kg)</td><td>No (charge > 1 kg)</td></tr>
<tr><td></td><td>Above ground</td><td colspan="2">No (charge > 1.5 kg)</td><td>Yes[8] (charge < 5 kg)</td></tr>
<tr><td rowspan="3">Supervised occupancy “b”: Offices</td><td colspan="2">Human comfort</td><td colspan="2">No (charge > 1 kg)</td><td>No[9]</td></tr>
<tr><td rowspan="2">Other applications</td><td>Below ground</td><td colspan="2">No (charge > 1.5 kg)</td><td>No (charge > 1 kg)</td></tr>
<tr><td>Above ground</td><td colspan="2">No (charge > 2.5 kg)</td><td>Yes (charge < 10 kg)</td></tr>
<tr><td rowspan="3">Authorized occupancy “c”: manufacturing facilities</td><td colspan="2">Human comfort</td><td colspan="2">No (charge > 1 kg)</td><td>Yes[10]</td></tr>
<tr><td rowspan="2">Other applications</td><td>Below ground</td><td colspan="2">No (charge > 1.5 kg)</td><td>No (charge > 1 kg)</td></tr>
<tr><td>Above ground</td><td>Yes[11] (charge < 10 kg)</td><td>Yes[11] (charge < 25 kg)</td><td>Yes (no charge restriction)</td></tr>
</table>

Table 3: Possible Applications of R-32 Prototypes

<table>
<tr><th colspan="2" rowspan="2">Occupancy category</th><th colspan="4">Location classification</th></tr>
<tr><th>I</th><th>II</th><th>III</th><th>IV</th></tr>
<tr><td rowspan="2">General occupancy “a”: hotels, schools, restaurant</td><td>Human comfort</td><td colspan="2">Yes[12] (charge < 12 kg)</td><td rowspan="6">Yes (no charge restriction)</td><td rowspan="6">Yes (charge < 60 kg)</td></tr>
<tr><td>Other applications</td><td colspan="2">Yes[13] (charge < 12 kg)</td></tr>
<tr><td rowspan="2">Supervised occupancy “b”: Offices</td><td>Human comfort</td><td colspan="2">Yes[12] (charge < 12 kg)</td></tr>
<tr><td>Other applications</td><td>Yes[13] (charge < 12 kg)</td><td>Yes[13] (charge < 25 kg)</td></tr>
<tr><td rowspan="2">Authorized occupancy “c”: manufacturing facilities</td><td>Human comfort</td><td colspan="2">Yes[12] (charge < 12 kg)</td></tr>
<tr><td>Other applications</td><td>Yes[13] (charge < 12 kg)</td><td>Yes[13] (charge < 25 kg)</td></tr>
</table>

[3] The refrigerating system or refrigerant-containing parts are located in the occupied space

[4] All compressors and pressure vessels are either located in a machinery room or in the open air; coil-type heat exchangers and pipework, including valves, can be located in an occupied space

[5] All refrigerant-containing parts are located in a machinery room or open air

[6] All refrigerant-containing parts are located in the ventilated enclosures

[7] In accordance with occupancy “a” other applications

[8] Only for 40 kW and 70 kW unit with charge not more than 5 kg

[9] In accordance with occupancy “b” other applications

[10] In accordance with occupancy “c” other applications

[11] Room volume larger than 526 m^3 for 70 kW unit, 658 m^3 for 40 kW unit, and 724 m^3 for 100 kW unit

[12] Floor area larger than 19 m^2 for 70 kW unit, 29 m^2 for 40 kW unit, and 34m^2 for 100 kW unit and height of supply vent at 1.8m

[13] Room volume larger than 73 m^3 for 70 kW unit, 90 m^3 for 40 kW unit, and 97 m^3 for 100 kW unit

Occupancy category		Location classification			
		I	II	III	IV
	< 1 person per 10 m^2	Yes[13] (charge < 50 kg)	Yes (no charge restriction)		

Tables 2 and 3 show possible applications of R-290 and R-32 that are germane to the chillers designed for this project. As such, the tables should not be viewed as universally applicable. Designers should always refer to ISO 5149 to ensure compliance with safety requirements.

<u>IEC 60335-2-40</u>

The prototype units were also designed to comply with the marking requirements of IEC 60335-2-40 [4]. These requirements are necessary to warn about the flammability hazard of both R-32 and R-290.

It should be noted that IEC 60335-2-40-2018 has also requirements on refrigerant charge limits, which in some instances may be different than the requirements of ISO 5149. However, given that the IEC standard was published in the first quarter of 2018 when the preliminary design of the units was well underway and almost complete, it was decided to stick with the refrigerant charge limit requirements of ISO 5149 instead.

<u>Prototype Unit Design</u>

A schematic of the 100 kW air-cooled chiller is shown in Figures 2 (general view) and 3 (top and side views). Both R-32 and R-290 units are the same except that scroll compressors were used for R-32 while semi-hermetic compressors were used for R-290 as scroll compressors were not yet available for this refrigerant. All components selected (expansion valves, solenoid valves etc.) were compatible with both R-32 and R-290.

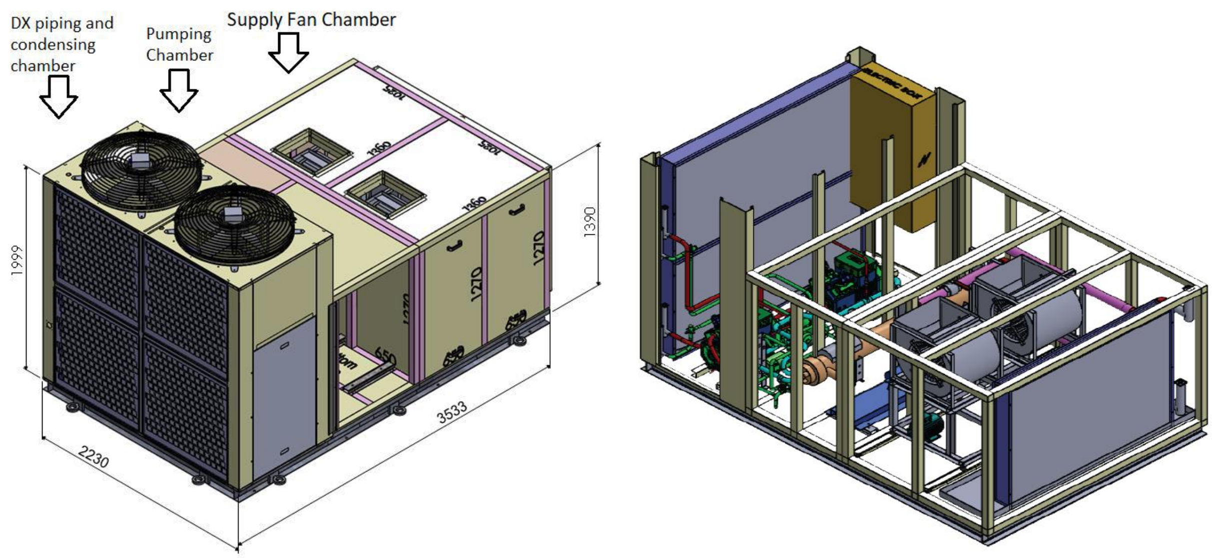


Figure 2: Schematic of 100 kW Prototype Air-Cooled Chiller

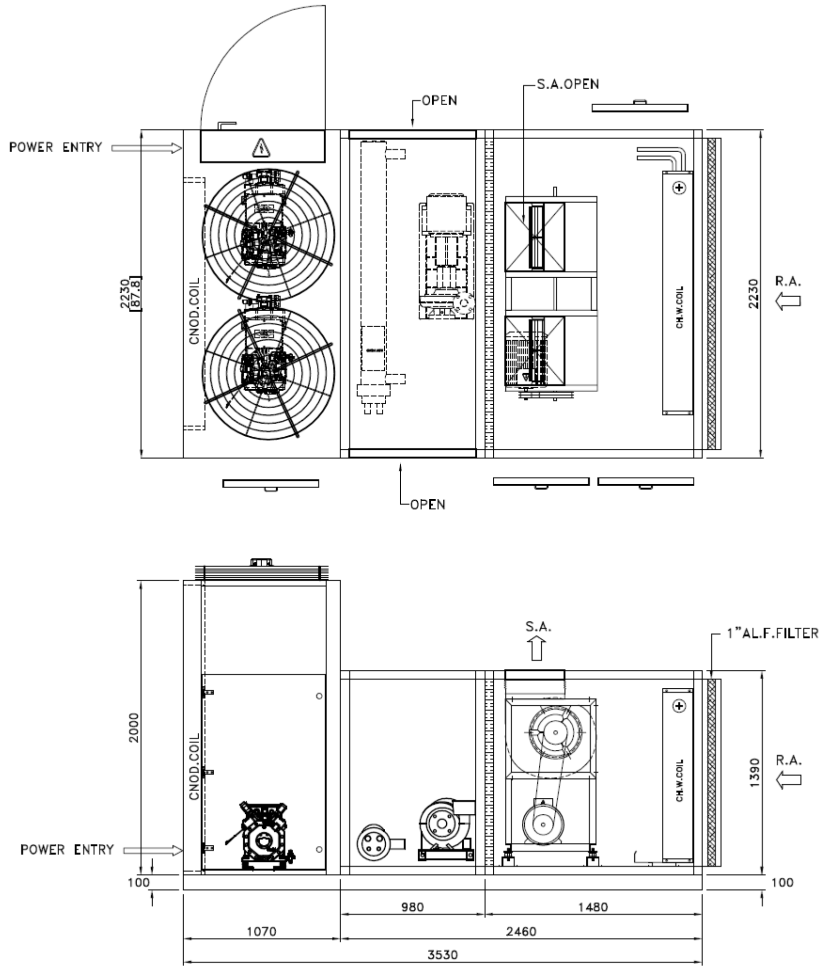


Figure 3: Top and Side Views of 100 kW Prototype Air-Cooled Chiller

As can be seen in the figures, the prototype units are of a hybrid design where the air-cooled chiller is connected with the air handlers in the same cabinet. By using an air-cooled chiller to generate chilled water and circulate it to the air handling unit via a water pump, any refrigerant leakage will be contained in the shell and tube heat exchanger and/or the finned tube cooling coil in the air handling unit so the main supply air stream will be safe from any flammable refrigerant leakage. Furthermore, PETRA separated the compressor and condenser in one chamber and shell and tube heat exchanger in another chamber to further minimize gas leakage to the air handling unit.

A schematic of the 70 kW air-cooled chiller is shown in Figures 4 (general view) and 5 (top and side views). The 40 kW units have the same dimensions but are equipped with only one compressor.

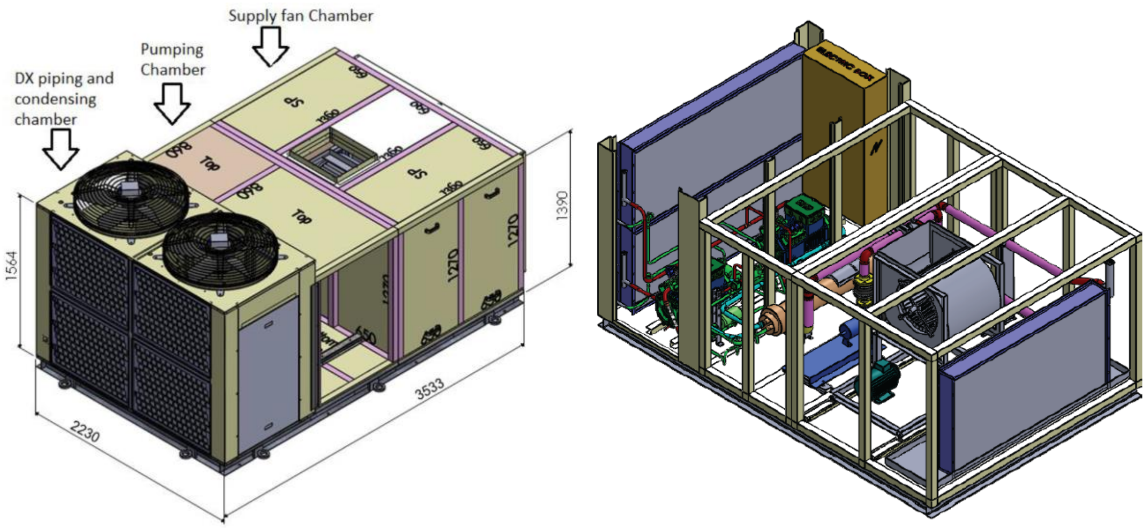


Figure 4: Schematic of 70 kW Prototype Air-Cooled Chiller

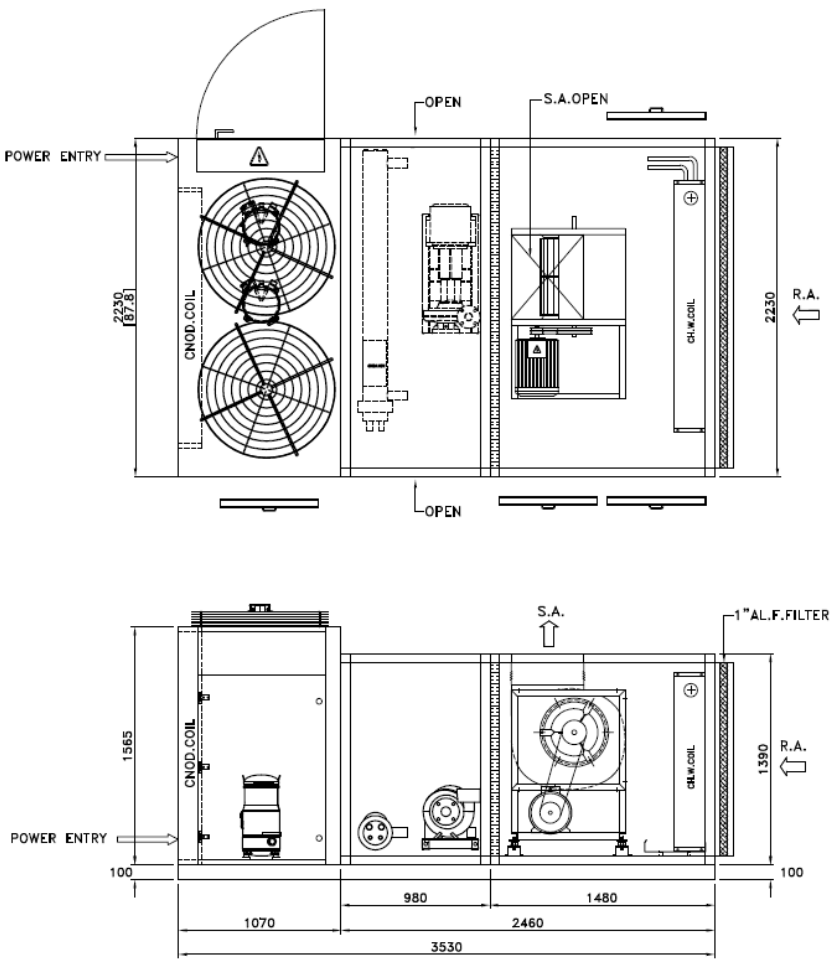


Figure 5: Top and Side Views of 70 kW Prototype Air-Cooled Chiller

Specific Design Features for Flammable Refrigerants

DX piping and condensing chamber

- Reduce number of junction boxes inside the chamber to reduce ignition source.
- Reduce number of welding joints as much as possible to prevent leakage.
- Use of automatic shut-off valves (liquid solenoid valves) to isolate parts of the refrigeration circuit when a leak occurs.
- Use of more than one independent refrigerant circuit on high capacity units to reduce refrigerant losses in case of a major leak.
- For R-290 units, installation of leak detector sensors to detect, in the event of a leak, the concentration of flammable refrigerants and immediately shut off the unit while operating the axial fans only to move the refrigerant out of the unit.

Electrical enclosure

- The electrical enclosure is located on the opposite end of the welding joints of the condenser
- NEMA 4X electrical enclosure is used to provide a degree of protection to unauthorized access and a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects.
- Installation of air flow switches insider the electrical panel to ensure that the panel always has a positive pressure.
- Emergency push button switch on the electrical panel door to immediate disconnect the power.
- Electrical conduits sealed with silicone to prevent flammable refrigerant to enter the enclosure in case of leakage.
- For the location classification and requirement according ATEX such as Class 1, Division 1, Group A, B, C, or D as defined in NFPA 70, the prototype can be fitted with NEMA 7 enclosure.

Other Design Features

- Electrical safety capsule on both discharge and suctions side of the compressor to protect the compressor and refrigeration system from unsafe high and low pressure conditions. A pressure relief valve is installed as mechanical protection to control high excessive pressure as additional protection to electrical mechanical capsule. This is particularly important for high ambient temperature countries like Saudi Arabia.

Finally, all prototype units were designed to meet the minimum energy efficiency standards currently in place in Saudi Arabia [5].

Prototype Units

Petra manufactured 6 prototype units, 3 units using R-32 at cooling capacities of 40 kW, 70 kW and 100 kW, and 3 other units using R-290 (same cooling capacities), some are shown in the following figures.

Figure 6: Prototypes

Figure 7: R-32 Prototype with Markings

Figure 8: R-32 Unit with Scroll Compressor

Figure 9: R-290 Unit with Semi-Hermetic Compressor

Figure 10: R-290 Leak Sensor

Figure 11: NEMA 7 Electrical Panel Upgrade

Refrigerant Charge Amounts

Each prototype unit was charged with the amount of refrigerant needed to achieve suitable superheat and sub-cooling temperatures. Table 4 shows the refrigerant charge amounts for each unit including the baseline R-410A.

Table 4: Total Refrigerant Charge Amounts (kg) per Unit

Capacity	No. of refrigeration circuit	R-410A	R-32	R-290
100 kW	2	16	12	11
70 kW	2	12	9	8
40 kW	1	6.5	5.5	5

3. Testing

After completing the production of the six prototype units, they were installed and tested one by one in PETRA's testing facility. PETRA's testing facility has a total area of more than 840 m^2 and is fully equipped to accurately test the units according to AHRI and ASHRAE industry standards. The facility has a thermal room capable of testing air-cooled chillers at various water flow rates and ambient temperatures. The facility has also a sound room equipped with instruments capable of measuring sound pressure levels.

Test Procedure

The test setup was prepared according to AHRI 550/590 [6] as shown in Figure 12, with air flow measurement station to measure air flow rate and air sampler tree to measure ambient, return and supply air dry and wet bulb temperatures.

Figure 12: Unit Test Setup

The tests involved measurements of net capacity (kW or Btu/h) and efficiency (COP in W/W or EER in Btu/W.h) when operating under specified design conditions according to AHRI 550/590, and were carried out under steady state conditions within the tolerances specified in the procedure.

All tests were conducted in the calorimeter laboratory to enable ambient and return air temperatures at conditions shown in Table 5 below.

Table 5: Testing Temperature Conditions (^{o}C)

Rating conditions	Indoor section		Outdoor section	
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb
T_1	27.0	19.0	35.0	24.0
T_3	29.0	19.0	46.0	24.0
T_3^+	29.0	19.0	52.0	24.0

<u>Laboratory Modifications for Flammable Refrigerants</u>

PETRA made minor modifications to its laboratory to safely handle and test flammable refrigerants. More specifically, PETRA added an alarm panel to detect R-290 (Figure 13) and control the exhaust fan in case the concentration of the refrigerant in the laboratory suddenly increases.

Figure 13: Control Alarm Panel and R-290 Sensors

III. Performance Results

Figure 14 to Figure 16 show variations in Energy Efficiency Ratio (EER) and cooling capacity for the 40 kW, 70 kW and 100 kW prototypes for refrigerants R-290, R-32 and R-410A at three ambient temperatures of 35°C, 46°C and 52°C.

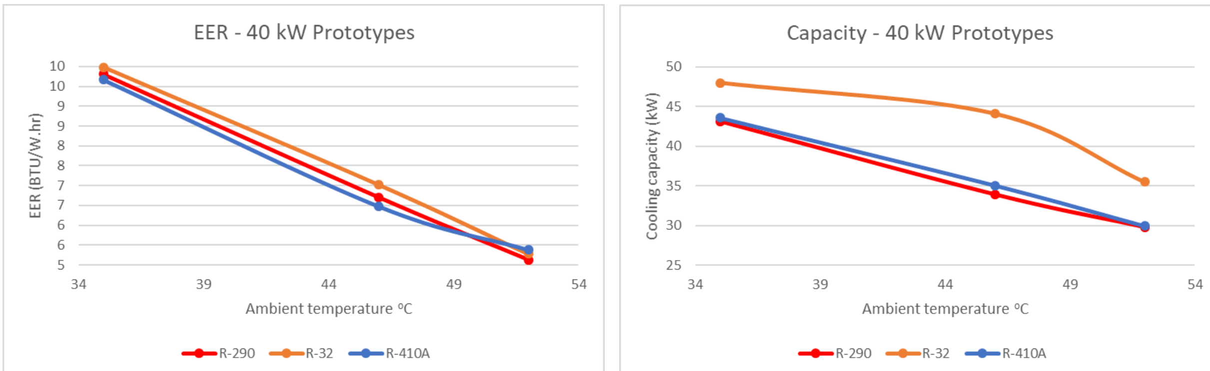


Figure 14: EER and Cooling Capacity at Various Ambient Temperatures – 40 kW Prototypes

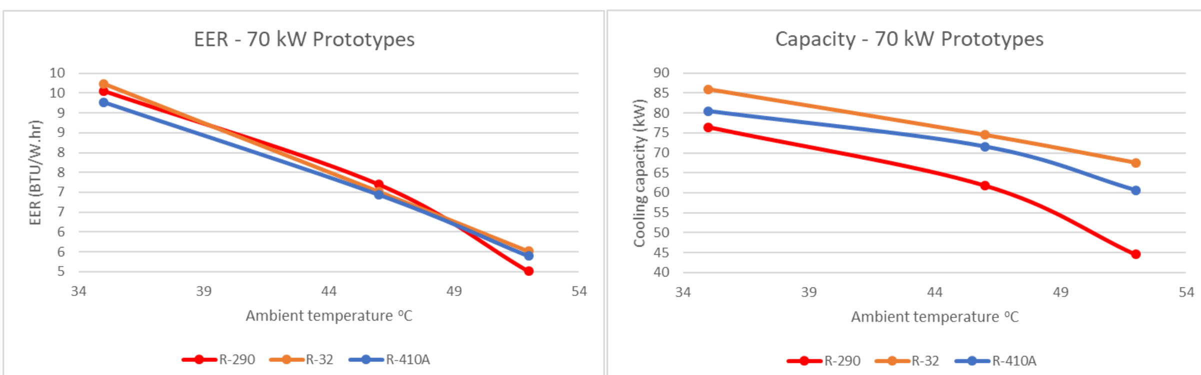


Figure 15: EER and Cooling Capacity at Various Ambient Temperatures – 70 kW Prototypes

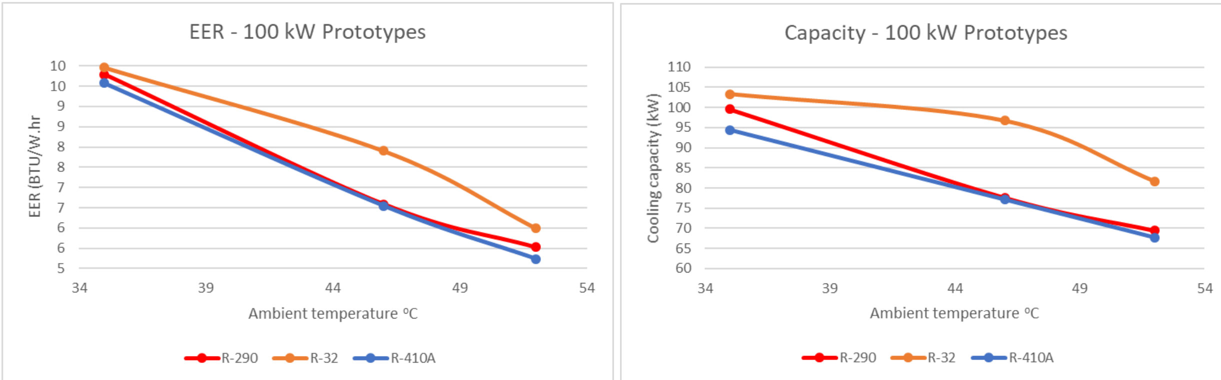


Figure 16: EER and Cooling Capacity at Various Ambient Temperatures – 100 kW Prototypes

As expected, all refrigerants experienced degradation in Energy Efficiency Ratio (EER) and cooling capacity when the ambient temperature increases. When comparing EER, both R-32 and R-290 had slightly better performance than the baseline R-410A at T1 and T3 condition but R-32 EER is lower than R-290 and R-410A at 52°C condition. The only exception is the 100 kW prototype where R-32 has better EER than both R-290 and R-410A at all testing conditions. In terms of cooling capacity, all R-32 prototypes have higher capacity than both R-290 and R-410A at each testing conditions. Comparing cooling capacity of R-410A and R-290 prototypes, the 40 kW and 100 kW have similar cooling capacity while the 70 kW R-410A has higher capacity than R-290 prototype. It should be noted that the performance of R-290 could be attributed to the semi-hermetic compressors which, in general, are less efficient than the scroll compressors used with R-32 and R-410A.

Figures 17, 18 and 19 illustrate the low GWP refrigerants' relative performance to the baseline R-410A for the 100 kW prototypes at the ambient temperatures of 35°C, 46ºC and 52ºC respectively. These figures give a better visualization of the performance of R-32 and R-290 relative to the baseline R-410A. Results in the upper right quadrant of the chart indicate a better efficiency and a better cooling capacity than R-410A. As can be seen from the figures, R-32 experienced a higher capacity and efficiency than R-410A for all three ambient temperatures. On the other hand, the R-290 prototype's performance was very similar to R-410A. As mentioned before, with better compressors, R-290 would have performed better. It should be stressed again that R-410A was tested as a drop in to R-32 and that the unit was not optimized for that refrigerant. Detailed test reports are included in Appendix A.

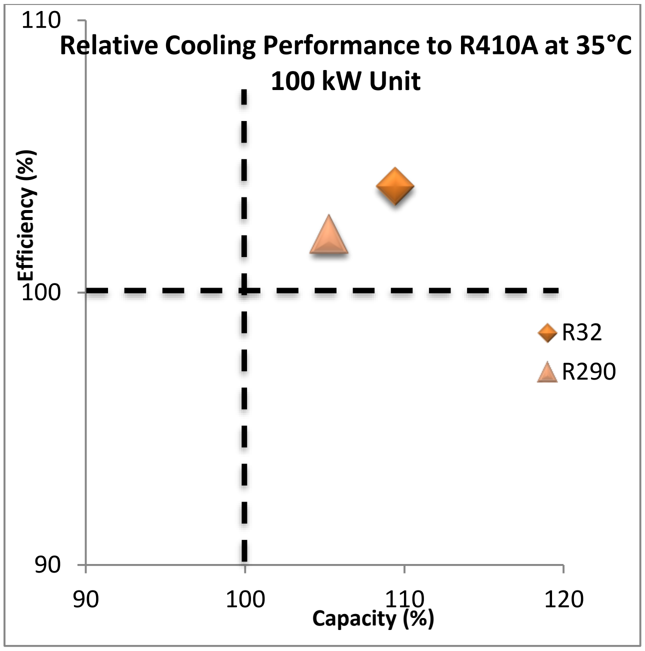


Figure 17: Low GWP refrigerants relative performance to R-410A at 35°C – 100 kW Prototypes

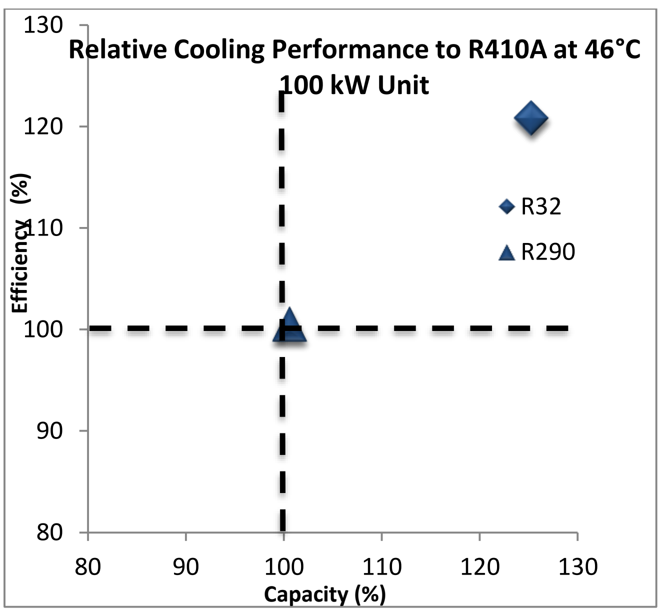


Figure 18: Low GWP refrigerants relative performance to R-410A at 46°C – 100 kW Prototypes

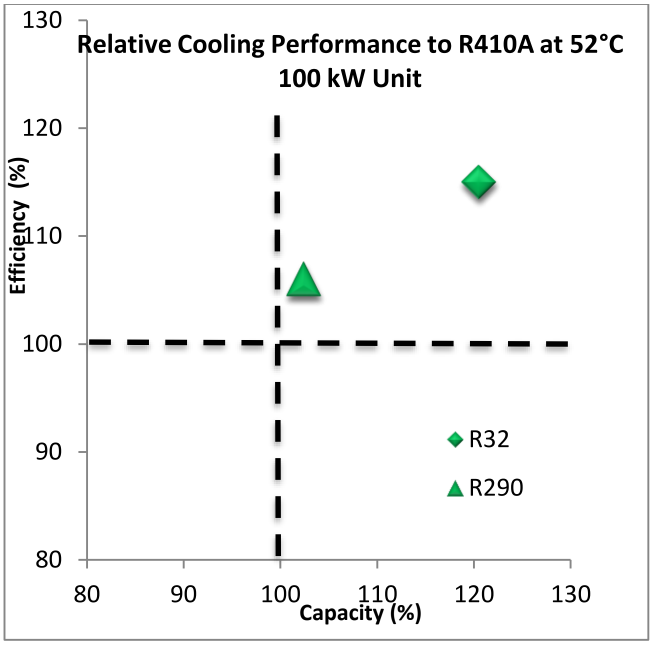


Figure 19: Low GWP refrigerants relative performance to R-410A at 52°C – 100 kW Prototypes

IV. Cost Analysis

An analysis was conducted to compare the cost of the low GWP alternative refrigerants and the major components of the chillers to the baseline R-410A. Tables 6, 7 and 8 indicate that the cost of charging the units with R-290 is 25 to 44% higher than R-410A. On the other hand, the cost of charging R-32 is about 50 to 57% less. The higher cost of R-290 is attributed to a weak demand for this refrigerant in the GCC countries and in particular Saudi Arabia.

Table 6: Cost Comparison of Refrigerant – 100 kW Unit

	R-410A	**R-32**	**R-290**
Refrigerant charge (kg)	16	12	11
Charge ratio to R-410A (%)		75%	68.8%
Unit cost ($/kg)	6.55	4.44	12.25
Cost of Refrigerant ($)	104.8	53.33	134.75
Cost ratio to R-410A (%)		50.88%	128.58%

Table 7: Cost Comparison of Refrigerant – 70 kW Unit

	R-410A	**R-32**	**R-290**
Refrigerant charge (kg)	12	9	8
Charge ratio to R-410A (%)		75%	66.7%
Unit cost ($/kg)	6.55	4.44	12.25
Cost of Refrigerant ($)	78.6	40.0	98.0
Cost ratio to R-410A (%)		50.89%	124.68%

Table 8: Cost Comparison of Refrigerant – 40 kW Unit

	R-410A	R-32	R-290
Refrigerant charge (kg)	6.5	5.5	5
Charge ratio to R-410A (%)		84.6%	76.9%
Unit cost ($/kg)	6.55	4.44	12.25
Cost of Refrigerant ($)	42.58	24.42	61.25
Cost ratio to R-410A (%)		57.35%	143.85%

Table 9 compares the cost of major components of the 100 kW chiller using R-32 and R-290 to the baseline R-410A. The last column in the table reflects the cost of the components designed to meet the European Directive 2014/34/EU also known as "ATEX Equipment Directive" [7]. The ATEX Directive covers equipment and protective systems intended for use in potentially explosive atmospheres. It specifies safety requirements and conformity assessment procedures that are to be applied before products are sold on the EU market.

Table 9: Cost Comparison of Major Components - 100 kW Unit (US $)

Major Components – 100 kW Unit	R-410A Unit (baseline)	R-32 Unit	R-290 Unit	R-290 Unit with ATEX Components
Compressor (2)	1,821	1,821	6,286	10,686
Condenser coil	2,560	2,560	2,560	2,560
Evaporator heat exchanger	1,829	1,829	1,829	1,829
Water Pump, water coil and supply fan	6,691	6,691	6,691	10,036
Expansion valve (2)	123	123	196	196
Electrical panel and cables	2,054	4,414	4,414	13,242
Piping (2)	693	640	693	693
Pressure relief valve (2)	275	275	246	246
Filter drier (2)	275	275	275	275
Solenoid valve (2)	156	156	156	467
Leak detector R-290 (2)	0	0	544	1,632
TOTAL (US $)	16,477	18,784	23,890	41,862
Percentage increase to R-410A unit	0%	14%	45%	154%

Results from Table 9 show that the exception of the electrical panel, the cost of R-32 components is very similar to R-410A. Overall, the cost is 14% higher than R-410A, mainly due to upgrade electrical panel. On the other hand, R-290 components are more expensive resulting in an overall cost increase of 45% over R-410A. This increase is mainly due to the high cost of the R-290 semi-hermetic compressor. The ATEX requirements increase significantly the cost of R-290 components; more than 150% over the cost of R-410A. However, while the cost of R-290 components is relatively high today, this cost could decrease if production increases in the future.

Cost comparisons for the 70 and 40 kW chillers can be found in Tables 10 and 11 respectively.

Table 10: Cost Comparison of Major Components - 70 kW Unit (US $)

Major Components – 70 kW Unit	R-410A Unit (baseline)	R-32 Unit	R-290 Unit	R-290 Unit with ATEX Components
Compressor (2)	1,493	1,493	5,155	8,763
Condenser coil	2,099	2,099	2,099	2,099
Evaporator heat exchanger	1,500	1,500	1,500	1,500
Water Pump, water coil and supply fan	6,259	6,259	6,259	9,389
Expansion valve (2)	101	101	161	161
Electrical panel and cables	1,684	3,619	3,619	10,858
Piping (2)	568	525	568	568
Pressure relief valve (2)	275	275	246	246
Filter drier (2)	275	275	275	275
Solenoid valve (2)	156	156	156	467
Leak detector R-290 (2)	0	0	544	1,632
TOTAL (US $)	14,411	16,302	20,582	32,828
Percentage increase to R-410A unit	0%	13%	43%	128%

Table 11: Cost Comparison of Major Components - 40 kW Unit (US $)

Major Components – 40 kW Unit	R-410A Unit (baseline)	R-32 Unit	R-290 Unit	R-290 Unit with ATEX Components
Compressor	911	911	3,143	5,343
Condenser coil	1,280	1,280	1,280	1,280
Evaporator heat exchanger	915	915	915	915
Water Pump, water coil and supply fan	5,896	5,896	5,896	8,844
Expansion valve (2)	62	62	98	98
Electrical panel and cables	1,027	2,207	2,207	6,621
Piping (2)	347	320	347	347
Pressure relief valve (2)	138	138	123	123
Filter drier (2)	138	138	138	138
Solenoid valve (2)	78	78	78	234
Leak detector R-290 (2)	0	0	544	1,632
TOTAL (US $)	10,789	11,943	14,768	25,573
Percentage increase to R-410A unit	0%	11%	37%	137%

V. Conclusions

This project successfully demonstrated that commercial air-cooled chillers can be designed and operated with flammable low GWP alternative refrigerants for a variety of cooling capacities and operating conditions, including high ambient temperatures. A total of six units were built with cooling capacities of 40 kW, 70 kW and 100 kW. The design of the products was in accordance with the safety requirements of ISO-5149 and IEC-60335-2-40.

The air-cooled chillers were tested at a standard ambient condition of 35ºC as well as at high ambient temperatures of 46ºC and 52ºC. In all cases, both R-32 and R-290 units showed similar or better performance (efficiency and cooling capacity) than the baseline R-410A chiller. The design changes necessary to mitigate the risk of using R-32 resulted in a marginal increase in the cost of the chillers. However, the cost increase was significantly higher in the case of the highly flammable refrigerant R-290. It is expected that both the cost of the R-32 and R-290 chillers will decrease in the future as production increases.

Requirements of current international safety standards did not limit the amount of flammable refrigerants used for this particular project because of the specific application and location of the chillers. However, it should be noted that in most commercial applications, the use of highly flammable refrigerants such as R-290 is severely restricted by current safety standards, which is not the case for mildly flammable refrigerants like R-32.

Finally, it is believed that findings from this project will help developing countries with high ambient temperature conditions accelerate their adoption and implementation of the Kigali Amendment.

VI. References

1- ANSI/ASHRAE 34, 2016, *Designation and Safety Classification of Refrigerants*, ASHRAE, Atlanta, Georgia, USA.

2- ISO 817, 2014, *Refrigerants -- Designation and safety classification*, International Organization for Standardization, Geneva, Switzerland.

3- ISO 5149, 2014, *Refrigerating systems and heat pumps — Safety and environmental requirements —Part 1: Definitions, classification and selection criteria*, International Organization for Standardization, Geneva, Switzerland.

4- IEC 60335-2-40, 2018, *Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers*, International Electrotechnical Commission, Geneva, Switzerland.

5- SASO 2874, 2016, *Air-Conditioners – Minimum Energy Performance Requirements and Testing Requirements*, Saudi Standards, Metrology and Quality Organization, Riyadh, Saudi Arabia.

6- AHRI 550/590, 2018, *Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle*, Air-Conditioning, Heating, and Refrigeration Institute, Arlington, Virginia, USA.

7- Directive 2014/34/EU, 2014, *Harmonization of the laws of the Member States Relating to Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres,* European Union, Brussels, Belgium.

VII. Appendix A

Test reports for all prototypes and low GWP alternatives as well as the baseline R-410A are shown in the following tables.

Test Results: 100 kW Prototype (R-32) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.51
		S-T	Volts	453.95
		R-T	Volts	456.45
	Current	R	Amps	58.83
		S	Amps	61.75
		T	Amps	59.39
	Watts	R	KW	13.27
		S	KW	13.77
		T	KW	12.97
		Total KW	KW	40.00
	Power Factor		---	0.85
	Total Power Exclude pump & fan		KW	35.40
	Frequency		Hz	60.49
COOLER	Water In		°C	10.42
	Water Out		°C	4.99
	Temperature Drop 1		°C	5.43
	Flow Rate		GPM	72.90
Air condition	Return Air Dry Bulb		°C	26.80
	Return Air Wet Bulb		°C	19.28
	Supply Air Dry Bulb		°C	15.04
	Supply Wet Bulb		°C	13.17
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	35.33
Compressor Data 1	Discharge Temp.		°C	92.90
	Liquid Temp.		°C	45.34
	Suction Temp.		°C	7.08
	Discharge Pressure		[psi]	407.70
	Liquid Pressure		[psi]	402.87
	Suction Pressure		[psi]	104.67
Compressor Data 2	Discharge Temp.		°C	91.04
	Liquid Temp.		°C	47.06
	Suction Temp.		°C	7.77
	Discharge Pressure		[psi]	423.66
	Liquid Pressure		[psi]	413.93
	Suction Pressure		[psi]	105.54

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	7.71
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.436
	water Flow Rate	ft^3/hr	584.86
Air Side	Enthalpy in	KJ/KG	54.87
	Enthalpy out	KJ/KG	37.110
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	359767
		KW	105.4
		TR	30.0
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	352556
		KW	103.3
		TR	29.4
Unit Eff.	UNIT EER	Btu/W.hr	9.96
	COP	W/W	2.92
Energy Balance	Heat Balance	Energy Balance Different Percentage	2%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-32) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.12
		S-T	Volts	452.52
		R-T	Volts	454.64
	Current	R	Amps	66.85
		S	Amps	70.64
		T	Amps	67.33
	Watts	R	KW	15.38
		S	KW	16.03
		T	KW	14.95
		Total KW	KW	46.35
	Power Factor		---	0.87
	Total Power Exclude pump & fan		KW	41.75
	Frequency		Hz	60.46
COOLER	Water In		°C	12.03
	Water Out		°C	6.88
	Temperature Drop 1		°C	5.15
	Flow Rate		GPM	72.70
Air condition	Return Air Dry Bulb		°C	29.15
	Return Air Wet Bulb		°C	19.00
	Supply Air Dry Bulb		°C	16.21
	Supply Wet Bulb		°C	13.23
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	45.92
Compressor Data 1	Discharge Temp.		°C	109.84
	Liquid Temp.		°C	55.17
	Suction Temp.		°C	9.48
	Discharge Pressure		[psi]	501.27
	Liquid Pressure		[psi]	501.17
	Suction Pressure		[psi]	111.34
Compressor Data 2	Discharge Temp.		°C	107.70
	Liquid Temp.		°C	56.78
	Suction Temp.		°C	10.20
	Discharge Pressure		[psi]	520.35
	Liquid Pressure		[psi]	511.27
	Suction Pressure		[psi]	111.05

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	9.45
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.428
	water Flow Rate	ft^3/hr	583.26
Air Side	Enthalpy in	KJ/KG	53.87
	Enthalpy out	KJ/KG	37.250
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	340037
		KW	99.7
		TR	28.3
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	329926
		KW	96.7
		TR	27.5
Unit Eff.	UNIT EER	Btu/W.hr	7.90
	COP	W/W	2.32
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-32) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.31
		S-T	Volts	452.72
		R-T	Volts	454.74
	Current	R	Amps	72.89
		S	Amps	77.31
		T	Amps	73.49
	Watts	R	KW	16.92
		S	KW	17.71
		T	KW	16.46
		Total KW	KW	51.09
	Power Factor		---	0.87
	Total Power Exclude pump & fan		KW	46.49
	Frequency		Hz	60.51
COOLER	Water In		°C	13.59
	Water Out		°C	9.22
	Temperature Drop 1		°C	4.37
	Flow Rate		GPM	72.80
Air condition	Return Air Dry Bulb		°C	29.23
	Return Air Wet Bulb		°C	18.82
	Supply Air Dry Bulb		°C	17.91
	Supply Wet Bulb		°C	13.99
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	51.80
Compressor Data 1	Discharge Temp.		°C	117.99
	Liquid Temp.		°C	60.76
	Suction Temp.		°C	11.94
	Discharge Pressure		[psi]	561.23
	Liquid Pressure		[psi]	562.55
	Suction Pressure		[psi]	119.86
Compressor Data 2	Discharge Temp.		°C	117.60
	Liquid Temp.		°C	62.68
	Suction Temp.		°C	12.77
	Discharge Pressure		[psi]	588.42
	Liquid Pressure		[psi]	578.44
	Suction Pressure		[psi]	119.05

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	11.41
	Specific Heat	Btu/lbm·°F	1.009
	Density	Ibm/ft^3	62.417
	water Flow Rate	ft^3/hr	584.06
Air Side	Enthalpy in	KJ/KG	53.28
	Enthalpy out	KJ/KG	39.240
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	289310
		KW	84.8
		TR	24.1
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	278710
		KW	81.7
		TR	23.2
Unit Eff.	UNIT EER	Btu/W.hr	6.00
	COP	W/W	1.76
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-410A) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.89
		S-T	Volts	454.27
		R-T	Volts	456.57
	Current	R	Amps	56.74
		S	Amps	59.45
		T	Amps	57.05
	Watts	R	KW	12.73
		S	KW	13.15
		T	KW	12.37
		Total KW	KW	38.25
	Power Factor		---	0.84
	Total Power Exclude pump & fan		KW	33.65
	Frequency		Hz	60.50
COOLER	Water In		°C	10.71
	Water Out		°C	5.66
	Temperature Drop 1		°C	5.05
	Flow Rate		GPM	72.70
Air condition	Return Air Dry Bulb		°C	26.85
	Return Air Wet Bulb		°C	19.51
	Supply Air Dry Bulb		°C	15.59
	Supply Wet Bulb		°C	14.02
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	35.16
Compressor Data 1	Discharge Temp.		°C	72.55
	Liquid Temp.		°C	43.96
	Suction Temp.		°C	7.77
	Discharge Pressure		[psi]	388.76
	Liquid Pressure		[psi]	382.02
	Suction Pressure		[psi]	102.71
Compressor Data 2	Discharge Temp.		°C	70.08
	Liquid Temp.		°C	44.37
	Suction Temp.		°C	7.17
	Discharge Pressure		[psi]	417.69
	Liquid Pressure		[psi]	406.09
	Suction Pressure		[psi]	104.40

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	8.19
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.434
	water Flow Rate	ft^3/hr	583.26
Air Side	Enthalpy in	KJ/KG	55.61
	Enthalpy out	KJ/KG	39.380
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	333695
		KW	97.8
		TR	27.8
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	322184
		KW	94.4
		TR	26.8
Unit Eff.	UNIT EER	Btu/W.hr	9.57
	COP	W/W	2.81
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-410A) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.58
		S-T	Volts	452.98
		R-T	Volts	455.35
	Current	R	Amps	65.44
		S	Amps	67.84
		T	Amps	63.36
	Watts	R	KW	14.88
		S	KW	15.44
		T	KW	14.49
		Total KW	KW	44.81
	Power Factor		---	0.87
	Total Power Exclude pump & fan		KW	40.21
	Frequency		Hz	60.48
COOLER	Water In		°C	13.19
	Water Out		°C	9.06
	Temperature Drop 1		°C	4.13
	Flow Rate		GPM	72.60
Air condition	Return Air Dry Bulb		°C	26.26
	Return Air Wet Bulb		°C	19.20
	Supply Air Dry Bulb		°C	17.69
	Supply Wet Bulb		°C	14.76
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	45.92
Compressor Data 1	Discharge Temp.		°C	86.68
	Liquid Temp.		°C	54.65
	Suction Temp.		°C	11.33
	Discharge Pressure		[psi]	488.66
	Liquid Pressure		[psi]	486.04
	Suction Pressure		[psi]	114.86
Compressor Data 2	Discharge Temp.		°C	83.82
	Liquid Temp.		°C	55.91
	Suction Temp.		°C	10.03
	Discharge Pressure		[psi]	529.55
	Liquid Pressure		[psi]	517.50
	Suction Pressure		[psi]	113.26

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	11.13
	Specific Heat	Btu/lbm·°F	1.009
	Density	Ibm/ft^3	62.418
	water Flow Rate	ft^3/hr	582.46
Air Side	Enthalpy in	KJ/KG	54.62
	Enthalpy out	KJ/KG	41.360
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	272656
		KW	79.9
		TR	22.7
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	263226
		KW	77.1
		TR	21.9
Unit Eff.	UNIT EER	Btu/W.hr	6.55
	COP	W/W	1.92
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-410A) @52°C Condition

TEST Results

Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.48
		S-T	Volts	452.77
		R-T	Volts	455.18
	Current	R	Amps	70.34
		S	Amps	73.13
		T	Amps	68.09
	Watts	R	KW	16.17
		S	KW	16.82
		T	KW	15.75
		Total KW	KW	48.74
	Power Factor		---	0.88
	Total Power Exclude pump & fan		KW	44.14
	Frequency		Hz	60.50
COOLER	Water In		°C	14.47
	Water Out		°C	10.85
	Temperature Drop 1		°C	3.62
	Flow Rate		GPM	72.80
Air condition	Return Air Dry Bulb		°C	29.15
	Return Air Wet Bulb		°C	18.90
	Supply Air Dry Bulb		°C	18.74
	Supply Wet Bulb		°C	14.96
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	51.50
Compressor Data 1	Discharge Temp.		°C	95.85
	Liquid Temp.		°C	60.43
	Suction Temp.		°C	13.03
	Discharge Pressure		[psi]	552.17
	Liquid Pressure		[psi]	550.15
	Suction Pressure		[psi]	117.73
Compressor Data 2	Discharge Temp.		°C	91.89
	Liquid Temp.		°C	60.72
	Suction Temp.		°C	11.14
	Discharge Pressure		[psi]	584.35
	Liquid Pressure		[psi]	572.26
	Suction Pressure		[psi]	114.22

Unit Performance Calculations

Parameter		Unit	READING
Water Prop	Mean Temp.	°C	12.66
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.408
	water Flow Rate	ft^3/hr	584.06
Air Side	Enthalpy in	KJ/KG	53.54
	Enthalpy out	KJ/KG	41.900
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	239717
		KW	70.3
		TR	20.0
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	231067
		KW	67.7
		TR	19.3
Unit Eff.	UNIT EER	Btu/W.hr	5.23
	COP	W/W	1.53
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-290) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.27
		S-T	Volts	453.94
		R-T	Volts	455.94
	Current	R	Amps	60.79
		S	Amps	62.70
		T	Amps	61.80
	Watts	R	KW	12.97
		S	KW	13.38
		T	KW	12.94
		Total KW	KW	39.29
	Power Factor		---	0.81
	Total Power Exclude pump & fan		KW	34.69
	Frequency		Hz	60.52
COOLER	Water In		°C	10.35
	Water Out		°C	5.06
	Temperature Drop 1		°C	5.29
	Flow Rate		GPM	72.90
Air condition	Return Air Dry Bulb		°C	27.00
	Return Air Wet Bulb		°C	19.40
	Supply Air Dry Bulb		°C	14.90
	Supply Wet Bulb		°C	13.56
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	35.46
Compressor Data 1	Discharge Temp.		°C	69.99
	Liquid Temp.		°C	39.41
	Suction Temp.		°C	8.57
	Discharge Pressure		[psi]	248.14
	Liquid Pressure		[psi]	241.92
	Suction Pressure		[psi]	56.25
Compressor Data 2	Discharge Temp.		°C	67.94
	Liquid Temp.		°C	39.52
	Suction Temp.		°C	6.73
	Discharge Pressure		[psi]	243.09
	Liquid Pressure		[psi]	237.48
	Suction Pressure		[psi]	59.74

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	7.71
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.436
	water Flow Rate	ft^3/hr	584.86
Air Side	Enthalpy in	KJ/KG	55.27
	Enthalpy out	KJ/KG	38.160
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	350492
		KW	102.7
		TR	29.2
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	339653
		KW	99.5
		TR	28.3
Unit Eff.	UNIT EER	Btu/W.hr	9.79
	COP	W/W	2.87
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-290) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.73
		S-T	Volts	453.36
		R-T	Volts	455.51
	Current	R	Amps	67.29
		S	Amps	69.78
		T	Amps	68.94
	Watts	R	KW	14.70
		S	KW	15.30
		T	KW	14.78
		Total KW	KW	44.78
	Power Factor		---	0.83
	Total Power Exclude pump & fan		KW	40.18
	Frequency		Hz	60.48
COOLER	Water In		°C	12.27
	Water Out		°C	8.15
	Temperature Drop 1		°C	4.12
	Flow Rate		GPM	72.60
Air condition	Return Air Dry Bulb		°C	28.89
	Return Air Wet Bulb		°C	19.30
	Supply Air Dry Bulb		°C	16.74
	Supply Wet Bulb		°C	14.81
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	45.50
Compressor Data 1	Discharge Temp.		°C	74.11
	Liquid Temp.		°C	48.42
	Suction Temp.		°C	8.18
	Discharge Pressure		[psi]	297.17
	Liquid Pressure		[psi]	290.70
	Suction Pressure		[psi]	62.75
Compressor Data 2	Discharge Temp.		°C	74.74
	Liquid Temp.		°C	47.59
	Suction Temp.		°C	10.98
	Discharge Pressure		[psi]	334.14
	Liquid Pressure		[psi]	330.71
	Suction Pressure		[psi]	62.28

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	10.21
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.424
	water Flow Rate	ft^3/hr	582.46
Air Side	Enthalpy in	KJ/KG	54.87
	Enthalpy out	KJ/KG	41.530
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	271953
		KW	79.7
		TR	22.7
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	264814
		KW	77.6
		TR	22.1
Unit Eff.	UNIT EER	Btu/W.hr	6.59
	COP	W/W	1.93
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 100 kW Prototype (R-290) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.93
		S-T	Volts	453.33
		R-T	Volts	455.33
	Current	R	Amps	70.63
		S	Amps	73.46
		T	Amps	72.33
	Watts	R	KW	15.58
		S	KW	16.25
		T	KW	15.62
		Total KW	KW	47.45
	Power Factor		---	0.84
	Total Power Exclude pump & fan		KW	42.85
	Frequency		Hz	60.45
COOLER	Water In		°C	13.69
	Water Out		°C	9.98
	Temperature Drop 1		°C	3.71
	Flow Rate		GPM	72.90
Air condition	Return Air Dry Bulb		°C	29.42
	Return Air Wet Bulb		°C	19.52
	Supply Air Dry Bulb		°C	17.87
	Supply Wet Bulb		°C	15.57
	Air Flow rate		CFM	10256
Condenser	Ambient		°C	52.01
Compressor Data 1	Discharge Temp.		°C	81.24
	Liquid Temp.		°C	54.74
	Suction Temp.		°C	10.61
	Discharge Pressure		[psi]	341.76
	Liquid Pressure		[psi]	335.48
	Suction Pressure		[psi]	67.78
Compressor Data 2	Discharge Temp.		°C	80.26
	Liquid Temp.		°C	53.74
	Suction Temp.		°C	13.19
	Discharge Pressure		[psi]	367.74
	Liquid Pressure		[psi]	366.24
	Suction Pressure		[psi]	69.00

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	11.84
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.414
	water Flow Rate	ft^3/hr	584.86
Air Side	Enthalpy in	KJ/KG	55.59
	Enthalpy out	KJ/KG	43.660
	Air Flow Rate	ft^3/min	10256
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	245973
		KW	72.1
		TR	20.5
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	236824
		KW	69.4
		TR	19.7
Unit Eff.	UNIT EER	Btu/W.hr	5.53
	COP	W/W	1.62
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-32) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.51
		S-T	Volts	454.20
		R-T	Volts	455.71
	Current	R	Amps	50.46
		S	Amps	48.12
		T	Amps	49.84
	Watts	R	KW	11.04
		S	KW	10.62
		T	KW	11.24
		Total KW	KW	32.90
	Power Factor		---	0.84
	Total Power Exclude pump & fan		KW	30.10
	Frequency		Hz	60.49
COOLER	Water In		°C	9.87
	Water Out		°C	4.62
	Temperature Drop 1		°C	5.26
	Flow Rate		GPM	62.90
Air condition	Return Air Dry Bulb		°C	26.49
	Return Air Wet Bulb		°C	19.60
	Supply Air Dry Bulb		°C	14.25
	Supply Wet Bulb		°C	13.06
	Air Flow rate		CFM	8068
Condenser	Ambient		°C	35.22
Compressor Data 1	Discharge Temp.		°C	99.27
	Liquid Temp.		°C	45.23
	Suction Temp.		°C	11.48
	Discharge Pressure		[psi]	427.41
	Liquid Pressure		[psi]	421.68
	Suction Pressure		[psi]	104.60
Compressor Data 2	Discharge Temp.		°C	100.02
	Liquid Temp.		°C	44.11
	Suction Temp.		°C	12.73
	Discharge Pressure		[psi]	440.95
	Liquid Pressure		[psi]	434.95
	Suction Pressure		[psi]	100.67

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	7.24
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.438
	water Flow Rate	ft^3/hr	504.63
Air Side	Enthalpy in	KJ/KG	55.62
	Enthalpy out	KJ/KG	36.850
	Air Flow Rate	ft^3/min	8068
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	300394
		KW	88.0
		TR	25.0
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	293114
		KW	85.9
		TR	24.4
Unit Eff.	UNIT EER	Btu/W.hr	9.74
	COP	W/W	2.85
Energy Balance	Heat Balance	Energy Balance Different Percentage	2%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-32) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	452.34
		S-T	Volts	453.20
		R-T	Volts	454.63
	Current	R	Amps	58.69
		S	Amps	55.72
		T	Amps	58.08
	Watts	R	KW	13.07
		S	KW	12.55
		T	KW	13.35
		Total KW	KW	38.97
	Power Factor		---	0.86
	Total Power Exclude pump & fan		KW	36.17
	Frequency		Hz	60.48
COOLER	Water In		°C	10.92
	Water Out		°C	6.32
	Temperature Drop 1		°C	4.60
	Flow Rate		GPM	62.80
Air condition	Return Air Dry Bulb		°C	28.61
	Return Air Wet Bulb		°C	19.13
	Supply Air Dry Bulb		°C	15.17
	Supply Wet Bulb		°C	13.52
	Air Flow rate		CFM	8068
Condenser	Ambient		°C	45.87
Compressor Data 1	Discharge Temp.		°C	120.56
	Liquid Temp.		°C	56.10
	Suction Temp.		°C	12.32
	Discharge Pressure		[psi]	551.61
	Liquid Pressure		[psi]	546.27
	Suction Pressure		[psi]	111.01
Compressor Data 2	Discharge Temp.		°C	119.90
	Liquid Temp.		°C	54.58
	Suction Temp.		°C	15.30
	Discharge Pressure		[psi]	557.59
	Liquid Pressure		[psi]	551.59
	Suction Pressure		[psi]	107.53

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	8.62
	Specific Heat	Btu/lbm·°F	1.008
	Density	Ibm/ft^3	62.432
	water Flow Rate	ft^3/hr	503.83
Air Side	Enthalpy in	KJ/KG	54.31
	Enthalpy out	KJ/KG	38.040
	Air Flow Rate	ft^3/min	8068
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	262584
		KW	77.0
		TR	21.9
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	254074
		KW	74.5
		TR	21.2
Unit Eff.	UNIT EER	Btu/W.hr	7.02
	COP	W/W	2.06
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-32) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	450.93
		S-T	Volts	452.00
		R-T	Volts	453.08
	Current	R	Amps	65.67
		S	Amps	63.94
		T	Amps	66.46
	Watts	R	KW	14.88
		S	KW	14.52
		T	KW	15.12
		Total KW	KW	44.52
	Power Factor		---	0.86
	Total Power Exclude pump & fan		KW	41.72
	Frequency		Hz	60.50
COOLER	Water In		°C	11.64
	Water Out		°C	7.44
	Temperature Drop 1		°C	4.20
	Flow Rate		GPM	62.60
Air condition	Return Air Dry Bulb		°C	29.19
	Return Air Wet Bulb		°C	19.42
	Supply Air Dry Bulb		°C	16.51
	Supply Wet Bulb		°C	14.45
	Air Flow rate		CFM	8068
Condenser	Ambient		°C	51.80
Compressor Data 1	Discharge Temp.		°C	126.40
	Liquid Temp.		°C	59.38
	Suction Temp.		°C	14.60
	Discharge Pressure		[psi]	595.49
	Liquid Pressure		[psi]	590.33
	Suction Pressure		[psi]	114.02
Compressor Data 2	Discharge Temp.		°C	125.17
	Liquid Temp.		°C	58.14
	Suction Temp.		°C	16.77
	Discharge Pressure		[psi]	602.08
	Liquid Pressure		[psi]	596.08
	Suction Pressure		[psi]	111.98

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	9.54
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.428
	water Flow Rate	ft^3/hr	502.23
Air Side	Enthalpy in	KJ/KG	55.25
	Enthalpy out	KJ/KG	40.500
	Air Flow Rate	ft^3/min	8068
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	239021
		KW	70.1
		TR	19.9
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	230338
		KW	67.5
		TR	19.2
Unit Eff.	UNIT EER	Btu/W.hr	5.52
	COP	W/W	1.62
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-410A) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.48
		S-T	Volts	454.27
		R-T	Volts	456.10
	Current	R	Amps	49.79
		S	Amps	47.44
		T	Amps	49.37
	Watts	R	KW	10.85
		S	KW	10.46
		T	KW	11.11
		Total KW	KW	32.41
	Power Factor		---	0.84
	Total Power Exclude pump & fan		KW	29.61
	Frequency		Hz	60.43
COOLER	Water In		°C	10.41
	Water Out		°C	5.50
	Temperature Drop 1		°C	4.91
	Flow Rate		GPM	63.20
Air condition	Return Air Dry Bulb		°C	26.68
	Return Air Wet Bulb		°C	19.50
	Supply Air Dry Bulb		°C	14.78
	Supply Wet Bulb		°C	13.51
	Air Flow rate		CFM	8068
Condenser	Ambient		°C	35.53
Compressor Data 1	Discharge Temp.		°C	82.12
	Liquid Temp.		°C	41.82
	Suction Temp.		°C	10.19
	Discharge Pressure		[psi]	433.96
	Liquid Pressure		[psi]	425.77
	Suction Pressure		[psi]	106.13
Compressor Data 2	Discharge Temp.		°C	80.68
	Liquid Temp.		°C	43.33
	Suction Temp.		°C	11.73
	Discharge Pressure		[psi]	437.66
	Liquid Pressure		[psi]	431.56
	Suction Pressure		[psi]	103.46

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	7.96
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.435
	water Flow Rate	ft^3/hr	507.04
Air Side	Enthalpy in	KJ/KG	55.61
	Enthalpy out	KJ/KG	38.030
	Air Flow Rate	ft^3/min	8068
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	282038
		KW	82.7
		TR	23.5
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	274531
		KW	80.5
		TR	22.9
Unit Eff.	UNIT EER	Btu/W.hr	9.27
	COP	W/W	2.72
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-410A) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.11
Electrical Data	Voltage	S-T	Volts	453.94
Electrical Data	Voltage	R-T	Volts	455.70
Electrical Data	Current	R	Amps	57.22
Electrical Data	Current	S	Amps	54.32
Electrical Data	Current	T	Amps	56.79
Electrical Data	Watts	R	KW	12.71
Electrical Data	Watts	S	KW	12.22
Electrical Data	Watts	T	KW	13.04
Electrical Data	Watts	Total KW	KW	37.97
Electrical Data	Power Factor		---	0.86
Electrical Data	Total Power Exclude pump & fan		KW	35.17
Electrical Data	Frequency		Hz	60.45
COOLER	Water In		°C	11.92
COOLER	Water Out		°C	7.49
COOLER	Temperature Drop 1		°C	4.43
COOLER	Flow Rate		GPM	62.80
Air condition	Return Air Dry Bulb		°C	29.05
Air condition	Return Air Wet Bulb		°C	19.24
Air condition	Supply Air Dry Bulb		°C	15.73
Air condition	Supply Wet Bulb		°C	13.89
Air condition	Air Flow rate		CFM	8068
Condenser	Ambient		°C	46.49
Compressor Data 1	Discharge Temp.		°C	99.08
Compressor Data 1	Liquid Temp.		°C	53.25
Compressor Data 1	Suction Temp.		°C	13.02
Compressor Data 1	Discharge Pressure		[psi]	556.60
Compressor Data 1	Liquid Pressure		[psi]	549.79
Compressor Data 1	Suction Pressure		[psi]	113.13
Compressor Data 2	Discharge Temp.		°C	97.21
Compressor Data 2	Liquid Temp.		°C	53.82
Compressor Data 2	Suction Temp.		°C	15.03
Compressor Data 2	Discharge Pressure		[psi]	551.21
Compressor Data 2	Liquid Pressure		[psi]	545.21
Compressor Data 2	Suction Pressure		[psi]	109.28

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	9.70
Water Prop	Specific Heat	Btu/lbm·°F	1.008
Water Prop	Density	lbm/ft^3	62.427
Water Prop	water Flow Rate	ft^3/hr	503.83
Air Side	Enthalpy in	KJ/KG	54.66
Air Side	Enthalpy out	KJ/KG	39.020
Air Side	Air Flow Rate	ft^3/min	8068
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	252808
Water Capacity & EER	Water Side Cooling Capacity	KW	74.1
Water Capacity & EER	Water Side Cooling Capacity	TR	21.1
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	244236
Air Capacity & EER	Air Side Cooling Capacity	KW	71.6
Air Capacity & EER	Air Side Cooling Capacity	TR	20.4
Unit Eff.	UNIT EER	Btu/W.hr	6.94
Unit Eff.	COP	W/W	2.04
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
Energy Balance	Heat Balance	Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-410A) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.72
		S-T	Volts	454.68
		R-T	Volts	456.08
	Current	R	Amps	61.51
		S	Amps	58.40
		T	Amps	61.05
	Watts	R	KW	13.78
		S	KW	13.25
		T	KW	14.12
		Total KW	KW	41.15
	Power Factor		---	0.87
	Total Power Exclude pump & fan		KW	38.35
	Frequency		Hz	60.49
COOLER	Water In		°C	14.71
	Water Out		°C	10.93
	Temperature Drop 1		°C	3.78
	Flow Rate		GPM	62.70
Air condition	Return Air Dry Bulb		°C	29.42
	Return Air Wet Bulb		°C	19.02
	Supply Air Dry Bulb		°C	18.66
	Supply Wet Bulb		°C	14.52
	Air Flow rate		CFM	8068
Condenser	Ambient		°C	51.53
Compressor Data 1	Discharge Temp.		°C	106.99
	Liquid Temp.		°C	60.66
	Suction Temp.		°C	21.52
	Discharge Pressure		[psi]	607.20
	Liquid Pressure		[psi]	599.55
	Suction Pressure		[psi]	121.60
Compressor Data 2	Discharge Temp.		°C	105.13
	Liquid Temp.		°C	60.04
	Suction Temp.		°C	19.31
	Discharge Pressure		[psi]	609.40
	Liquid Pressure		[psi]	603.40
	Suction Pressure		[psi]	118.00

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	12.82
	Specific Heat	Btu/lbm·°F	1.009
	Density	Ibm/ft^3	62.406
	water Flow Rate	ft^3/hr	503.03
Air Side	Enthalpy in	KJ/KG	53.92
	Enthalpy out	KJ/KG	40.670
	Air Flow Rate	ft^3/min	8068
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	215592
		KW	63.2
		TR	18.0
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	206914
		KW	60.6
		TR	17.2
Unit Eff.	UNIT EER	Btu/W.hr	5.40
	COP	W/W	1.58
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-290) @T1 Condition

TEST Results

Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	454.74
		S-T	Volts	455.01
		R-T	Volts	457.20
	Current	R	Amps	47.37
		S	Amps	48.60
		T	Amps	47.95
	Watts	R	KW	9.97
		S	KW	10.22
		T	KW	9.92
		Total KW	KW	30.12
	Power Factor		---	0.80
	Total Power Exclude pump & fan		KW	27.32
	Frequency		Hz	60.49
COOLER	Water In		°C	11.63
	Water Out		°C	6.86
	Temperature Drop 1		°C	4.77
	Flow Rate		GPM	62.10
Air condition	Return Air Dry Bulb		°C	27.31
	Return Air Wet Bulb		°C	19.50
	Supply Air Dry Bulb		°C	15.02
	Supply Wet Bulb		°C	13.85
	Air Flow rate		CFM	8085
Condenser	Ambient		°C	35.56
Compressor Data 1	Discharge Temp.		°C	67.71
	Liquid Temp.		°C	40.63
	Suction Temp.		°C	15.76
	Discharge Pressure		[psi]	244.23
	Liquid Pressure		[psi]	236.60
	Suction Pressure		[psi]	56.83
Compressor Data 2	Discharge Temp.		°C	65.42
	Liquid Temp.		°C	44.40
	Suction Temp.		°C	11.55
	Discharge Pressure		[psi]	222.11
	Liquid Pressure		[psi]	213.44
	Suction Pressure		[psi]	50.49

Unit Performance Calculations

Parameter		Unit	READING
Water Prop	Mean Temp.	°C	9.24
	Specific Heat	Btu/lbm·°F	1.008
	Density	lbm/ft^3	62.429
	water Flow Rate	ft^3/hr	498.22
Air Side	Enthalpy in	KJ/KG	55.60
	Enthalpy out	KJ/KG	38.930
	Air Flow Rate	ft^3/min	8085
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	269448
		KW	79.0
		TR	22.5
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	260869
		KW	76.5
		TR	21.7
Unit Eff.	UNIT EER	Btu/W.hr	9.55
	COP	W/W	2.80
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-290) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	454.32
		S-T	Volts	454.74
		R-T	Volts	456.76
	Current	R	Amps	49.67
		S	Amps	51.15
		T	Amps	50.32
	Watts	R	KW	10.62
		S	KW	10.92
		T	KW	10.56
		Total KW	KW	32.10
	Power Factor		---	0.81
	Total Power Exclude pump & fan		KW	29.30
	Frequency		Hz	60.47
COOLER	Water In		°C	12.85
	Water Out		°C	8.96
	Temperature Drop 1		°C	3.89
	Flow Rate		GPM	62.10
Air condition	Return Air Dry Bulb		°C	29.16
	Return Air Wet Bulb		°C	19.77
	Supply Air Dry Bulb		°C	16.13
	Supply Wet Bulb		°C	15.31
	Air Flow rate		CFM	8085
Condenser	Ambient		°C	46.04
Compressor Data 1	Discharge Temp.		°C	76.31
	Liquid Temp.		°C	48.40
	Suction Temp.		°C	18.28
	Discharge Pressure		[psi]	286.08
	Liquid Pressure		[psi]	279.37
	Suction Pressure		[psi]	60.23
Compressor Data 2	Discharge Temp.		°C	75.40
	Liquid Temp.		°C	52.47
	Suction Temp.		°C	13.60
	Discharge Pressure		[psi]	282.87
	Liquid Pressure		[psi]	275.00
	Suction Pressure		[psi]	58.84

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	10.91
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.420
	water Flow Rate	ft^3/hr	498.22
Air Side	Enthalpy in	KJ/KG	56.44
	Enthalpy out	KJ/KG	42.960
	Air Flow Rate	ft^3/min	8085
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	219661
		KW	64.4
		TR	18.3
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	210949
		KW	61.8
		TR	17.6
Unit Eff.	UNIT EER	Btu/W.hr	7.20
	COP	W/W	2.11
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 70 kW Prototype (R-290) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	453.97
		S-T	Volts	454.18
		R-T	Volts	456.43
	Current	R	Amps	50.93
		S	Amps	52.44
		T	Amps	51.57
	Watts	R	KW	10.96
		S	KW	11.26
		T	KW	10.89
		Total KW	KW	33.11
	Power Factor		---	81.00
	Total Power Exclude pump & fan		KW	30.31
	Frequency		Hz	60.49
COOLER	Water In		°C	13.01
	Water Out		°C	10.20
	Temperature Drop 1		°C	2.81
	Flow Rate		GPM	62.30
Air condition	Return Air Dry Bulb		°C	29.24
	Return Air Wet Bulb		°C	19.58
	Supply Air Dry Bulb		°C	17.06
	Supply Wet Bulb		°C	16.39
	Air Flow rate		CFM	8085
Condenser	Ambient		°C	51.68
Compressor Data 1	Discharge Temp.		°C	80.83
	Liquid Temp.		°C	53.24
	Suction Temp.		°C	19.80
	Discharge Pressure		[psi]	334.11
	Liquid Pressure		[psi]	327.98
	Suction Pressure		[psi]	62.66
Compressor Data 2	Discharge Temp.		°C	80.10
	Liquid Temp.		°C	57.17
	Suction Temp.		°C	15.06
	Discharge Pressure		[psi]	327.32
	Liquid Pressure		[psi]	319.75
	Suction Pressure		[psi]	60.31

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	11.61
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.415
	water Flow Rate	ft^3/hr	499.82
Air Side	Enthalpy in	KJ/KG	55.79
	Enthalpy out	KJ/KG	46.080
	Air Flow Rate	ft^3/min	8085
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	159207
		KW	46.7
		TR	13.3
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	151952
		KW	44.5
		TR	12.7
Unit Eff.	UNIT EER	Btu/W.hr	5.01
	COP	W/W	1.47
Energy Balance	Heat Balance	Energy Balance Different Percentage	5%
		Allowable tolerance as AHRI 550/590	5%

Test Results: 40 kW Prototype (R-32) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	454.31
		S-T	Volts	454.64
		R-T	Volts	457.21
	Current	R	Amps	26.89
		S	Amps	28.17
		T	Amps	27.29
	Watts	R	KW	6.18
		S	KW	6.43
		T	KW	6.10
		Total KW	KW	18.71
	Power Factor		---	0.86
	Total Power Exclude pump & fan		KW	16.41
	Frequency		Hz	60.48
COOLER	Water In		°C	14.71
	Water Out		°C	10.17
	Temperature Drop 1		°C	4.54
	Flow Rate		GPM	39.90
Air condition	Return Air Dry Bulb		°C	26.22
	Return Air Wet Bulb		°C	19.40
	Supply Air Dry Bulb		°C	15.90
	Supply Wet Bulb		°C	14.60
	Air Flow rate		CFM	5900
Condenser	Ambient		°C	35.24
Compressor Data	Discharge Temp.		°C	100.63
	Liquid Temp.		°C	47.48
	Suction Temp.		°C	11.29
	Discharge Pressure		[psi]	492.93
	Liquid Pressure		[psi]	489.31
	Suction Pressure		[psi]	126.38

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	12.44
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.409
	water Flow Rate	ft^3/hr	320.11
Air Side	Enthalpy in	KJ/KG	55.30
	Enthalpy out	KJ/KG	40.960
	Air Flow Rate	ft^3/min	5900
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	164766
		KW	48.3
		TR	13.7
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	163760
		KW	48.0
		TR	13.6
Unit Eff.	UNIT EER	Btu/W.hr	9.98
	COP	W/W	2.93
Energy Balance	Heat Balance	Energy Balance Different Percentage	1%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-32) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	455.49
		S-T	Volts	455.93
		R-T	Volts	458.14
	Current	R	Amps	33.25
		S	Amps	35.20
		T	Amps	33.79
	Watts	R	KW	7.82
		S	KW	8.21
		T	KW	7.70
		Total KW	KW	23.72
	Power Factor		---	0.88
	Total Power Exclude pump & fan		KW	21.42
	Frequency		Hz	60.51
COOLER	Water In		°C	16.09
	Water Out		°C	11.81
	Temperature Drop 1		°C	4.28
	Flow Rate		GPM	39.70
Air condition	Return Air Dry Bulb		°C	29.42
	Return Air Wet Bulb		°C	19.49
	Supply Air Dry Bulb		°C	17.20
	Supply Wet Bulb		°C	15.09
	Air Flow rate		CFM	5900
Condenser	Ambient		°C	45.19
Compressor Data	Discharge Temp.		°C	119.92
	Liquid Temp.		°C	57.99
	Suction Temp.		°C	15.67
	Discharge Pressure		[psi]	628.25
	Liquid Pressure		[psi]	626.47
	Suction Pressure		[psi]	134.72

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	13.95
	Specific Heat	Btu/lbm·°F	1.010
	Density	lbm/ft^3	62.397
	water Flow Rate	ft^3/hr	318.51
Air Side	Enthalpy in	KJ/KG	55.48
	Enthalpy out	KJ/KG	42.300
	Air Flow Rate	ft^3/min	5900
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	154747
		KW	45.4
		TR	12.9
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	150513
		KW	44.1
		TR	12.5
Unit Eff.	UNIT EER	Btu/W.hr	7.03
	COP	W/W	2.06
Energy Balance	Heat Balance	Energy Balance Different Percentage	3%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-32) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	455.43
		S-T	Volts	455.90
		R-T	Volts	458.06
	Current	R	Amps	36.41
		S	Amps	36.77
		T	Amps	35.65
	Watts	R	KW	8.42
		S	KW	8.52
		T	KW	8.30
		Total KW	KW	25.24
	Power Factor		---	0.88
	Total Power Exclude pump & fan		KW	22.94
	Frequency		Hz	60.51
COOLER	Water In		°C	16.91
	Water Out		°C	13.42
	Temperature Drop 1		°C	3.49
	Flow Rate		GPM	39.80
Air condition	Return Air Dry Bulb		°C	29.49
	Return Air Wet Bulb		°C	19.07
	Supply Air Dry Bulb		°C	18.16
	Supply Wet Bulb		°C	15.51
	Air Flow rate		CFM	5900
Condenser	Ambient		°C	51.90
Compressor Data	Discharge Temp.		°C	126.40
	Liquid Temp.		°C	63.10
	Suction Temp.		°C	16.10
	Discharge Pressure		[psi]	635.10
	Liquid Pressure		[psi]	632.20
	Suction Pressure		[psi]	142.40

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	15.17
	Specific Heat	Btu/lbm·°F	1.010
	Density	lbm/ft^3	62.386
	water Flow Rate	ft^3/hr	319.31
Air Side	Enthalpy in	KJ/KG	54.09
	Enthalpy out	KJ/KG	43.480
	Air Flow Rate	ft^3/min	5900
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	126422
		KW	37.1
		TR	10.5
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	121164
		KW	35.5
		TR	10.1
Unit Eff.	UNIT EER	Btu/W.hr	5.28
	COP	W/W	1.55
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-410A) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	454.94
		S-T	Volts	455.19
		R-T	Volts	457.85
	Current	R	Amps	25.62
		S	Amps	26.78
		T	Amps	25.96
	Watts	R	KW	5.85
		S	KW	6.06
		T	KW	5.76
		Total KW	KW	17.67
	Power Factor		---	0.86
	Total Power Exclude pump & fan		KW	15.37
	Frequency		Hz	60.46
COOLER	Water In		°C	14.32
	Water Out		°C	10.18
	Temperature Drop 1		°C	4.14
	Flow Rate		GPM	40.10
Air condition	Return Air Dry Bulb		°C	26.44
	Return Air Wet Bulb		°C	19.47
	Supply Air Dry Bulb		°C	16.50
	Supply Wet Bulb		°C	15.10
	Air Flow rate		CFM	5900
Condenser	Ambient		°C	35.56
Compressor Data	Discharge Temp.		°C	83.36
	Liquid Temp.		°C	47.93
	Suction Temp.		°C	14.27
	Discharge Pressure		[psi]	474.30
	Liquid Pressure		[psi]	470.11
	Suction Pressure		[psi]	124.16

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	12.25
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.411
	water Flow Rate	ft^3/hr	321.71
Air Side	Enthalpy in	KJ/KG	55.52
	Enthalpy out	KJ/KG	42.500
	Air Flow Rate	ft^3/min	5900
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	150997
		KW	44.3
		TR	12.6
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	148686
		KW	43.6
		TR	12.4
Unit Eff.	UNIT EER	Btu/W.hr	9.67
	COP	W/W	2.83
Energy Balance	Heat Balance	Energy Balance Different Percentage	2%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-410A) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	454.61
		S-T	Volts	455.00
		R-T	Volts	457.51
	Current	R	Amps	29.46
		S	Amps	30.96
		T	Amps	29.91
	Watts	R	KW	6.85
		S	KW	7.15
		T	KW	6.76
		Total KW	KW	20.75
	Power Factor		---	0.87
	Total Power Exclude pump & fan		KW	18.45
	Frequency		Hz	60.48
COOLER	Water In		°C	16.96
	Water Out		°C	13.59
	Temperature Drop 1		°C	3.37
	Flow Rate		GPM	39.90
Air condition	Return Air Dry Bulb		°C	28.92
	Return Air Wet Bulb		°C	19.32
	Supply Air Dry Bulb		°C	19.28
	Supply Wet Bulb		°C	15.86
	Air Flow rate		CFM	5900
Condenser	Ambient		°C	46.16
Compressor Data	Discharge Temp.		°C	100.66
	Liquid Temp.		°C	57.25
	Suction Temp.		°C	18.50
	Discharge Pressure		[psi]	589.98
	Liquid Pressure		[psi]	586.74
	Suction Pressure		[psi]	128.13

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	15.28
	Specific Heat	Btu/lbm·°F	1.010
	Density	lbm/ft^3	62.385
	water Flow Rate	ft^3/hr	320.11
Air Side	Enthalpy in	KJ/KG	54.93
	Enthalpy out	KJ/KG	44.460
	Air Flow Rate	ft^3/min	5900
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	122386
		KW	35.9
		TR	10.2
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	119565
		KW	35.0
		TR	10.0
Unit Eff.	UNIT EER	Btu/W.hr	6.48
	COP	W/W	1.90
Energy Balance	Heat Balance	Energy Balance Different Percentage	2%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-410A) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	455.99
		S-T	Volts	456.58
		R-T	Volts	458.73
	Current	R	Amps	30.08
		S	Amps	31.72
		T	Amps	30.56
	Watts	R	KW	7.02
		S	KW	7.35
		T	KW	6.92
		Total KW	KW	21.29
	Power Factor		---	0.87
	Total Power Exclude pump & fan		KW	18.99
	Frequency		Hz	60.50
COOLER	Water In		°C	17.42
	Water Out		°C	14.48
	Temperature Drop 1		°C	2.94
	Flow Rate		GPM	39.80
Air condition	Return Air Dry Bulb		°C	29.14
	Return Air Wet Bulb		°C	19.16
	Supply Air Dry Bulb		°C	20.08
	Supply Wet Bulb		°C	16.21
	Air Flow rate		CFM	5900
Condenser	Ambient		°C	51.90
Compressor Data	Discharge Temp.		°C	103.74
	Liquid Temp.		°C	58.78
	Suction Temp.		°C	19.38
	Discharge Pressure		[psi]	606.45
	Liquid Pressure		[psi]	604.02
	Suction Pressure		[psi]	134.49

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	15.95
	Specific Heat	Btu/lbm·°F	1.011
	Density	lbm/ft^3	62.379
	water Flow Rate	ft^3/hr	319.31
Air Side	Enthalpy in	KJ/KG	54.40
	Enthalpy out	KJ/KG	45.460
	Air Flow Rate	ft^3/min	5900
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	106522
		KW	31.2
		TR	8.9
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	102093
		KW	29.9
		TR	8.5
Unit Eff.	UNIT EER	Btu/W.hr	5.38
	COP	W/W	1.58
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-290) @T1 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	454.85
		S-T	Volts	455.10
		R-T	Volts	457.35
	Current	R	Amps	26.84
		S	Amps	27.55
		T	Amps	27.18
	Watts	R	KW	5.72
		S	KW	5.87
		T	KW	5.70
		Total KW	KW	17.29
	Power Factor		---	0.81
	Total Power Exclude pump & fan		KW	14.99
	Frequency		Hz	60.48
COOLER	Water In		°C	14.64
	Water Out		°C	10.50
	Temperature Drop 1		°C	4.14
	Flow Rate		GPM	39.70
Air condition	Return Air Dry Bulb		°C	26.47
	Return Air Wet Bulb		°C	18.95
	Supply Air Dry Bulb		°C	15.66
	Supply Wet Bulb		°C	14.66
	Air Flow rate		CFM	6008
Condenser	Ambient		°C	35.44
Compressor Data	Discharge Temp.		°C	78.36
	Liquid Temp.		°C	42.21
	Suction Temp.		°C	13.90
	Discharge Pressure		[psi]	289.01
	Liquid Pressure		[psi]	286.76
	Suction Pressure		[psi]	62.87

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	12.57
	Specific Heat	Btu/lbm·°F	1.009
	Density	lbm/ft^3	62.408
	water Flow Rate	ft^3/hr	318.51
Air Side	Enthalpy in	KJ/KG	53.79
	Enthalpy out	KJ/KG	41.140
	Air Flow Rate	ft^3/min	6008
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	149645
		KW	43.9
		TR	12.5
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	147105
		KW	43.1
		TR	12.3
Unit Eff.	UNIT EER	Btu/W.hr	9.82
	COP	W/W	2.88
Energy Balance	Heat Balance	Energy Balance Different Percentage	2%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-290) @T3 Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	455.44
		S-T	Volts	455.54
		R-T	Volts	457.93
	Current	R	Amps	29.77
		S	Amps	30.48
		T	Amps	30.23
	Watts	R	KW	6.45
		S	KW	6.63
		T	KW	6.47
		Total KW	KW	19.55
	Power Factor		---	0.82
	Total Power Exclude pump & fan		KW	17.25
	Frequency		Hz	60.48
COOLER	Water In		°C	16.96
	Water Out		°C	13.64
	Temperature Drop 1		°C	3.32
	Flow Rate		GPM	39.70
Air condition	Return Air Dry Bulb		°C	29.28
	Return Air Wet Bulb		°C	18.99
	Supply Air Dry Bulb		°C	18.17
	Supply Wet Bulb		°C	15.65
	Air Flow rate		CFM	6008
Condenser	Ambient		°C	45.06
Compressor Data	Discharge Temp.		°C	89.97
	Liquid Temp.		°C	54.49
	Suction Temp.		°C	18.18
	Discharge Pressure		[psi]	364.19
	Liquid Pressure		[psi]	363.75
	Suction Pressure		[psi]	71.22

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	15.30
	Specific Heat	Btu/lbm·°F	1.010
	Density	lbm/ft^3	62.385
	water Flow Rate	ft^3/hr	318.51
Air Side	Enthalpy in	KJ/KG	53.83
	Enthalpy out	KJ/KG	43.880
	Air Flow Rate	ft^3/min	6008
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	119966
		KW	35.2
		TR	10.0
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	115707
		KW	33.9
		TR	9.6
Unit Eff.	UNIT EER	Btu/W.hr	6.71
	COP	W/W	1.97
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Test Results: 40 kW Prototype (R-290) @52°C Condition

TEST Results				
Parameter			Unit	Reading
Electrical Data	Voltage	R-S	Volts	455.23
		S-T	Volts	455.36
		R-T	Volts	457.73
	Current	R	Amps	33.83
		S	Amps	34.05
		T	Amps	33.43
	Watts	R	KW	7.38
		S	KW	7.43
		T	KW	7.33
		Total KW	KW	22.14
	Power Factor		---	0.83
	Total Power Exclude pump & fan		KW	19.84
	Frequency		Hz	60.49
COOLER	Water In		°C	17.68
	Water Out		°C	14.74
	Temperature Drop 1		°C	2.94
	Flow Rate		GPM	39.80
Air condition	Return Air Dry Bulb		°C	29.43
	Return Air Wet Bulb		°C	19.10
	Supply Air Dry Bulb		°C	19.23
	Supply Wet Bulb		°C	16.20
	Air Flow rate		CFM	6008
Condenser	Ambient		°C	52.10
Compressor Data	Discharge Temp.		°C	94.90
	Liquid Temp.		°C	59.21
	Suction Temp.		°C	20.37
	Discharge Pressure		[psi]	404.13
	Liquid Pressure		[psi]	401.00
	Suction Pressure		[psi]	74.77

Unit Performance Calculations			
Parameter		Unit	READING
Water Prop	Mean Temp.	°C	16.21
	Specific Heat	Btu/lbm·°F	1.011
	Density	Ibm/ft^3	62.376
	water Flow Rate	ft^3/hr	319.31
Air Side	Enthalpy in	KJ/KG	54.19
	Enthalpy out	KJ/KG	45.450
	Air Flow Rate	ft^3/min	6008
Water Capacity & EER	Water Side Cooling Capacity	Btu/hr	106385
		KW	31.2
		TR	8.9
Air Capacity & EER	Air Side Cooling Capacity	Btu/hr	101636
		KW	29.8
		TR	8.5
Unit Eff.	UNIT EER	Btu/W.hr	5.12
	COP	W/W	1.50
Energy Balance	Heat Balance	Energy Balance Different Percentage	4%
		Allowable tolerance as AHRI 550/590	4%

Annex V

DEMONSTRATION PROJECT AT FOAM SYSTEM HOUSES IN THAILAND TO FORMULATE PRE-BLENDED POLYOL FOR SPRAY POLYURETHANE FOAM APPLICATIONS USING LOW-GWP BLOWING AGENTS

WORLD BANK REPORT
SUBMITTED ON BEHALF OF THE ROYAL GOVERNMENT OF THAILAND

April 22, 2019

Introduction

1. The demonstration project at two foam system houses to formulate pre-blended polyol for spray polyurethane (PU) foam applications using low-global warming potential (GWP) blowing agent was submitted by the World Bank on behalf of the Royal Thai Government to the 75th meeting of the Executive Committee (ExCom) and resubmitted for the ExCom's approval at the 76th meeting. At the 76th meeting, the ExCom approved the project at a total cost of US $355,905.

2. The project was prepared consistent with the decision of the Meeting of the Parties (Dec. XIX/6) whereby there was a concern of the availability of validated cost effective and environmentally sound technologies to phase out HCFC-141b in the different foam applications in Article 5 countries.

3. The PU foam sector in Thailand comprises of 215 enterprises using 1,723 metric tons (MT) of HCFC-141b, in the manufacturing of rigid PU foam, including spray foam applications. Stage I of the HCFC Phase-out Management Plan (HPMP) of Thailand addressed 1,517 MT of HCFC-141b using in all PU foam applications, excluding consumption in the spray foam sub-sector due to the absence of low-GWP alternatives for this sub-sector. According to Stage II HPMP, the current HCFC-141b consumption in the spray foam sub-sector reduces from 349.1 MT in 2010 to 286.65 MT in 2017. The total HCFC-141b consumption is distributed among 102 spray foam enterprises of which, 71 enterprises were established prior to September 2007. Existing spray foam companies and their consumption is shown in Table 1.

Table 1: Summary of Spray Foam Companies and their Average HCFC-141b Consumption

	No. of Companies	**No. of Eligible Companies**	**Total HCFC-141b Consumption**
Companies consume more than 10 MT	5	5	216.34
Companies consume more than 2 but less than 10 MT	10	8	52.41
Companies consume less than 2 MT	87	58	17.90
Total	**102**	**71**	**286.65**

4. The Stage II HPMP including funding for phasing out HCFC-141b in the spray foam was approved at the 82nd ExCom Meeting. The total funding provided for the spray foam sector, which is the only PU foam applications using HCFC-141b in Thailand, under the Stage II HPMP is US $1,732,597 to be released to Thailand from 2018 – 2022.

Background

5. For developing countries, the proven technical options to replace HCFC-141b as a blowing agent for PU rigid foam are mainly limited to high GWP HFCs as HFC-245fa or HFC-365mfc/HFC-227ea blend, which have GWP values of 1030 and 965, respectively (100 years ITH, IPCC 4th Assessment Report 2008). Recent publications show promising results with the new unsaturated HFC/HCFC blowing agents, commonly known as HFOs, that exhibit GWP values lower than 10 (Bodgan, 2011; Costa, 2011). These options present themselves as viable alternatives not only their low GWP but also their better safety performance in comparison with hydrocarbon technology. Flammability is the critical barrier to the spray foam applications where most foam applicators are small and medium scale enterprise and the nature of the applications where significant leakage of blowing agents make hydrocarbon unacceptable.

6. The project was designed to evaluate two HFO molecules as co-blowing agents with CO2 generated from the water-isocyanate reaction: HFO-1336mzz(Z) and HFO-1233zd(E) as per the project proposal that was approved by the ExCom. Figures 1 and 2 show the chemical formulas of the blowing agents evaluated in this project. The physical properties of the two HFO molecules are summarized in Table 2.

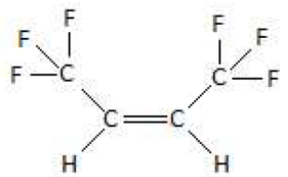
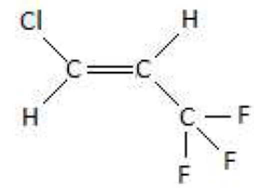
 cis-1,1,1,4,4,4-hexafluoro-2-butene	 (E) 1-chloro-3,3,3-trifluoropropene
Figure 1. HFO-1336mzz(Z)	**Figure 2.** HFO-1233zd(E)

Table 2: Physical Properties of HCFC-141b and HFOs

Property	**HCFC-141b**	**HFO-1336mzz(Z)**	**HFO-1233zd(E)**
Suppliers	-	Chemours	Arkema
Boiling Point (°C)	32	33	19
Thermal Conductivity of Gas (Mw/m.K) at 25oC	9.5	10.7	10
ODP	0.11	0	0
GWP	782	2	1

Project Objectives

(a) To strengthen the capacity of two local system houses to formulate, test and produce pre-blended polyol using HFOs (namely, HFO-1336mzz(Z) and HFO-1233zd(E)) for small and medium-sized enterprises (SMEs) in the PU spray foam sector;
(b) To validate and optimize the use of HFOs co-blown with CO2 for spray foam applications to achieve a similar thermal performance to that of HCFC-141b with minimum incremental operating costs (to optimize the HFO ratio to 10 per cent);
(c) To prepare a cost analysis of the different HFO-reduced formulations versus HCFC-141b-based formulations; and
(d) To disseminate the results of the assessment to system houses in Thailand and other countries.

7. The approved demonstration project selected Bangkok Integrated Trading (BIT) and South City Petroleum, which are the two major suppliers of HCFC-141b pre-blended polyol to spray foam enterprises in Thailand. The two companies have different baseline technical capacities. BIT is a small-scaled system house with one chemist in its research team, while South City Petroleum is a much larger chemical company with a variety of products in addition to polyol systems. South City Petroleum has more than 4 chemists in their research and development team.

8. The project started on November 13, 2017 after the sub-grant agreements were signed by the enterprises and Government Savings Bank (GSB), the financial agent for the Multilateral Fund supported projects in Thailand. The implementation of the project was completed on December 15, 2018.

Project Implementation

Table 3. Project Implementation Timeframe

Activities	Actual Date
Planning for system development and verification testing	December 2017
Specification of foaming equipment and site preparation	July 2018
Procurement and installation of equipment at the system houses	July 2018
Raw materials acquisition	September 2018
Trials/testing/analysis	December 2018
Report and Review meeting.	December 2018
Technology dissemination workshop	December 2018
End of formula development	Mid of December 2018
Project completion (External testing completion)	Mid of January 2019
Submission of PCR	February 2019

Experimental

Experimental Design

9. At the beginning of the project, an international expert on foam formulations visited the two companies and provided them with technical training on the theory of the PU foam technology, and the basic concept for conducting the experiments. However, the actual design and implementation of the experiment was the responsibility of each system house. Therefore, the actual research and development process was varied from one company to another depending on the baseline technical capacity and the final formulations could be different as they were designed to meet the need of the different groups of clients.

10. In general, the experiments were conducted in three stages. The first stage was to determine blend stability of different formulations. The second stage was to determine the lowest percentages of the blowing agents in the blended polyol that provide desirable reactivity including cream time, gel time, and tact-free time. Once these percentages were determined, additional tests were done to determine physical properties of the foam products. These physical properties were density, K-factor, compressive strength, and dimension stability. The properties of new formulations were compared with the baseline HCFC-141b formulations.

Bangkok Integrated Trading

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11. To determine the optimum percentage of the new blowing agents, reactivity tests were carried out for 5 different percentages by weight of blowing agent to polyol (i.e., 5%, 10%, 15%, 20% and 25%). Compositions of raw materials are shown in Tables 4 and 5.

Table 4: Compositions of raw materials in HFO-1233zd(E) blended polyol formulation

Percentage of Blowing Agent	5%	10%	15%	20%	25%
Polyol (kg)	18	18	18	18	18
Water (kg)	0.558	0.486	0.414	0.342	0.27
Blowing Agent: 1233zd(E) (kg)	0.9	1.8	2.7	3.6	4.5

Table 5: Compositions of raw materials in HFO-1336mzz(Z) blended polyol formulation

Percentage of Blowing Agent	5%	10%	15%	20%	25%
Polyol (kg)	18	18	18	18	18
Water (kg)	0.63	0.54	0.45	0.36	0.27
Blowing Agent: 1336mzz(Z) (kg)	0.9	1.8	2.7	3.6	4.5

12. The detailed foam formulations for HFO-1233zd(E) and HFO-1336mzz(Z) developed by BIT for this demonstration project are summarized in Tables 6 and 7. Each formulation consisted of polyol, blowing agent, catalyst and additive, and isocyanate. For this demonstration project, BIT used a blend of sucrose-initiated polyol, Mannich-initiated polyol and polyester-initiated polyol. In addition, a combination of at least three catalysts were used to achieve desirable blowing, gelling and trimerization reactions. The test results provided initial indications on the optimal percentages of the blowing agents which did not severely affect the reactivity of the formulation. Once the optimal percentages were determined, further refinement of formulations were carried out to address other foam properties. The final percentage of the blowing agents may be slightly different from these initial tests.

Table 6: Foam system formulation for various percentage of HFO-1233zd(E) blowing agent and cost impact

Ingredients/HFO-1233zd(E)	5%	10%	15%	20%	25%	HCFC-141b
Blend of polyols, parts by weight	100	100	100	100	100	100
Catalyst package, parts by weight	5.30	5.30	5.30	5.30	5.30	5.44
HFO-1233zd(E), parts by weight	5.97	11.93	17.90	23.86	29.83	30.14
Iso/polyol index	1.15	1.15	1.15	1.15	1.15	1.15
HFO mole fraction in cell gas	0.18	0.34	0.47	0.59	0.70	0.85
HFO percent in foam, %	2.01	4.06	6.15	8.28	10.45	9.88
Cost of PU system, US$/kg*	2.18	2.39	2.61	2.83	3.06	2.15
Reduction percent, %	79.64	58.85	37.70	16.15	-5.80	

*Best estimates based on the initial formulations provided by the enterprise.

Table 7: Foam system formulation for various percentage of HFO-1336mzz(Z) blowing agent and cost impact

Ingredients/HFO-1336mzz(Z)	5%	10%	15%	20%	25%	HCFC-141b
Blend of polyols, parts by weight	100	100	100	100	100	100
Catalyst package, parts by weight	7.46	7.46	7.46	7.46	7.46	5.44

HFO-1336mzz(Z), parts by weight	6.33	12.65	18.98	25.30	31.63	30.14
Iso/polyol index	1.15	1.15	1.15	1.15	1.15	1.15
HFO mole fraction in cell gas	0.14	0.27	0.40	0.52	0.65	0.85
HFO percent in foam, %	2.01	4.09	6.24	8.46	10.76	9.88
Cost of PU system, US$/kg*	2.22	2.60	3.00	3.41	3.83	2.15
Reduction percent, %	79.64	58.60	36.85	14.34	-8.95	

*Best estimates based on the initial formulations provided by the enterprise.

13. Reactivities of all the formulations shown in Tables 6 and 7 were conducted by using cup tests. The following parameters were measured: (i) cream time; (ii) gel time; (iii) tact-free time; and (iv) free-rise density. The results of these tests are shown in Table 8.

Table 8: Results of Reactivity Tests for both blowing agents

Blowing Agent	**HFO-1233zd(E)**					**HFO-1336mzz(Z)**				
Percentage	5%	10%	15%	20%	25%	5%	10%	15%	20%	25%
Cream time (sec)	4	4	4	4	4	5	5	5	5	5
Gel time (sec)	9	9	10	10	10	9	9	9	9	9
Tact-free-time (sec)	15	16	16	16	16	15	16	15	16	15
Free-rise Density (Kg/m3)	35.5	35.5	35.5	35.6	35.6	36.7	36.7	36.75	36.7	36.7

14. Based on the results of the reactivity tests, all foam formulations exhibited similar and acceptable cream time, gel time, tact-free-time and free-rise density for both HFO-1233zd(E) and HFO-1336mzz(Z). Additional tests on adhesion and foam shrinkage were conducted. The 5% formulations for both HFO-1233zd(E) and HFO-1336mzz(Z) provided poor performance on the adhesion and shrinkage. At the 10% level and higher, the HFO-1336mzz(Z) blown foam rendered acceptable adhesion performance, and shrinkage was found to be limited. Through the evaluation of foam adhesion and shrinkage, the final percentages of blowing agent of 13% and 10% were selected for HFO-1233zd(E) and HFO-1336mzz(Z) formulations, respectively.

Table 9. Experimental Design

Factors (Independent Variables)	**Levels**
	Bangkok Integrated Trading
Type of HFO	HFO-1336mzz(Z)
	HFO-1233zd(E)
Mole fraction of HFO into the gas cells (reduction percent of HFO compared to HCFC-141b formulation)	0.85 (0%)
	0.35 (59%) HFO-1336mzz(Z)
	0.45 (47%) HFO-1233zd(E)

15. BIT's baseline HCFC-141b foam formulation having 0.85 mole fraction in the gas cells was used as a reference standard. Three specimens for each blowing agents were produced. The objective of BIT is to reduce HFO in the formulation in order to maintain price competitiveness to the extent possible when comparing with HCFC-141b formulation. The 10% HFO-1336mzz(Z) formulation results in the reduction of the mole fraction of the blowing agent in the gas cells to 0.35, which is equivalent to 59% reduction compared to HCFC-141b. Similarly, the 13% HFO-1233zd(E) formulation reduces the mole fraction of the blowing agent in the gas cells to 0.45, which is equivalent to 47% reduction compared to HCFC-141b formulation.

16. The isocyanate/polyol index is 115/100 for HFO-1336mzz(Z) and 115/100 for HFO-1233zd(E). The gel time and the free rise density are kept constant for all the experiments.

Responses and Test Methods

17. Table 10 summarizes the responses and associated test methods employed for determining the respective responses.

Table 10. Responses and Test Methods Employed by Bangkok Integrated Trading

Table 8 Responses and Test Methods: Bangkok Integrated Trading			
Property		**Test**	**Testing Laboratory**
Reactivity at machine		Visual	In-house
Density		ASTM D-1622	In-house
K-Factor		ASTM C-518	In-house
Compressive strength		ASTM D-1621	In-house
Adhesion strength		Metal Sheet and Roof Tile	In-house
Dimensional stability		ASTM D-2126	In-house
Aging (*)	K-Factor	ASTM C-518	In-house
	Compressive Strength	ASTM D-1621	In-house
Fire Performance		ASTM D-568-77, ASTM D-635-03	KMUTT

(*) K-Factor and Compressive Strength: 2 weeks, 3 weeks, 1 month

Preparation of Foam Samples

18. After blending the fully formulated polyol, the fully formulated polyol and isocyanate were applied by using a high-pressure machine GRACO Reactor H-VR sprayer (financed by the Project) at the conditions shown in Table 11. The final spray foam sheet was made by spraying the mixture of formulated polyol and isocyanate horizontally back-and-fort on a large cardboard paper at a rate of 3 – 4 passes per one inch of thickness. The final foam sheet has a thickness of 4 – 5 inches. Three foam sheets were made (one for each blowing agent: standard HCFC-141b; 13% HFO-1233zd(E) formulation; and 10% HFO-1336mzz(Z) formulation). All foam samples/specimens for different blowing agents were made from the respective foam sheets by cutting the sheets into a number of pieces with specific dimensions conforming with testing standards summarized in Table 10.

Table 11. Spray Foam Conditions

Spray machine	GRACO Reactor H-VR Sprayer
Spray gun	Air Purge Spray Gun
Percentage by weight of CO_2, %	Not applicable
Ambient Temperature, ºC	28º – 32ºC
Relative Humidity, %	52% - 62%
Substrate Temperature, ºC	40ºC
Iso Temperature, ºC	50ºC
Polyol Temperature, ºC	50ºC
Primary Heater	Off

Hose length, m	15
Hose Temperature, ºC	50ºC
Static Pressure, psi	1,700
Dynamic Pressure, psi	1,700

Stability of Polyol Blend

19. Polyol blended with HFO-1336mzz(Z) using regular catalysts demonstrates excellent stability. To achieve the same results with HFO-1233zd(E), special catalysts are required. Polyol with catalysts and additives were mixed and retained in test tubes from 1 – 3 weeks. All formulations showed good stability. There was no precipitation observed after three weeks. Table 12 summarizes the reaction times of the three different foam formulations.

Table 12. Reactivities of Baseline Foam Formulations and those with New Blowing Agents

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
Mole fraction in the gas cells	0.85	0.45	0.35
Weight of blowing agent in formulation (%)	9.88	4.32	5.43
Reduction by weight (%)	0	56.25	44.99
Cream time (sec)	4	4	5
Tack free time (sec)	14	16	16
Cream time (sec) after 1 week	4	4	5
Tack free time (sec) after 1 week	14	16	16

20. The stability tests on foam reactivity and physical properties such as dimensional stability, K-factor, and compressive strength were conducted and the results of three different blowing agent formulations are shown in Tables 13 - 15. It was found that reactivity times of new foam formulations (with 13% of HFO-1233zd(E) are similar to reactivity times of HCFC-141b blown foam.

Table 13. Dimensional Stability

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
Foam density (kg/m^3)	38.04	38.77	39.07
Dimension stability 70ºC (%ΔV), 24 hrs	0.30	0.59	0.47
1st week	0.40	0.68	0.58
2nd week	0.46	0.73	0.63
Dimension stability -30ºC (%ΔV), 24 hrs	-0.64	-0.57	-0.70
1st week	-0.87	-0.77	-0.83
2nd week	-0.90	-0.82	-0.92
Dimension stability 70ºC+95% RH (%ΔV), 24 hrs	0.47	2.03	1.82
1st week	0.71	2.06	1.86

2nd week	0.94	2.13	2.02

21. The density of the foam blown with HFO-1233zd(E) an HFO-1336mzz(Z) was slightly higher than the density of the HCFC-141b blown foam. The density increase was less than 3% in comparison with the HCFC-141b blown foam. Dimension stability of foam produced with new HFO formulation was comparable to HCFC-141b blown foam. After two weeks, the foam dimension changes were within 1 - 2% for the three testing conditions (-30°C, 70°C, and 70°C with high humidity level).

Table 14. Comparison of K-Value of HFCF-141b with K-Factor of HFOs Blown Foam

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
Initial K-Factor (mW/m.K)	21.40	24.20	26.10
2nd week	22.00	24.90	27.00
3rd week	22.40	25.40	27.30
4th week	22.70	26.00	27.80

Note: The variance in densities of foam samples from unevenly spraying makes comparison a challenge.

22. The initial K-values of 13% HFO-1233zd(E) and 10% HFO-1336mzz(Z) blown foam were higher than the K-value of HCFC-141b blown foam. The increase is about 10% for the HFO-1233zd(E) formulation and about 20% for the HFO-1336mzz(Z) formulation). The insulation property gradually deteriorated over time. While the K-value of the HFO-1336mzz(Z) formulation was the highest; however, it showed a slower rate of increase after four weeks in comparison with the HFO-1233zd(E) formulation.

23. The 10% increase in the K-value was acceptable to BIT's spray foam customers. Hence, the HFO-1233zd(E) formulation was more desirable. To make the insulation performance of the HFO-1336mzz(Z) formulation comparable to the HFO-1233zd(E) formulation, BIT could have increased the amount of the blowing agent; however, such increase would result in a higher cost which was not desirable.

Table 15. Compressive Strength

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
Initial Compressive Strength (kPa)	184.80	188.20	190.59
2nd week	185.97	187.38	189.34
3rd week	183.94	188.75	191.49

Note: Compressive strength of test samples vary depending on quality of the foam cells which affects the compressive strength of the test samples.

24. The experiment showed that the compressive strength of spray foams produced by three different formulations were comparable and stable over the experiment period of three weeks.

Fire Performance

Table 16. Results of Fire Performance Tests Based on ASTM Standards

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
ASTM D568-77	-	Extinguished	Extinguished
ASTM D635-03	-	Extinguished	Extinguished

Note: Tests were conducted at KMUTT

25. The foam specimens based on the two HFO formulations were subject to fire safety tests which were conducted by King Mongkut University of Technology Thonburi's (KMUTT) laboratory. The testing procedures of ASTM D568-77 and ASTM D635-03 were employed. The test results confirmed that HFO-1233zd(E) blown foam and HFO-1336mzz(Z) foam met the fire safety standards.

Field Test

26. Two field tests were conducted at Bangkok Integrated Trading's facility. Two of its major customers were invited to witness the field test. The test simulates applying spray foam on the wall by spraying two new foam formulations against a metal sheet and roof tiles. Visual inspection and simple tests were conducted at the sites. Based on this set-up, the customers are satisfied with the basic properties of the spray foam made from both HFO-1233zd(E) and HFO-1336mzz(Z) formulations. These properties include cell size appearance, reaction time, adhesion and foam strength. The costs of the two formulations are similar. The customers preferred the spray foam made from HFO-1233zd(E) blowing agent due to its foam appearance.

Fig. 3 Field Demonstration of HFO blown foam (HFO-1233zd(E)) at BIT

Fig. 4 Field Demonstration of HFO blown foam (HFO-1336mzz(Z)) at BIT

Incremental Capital Cost

27. The demonstration project as approved by the ExCom also provided financial supports to BIT to acquire one spray foam machine and thermal conductivity testing machine. These pieces of equipment were critical to the development of new foam formulations and for demonstration of the final products. As described in the project proposal, the enterprise anticipated that reduction of the blowing agent in the formulation would require additional water content in the polyol system and that consequently led to the increasing ratio of isocyanate and polyol (different foam index). Therefore, the spray foam machine with adjustable ratios of isocyanate and polyol was acquired by the project. To facilitate development and testing of new formulation, the thermal conductivity testing machine was provided.

28. The spray foam machine purchased by BIT was made by a Graco machine (Model: Reactor H-VR). The injection rates of isocyanate and polyol could be varied within the range from 1:1 to 2.5:1. The thermal conductivity tester purchased by BIT are Thermtest Model HFM-100. The approved funding levels for the spray foam machine and thermal conductivity tester were US $40,000 and US $5,000, respectively. The actual costs paid by BIT were US $43,675 and US $29,821, respectively. Detailed financial information will be provided in the Project Completion Report.

Cost Effectiveness of BIT's HFO Based Formulations

29. Cost comparison and cost effectiveness of the two new foam formulations were calculate based on the chemical costs purchased by BIT. Table 17 was developed based on the following costs of the following chemicals: US \$3.20/kg of HCFC-141b; US \$16/kg of HFO-1233zd(E); and US \$22/kg of HFO-1336mzz(Z).

Table 17. Cost of Foam Production and Incremental Operating Cost of HFO Formulations

BIT	141b system			1233zd(E) system			1336mzz(Z) system		
	Parts	Unit Cost (US\$/kg)	Price	Parts	Unit Cost (US\$/kg)	Price	Parts	Unit Cost (US\$/kg)	Price
Polyol Blend	100.00	1.86	186.00	100.00	1.71	171.00	100.00	1.69	169.00
Additives & Catalysts	5.44	10.50	57.12	5.30	12.50	66.27	13.26	3.98	52.74
Other Additives	15.13	2.50	37.83	16.00	2.26	36.20	16.57	1.90	31.48
Blowing Agent	30.14	3.20	96.45	12.00	16.00	192.00	16.57	22.00	364.54
Sub-total	150.71		377.39	133.30		465.47	146.40		617.76
Isocyanate	154.48	1.80	278.06	144.41	1.80	259.94	158.60	1.80	285.48
Sub-total	154.48		278.06	144.41		259.94	158.60		285.48
Total	305.19		655.46	277.71		725.41	305.00		903.24
Price of foam (US\$/kg)			2.15			2.61			2.96
IOC (US\$/kg 141b)						4.72			8.24

30. While the cost of producing on kg of foam increased by 20% - 40% in comparison with the cost of the baseline foam produced with HCFC-141b. The incremental operating costs of the new HFOs formulations were about US \$4.72 – US \$8.24/kg of HCFC-141b.

South City Petroleum

31. Almost all spray foams in Thailand prefer to purchase polyol systems pre-mixed with a blowing agent. The objective is to replace HCFC-141b with HFO-1233zd(E) and HFO-1336mzz(Z) without significantly increasing the price of the pre-blended polyol since the spray foam market is extremely price sensitive. Because of this constraint, the company aims to develop new HFO formulations with the HFO content not exceeding 10% of the weight of the polyol without significantly compromising the foam performance. Reactivity tests were conducted for two different percentages of the blowing agents (both HFO-1233zd(E) and HFO-1336mzz(Z)) at 5% and 10% of the weight of the polyol. At the five percent of both blowing agents, the amount of the water content to compensate the lower amount of blowing agents exceeded 4.5% in the formulations. The higher water content demonstrates adverse effects on the foam stability. Hence, only the 10 percent blowing agent formulation was further developed. The isocyanate/polyol index of at least 120 was employed to reduce friability problems and increase the catalyst to enhance trimerization in order to improve flam retardant property and foam strength.

Table 18. Experimental Design

Factors	Levels		
Blowing Agent	**% Usage in Blended Polyol**	**Mole Fraction in Gas Cell**	**% Reduction**
HCFC-141b	30	0.84	
HFO-1336mzz(Z)	10	0.34	59.52
HFO-1233zd(E)	10	0.37	55.95
HFO-1336mzz(Z)	5	0.17	79.76
HFO-1233zd(E)	5	0.16	80.95

Type	HCFC-141b	HFO-1233zd(E)	HFO-1336mzz(Z)	HFO-1233zd(E)	HFO-1336mzz(Z)
	30%	10%		5%	
Initial mole fraction, CO_2	0.16	0.63	0.66	0.64	0.83
Initial mole fraction, blowing agent	0.84	0.37	0.34	0.16	0.17

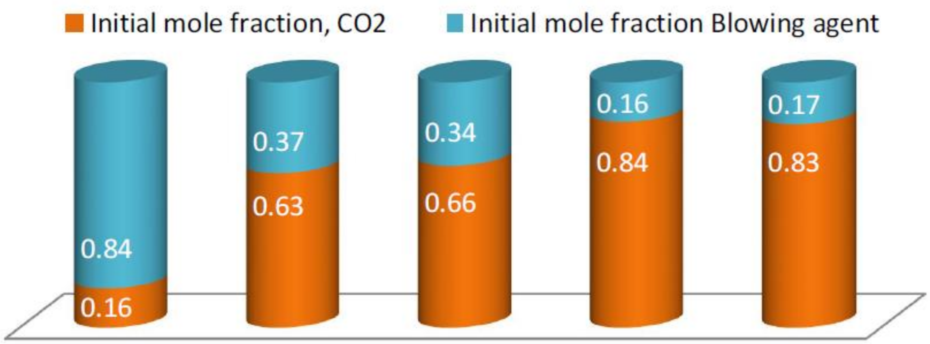


Fig. 5 Initial mole fractions of two co-blowing agents

Fig. 6 Cup tests for the two new HFO formulations

32. As mentioned above, the 5% HFO formulations contained more than 4.5% of water in the formulations. The high-water content could adversely affect chemical stability of polyester initiated polyols and some water-sensitive catalysts, which could result in formation of more opened cells, higher K factors and friability of the final foam products.

33. The characteristics of foam blown with 10% of HFO-1233zd(E) and HFO-1336mzz(Z) are summarized in Table 19. With 10% of the blowing agents, both formulations require an additional amount of water in order to maintain the free rise density at the same level as the HCFC-141b formulations.

Table 19. Characteristics of Foam with Alternative Glowing Agents

Type	**HCFC-141b**	**HFO1233zd(E)**	**HFO-1336mzz(Z)**
CO_2 moles/kg of polymer	0.23	0.63	0.68
Blowing agent moles/kg of polymer	1.24	0.36	0.34
Total gas moles/kg of polymer	1.47	0.99	1.02
Initial mole fraction, CO_2	0.16	0.63	0.66
Initial mole fraction, Blowing agent	0.84	0.37	0.34
Blowing agent in foam (%)	12.66	4.49	5.28
Reduction percent (%)	-	64.56	58.29

Preparation of Foam Samples

34. After blending the fully formulated polyol, the fully formulated polyol and isocyanate were applied by using a high-pressure machine GRACO Reactor H-VR sprayer (financed by the Project) at the conditions shown in Table 20.

Table 20. Spray Conditions

Spray Gun	Fusion AP
Injection pressure, psi	1200
Isocyanate temperature, ^{o}C	Room temperature
Polyol temperature, ^{o}C	40 - 45
Substrate (metal sheet and roof tile) temperature* ^{o}C	Room temperature (28^{o}C)

*Samples for adhesion tests

35. The final spray foam sheet was made by spraying the mixture of formulated polyol and isocyanate horizontally back-and-fort on a large cardboard paper at a rate of 3 – 4 passes per one inch of thickness. The final foam sheet has a thickness of 4 – 5 inches. Three foam sheets were made (one for each blowing agent: standard HCFC-141b; 10% HFO-1233zd(E) formulation; and 10% HFO-1336mzz(Z) formulation). All foam samples/specimens for different blowing agents were made from the respective foam sheets by cutting the sheets into several pieces with specific dimensions conforming with testing standards summarized in Table 21.

Table 21. Test Methods Employed by South City Petroleum

<table>
<tr><th colspan="5">Table X. Test Methods: South City Petroleum</th></tr>
<tr><th colspan="2">Property</th><th>Test</th><th>Testing Laboratory</th><th>Specimen Dimension</th></tr>
<tr><td colspan="2">Reactivity at machine</td><td>Visual</td><td></td><td></td></tr>
<tr><td colspan="2">Density</td><td>ASTM D-1622</td><td>In-house</td><td>10 cm * 10 cm * 10 cm</td></tr>
<tr><td colspan="2">K Factor</td><td>ASTM C-518</td><td>HFM-100 Heat flow meter from Thermtest, Canada and Eko Japan</td><td>30 cm * 30 cm * 2.54 cm</td></tr>
<tr><td colspan="2">Compressive Strength</td><td>ASTM D-1621</td><td>In-house</td><td>3 cm * 3 cm * 3 cm</td></tr>
<tr><td colspan="2">Adhesion Strength</td><td>Hand Peeling</td><td>In-house</td><td>Roof tile and netal sheet</td></tr>
<tr><td colspan="2">Dimension Stability</td><td>ASTM D-2126</td><td>In-house</td><td>10 cm * 10 cm * 10 cm</td></tr>
<tr><td colspan="2">Water Absorbent*</td><td>Volume (%)</td><td>In-house</td><td>10 cm * 10 cm * 2.54 cm</td></tr>
<tr><td rowspan="2">Aging*</td><td>K Factor</td><td>ASTM C-518</td><td>HFM-100 Heat flow meter from Thermtest, Canada and Eko Japan</td><td>30 cm * 30 cm * 2.54 cm</td></tr>
<tr><td>Compressive Strength</td><td>ASTM D-1621</td><td>In-house</td><td>3 cm * 3 cm * 3 cm</td></tr>
<tr><td colspan="2" rowspan="2">Fire Performance</td><td>UL94</td><td>National Metal and Materials Technology Center (MTEC)</td><td>1.3 cm * 12.5 cm * 1.3 cm</td></tr>
<tr><td>ASTM D-568 and ASTM D-635</td><td>Institute for Scientific and Technological Research and Services (ISTRS), King Mongkut University of Technology Thonburi (KMUTT)</td><td>50 cm * 10 cm * 3 cm</td></tr>
</table>

*K factor: 1 week and 1 month; compressive strength: initial and 1 month; and water absorbent: 2 hours and 24 hours.

Stability of Polyol Blend

36. The stability of fully formulated polyol was evaluated by monitoring the hand-mixed reactivity in the laboratory. The results are summarized in Table 22.

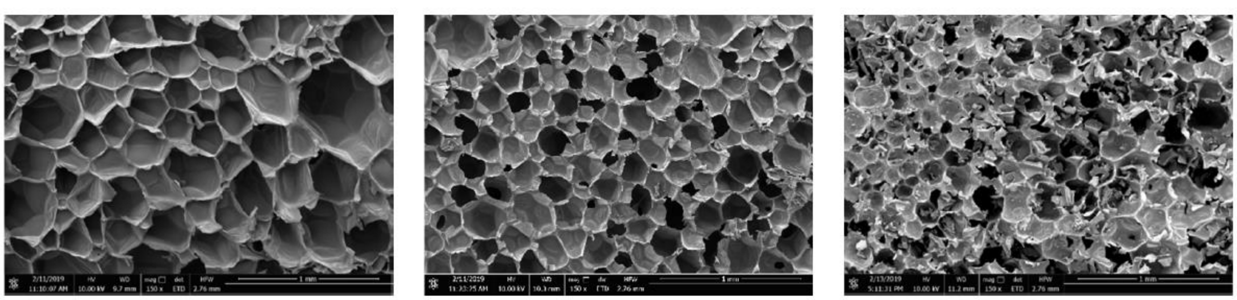
Table 22. Stability of Polyol Blends

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**			**HFO-1336mzz(Z)**		
Mole fraction in gas cells	0.84	0.37			0.34		
Weight percent of blowing agent in formulation (%)	30.00	10.00			10.00		
Mole fraction different percent (%)	-	55.95			59.52		
Chemical characteristics	initial	initial	2nd Week	4th Week	initial	2nd Week	4th Week
Cream time (sec)	3	4	4	4	4	4	4
Gel time (sec)	5	6	6	6	6	7	6
Track free time (sec)	8	7	7	7	7	8	7
End of rise (sec)	12	13	13	14	14	14	15
Cup density (kg/m^3)	30.63	32.98	34.45	34.96	35.14	35.68	36.55
Upper cup density (kg/m^3)	26.09	26.29	25.59	26.86	27.23	28.13	26.26

37. All samples were kept at the normal room temperature which is the industry practice for storing the raw materials. The results confirmed that reaction activities of both HFO formulations are quite stable. However, it was still advisable that the HFO-1233zd(E) pre-blended polyol be stored in air-conditioned room as the temperature of the storage rooms could become much higher in summer.

Cell Structure Appearance

38. Cell structures of foams produced by different blowing agents are showed in Fig. X. The test results confirmed that foams produced by the three formulations (30% HCFC-141b; 10% HFO-1233zd(E); and 10% HFO-1336mzz(Z) contained mostly spherical shapes resulting in higher compressive strength and good dimension stability. However, the test results also showed that due to a higher water level in the formulations, the foam structures contained more opened cells.



(a) 30% HCFC-141b (b) 10% HFO-1233zd(E) (c) 10% HFO-1336mmz(Z)

Fig. 7 Cell Structures of Foam Produced from Three Different Blowing Agents

Compressive Strength

39. Comprehensive strength of foam produced with three different blowing agents: (i) 30% HCFC-141b formulation; (ii) 10% HFO-1233zd(E) formulation; and (iii) 10% HFO-1336mzz(Z) formulations was measured immediately after the production and one month later. For each formulation, separate sets of samples were tested for the initial compressive strength and the compressive strength after 1 month. Since the foam samples were made from larger foam sheets that were sprayed manually, the property of the foams may not be consistent, and it may affect the accuracy of the results.

Table 23. Compressive Strength (kPa)

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
Initial	194.00	256.00	206.00
1 month later	189.73	204.77	244.37

40. In spite of the above imperfection, the test results suggested that the new HFO formulations provided the final foam products with higher compressive strength than the foam products made with the HCFC-141b formulation. This improvement may be attributed to the use of different combinations of polyol types to compensate with the counter effect from the higher level of water in the formulations.

Dimension Stability

41. The dimension stability tests were conducted at two different temperature levels at two different occasions. The first tests were undertaken one week after the foam samples were made, and the second tests were done another week later. At both temperature levels, the foam products made by the new formulations exhibited acceptable dimension stability. That is, the volumes of the samples changed less than 2% during the first two weeks after the samples were made. The results are shown in Table 24.

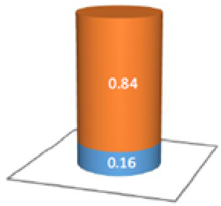
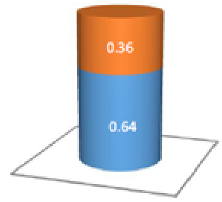
Table 24. Results of Dimension Stability Tests

Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
Foam Density (kg/m^3)	38.18	39.51	34.64
Dimension Stability at 70 ºC (%ΔV)			
1st Week	1.96	0.43	-0.56
2nd Week	1.90	0.37	-0.71
Dimension Stability at -30 ºC (%ΔV)			
1st Week	-0.34	-0.46	-0.48
2nd Week	-1.39	-0.46	-0.31

K-Factor

42. The test results confirmed that the new HFO formulations had higher thermal conductivity than the HCFC-141b formulation. This was anticipated since the HFO formulations resulted in foam products with a higher mole fraction of CO_2 in the foam cells.

Table 25. K-Factors (mW/mK)*

Blowing Agent	HCFC-141b		HFO-1233zd(E)		HFO-1336mzz(Z)	
Mole Fraction in Gas Cell Blowing Agent CO_2						
Foam Density (kg/m^3)	38.57	40.67	47.82	44.38	43.86	47.24
1st Week	20.00	21.94	24.74	22.19	26.88	21.58
4th Week	23.40	23.70	28.56	29.50	31.16	30.70

*Upper temperature: 35ºC; Lower temperature: 15ºC; Mean temperature: 25ºC

43. Because of the expected ununiform foam structure due to the manual spray operations, two samples were used for each test condition. The variance densities of the foam samples were the outcome of the unevenly spraying process.

44. In general, it was still reasonable to draw a conclusion that the foam products manufactured from the two HFO formulations had higher thermal conductivity that those produced with the HCFC-141b formulations. This was the direct implication of having a higher mole fraction of CO2 in the gas cells. However, the increase was slightly higher, which was around 21.58 – 26.88 mW/mK, when the foam products were kept at the room conditions for one week. This range was acceptable to the industry. The thermal conductivity continued to change over the course of one month.

Hand Peeling Adhesion Tests

45. Since most spray foam applications in Thailand were done on metal sheet roof and roof tile or concrete, the adhesion tests were made to demonstrate the adhesion strength of the spray foams against these two substrates. The samples were prepared by spraying three different fully blended polyols and isocyanate on the two substrates at 28ºC. The adhesion tests were done by peeling the foam out from the substrates. Three different failure types including the foam adhesive failure, thin layer cohesive failure, and cohesive failure, were observed. It was considered an adhesive failure if the foam could be removed completely from the surface. The thin layer cohesive failure was considered if it left a thin layer of foam on the surface of the substrates. Foams with a good adhesion property were those foams that could not be peeled off from the surface of the substrates. The peeling force applied to the samples would result in foam cracks. The test results are summarized in Table 26.

Table 26. Hand-Peeling Adhesion Test Results

Materials	HCFC-141b	HFO-1233zd(E)	HFO-1336mzz(Z)
Metal sheet roof	**100% Thin layer Failure**	**100% Thin Layer Failure**	**100% Thin Layer Failure**
Adhesion Performance	Good	Good	Good
Roof tile	**100% Cohesive Failure**	**100% Cohesive Failure**	**100% Cohesive Failure**
Adhesion Performance	Excellent	Excellent	Excellent

46. All foams adhered excellently on the roof tile. High peeling force was required and resulted in breaking the foam. This failure mode is shown in Fig. 8.

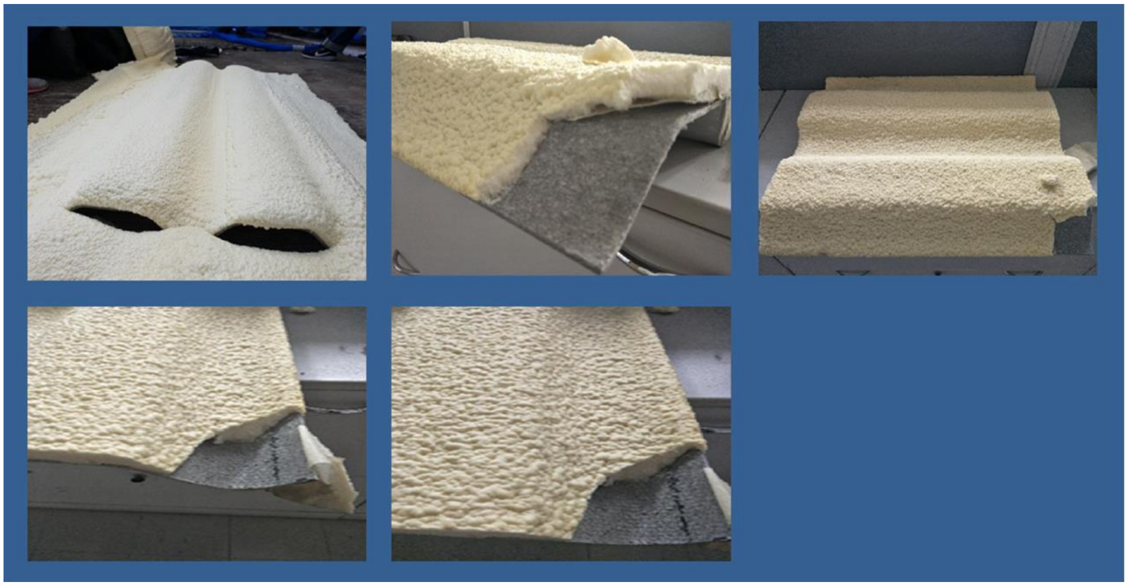


Fig. 8 Hand-peeling tests for spray foam with a roof tile as substrate

47. For the metal roof surface, all foams were peeled out of the surface of the substrate by high peeling force; however, there was thin skin of foam remaining on the metal surface as shown in Fig. 9.

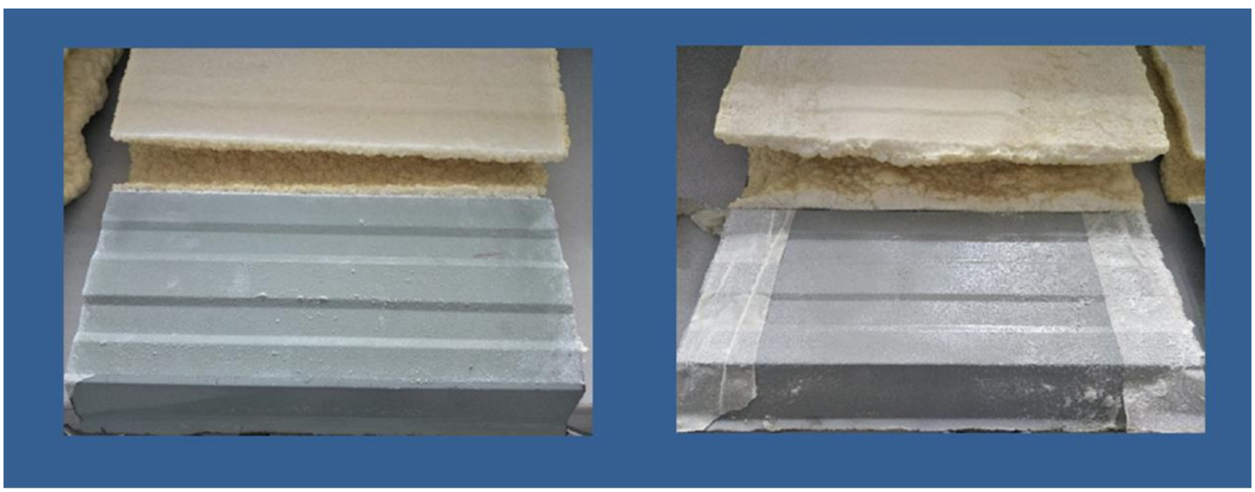


Fig. 9. Hand-Peeling Tests for spray foam with metal roof sheet as a substrate.

Water Absorbent

48. South City Petroleum also conducted water absorbent tests of their baseline and new HFO formulations because this property was considered as one of the key parameters in its product specifications. Four samples from each formulation were prepared. The four samples were divided into two groups. The first two were immerged into water for two hours. Another set of two samples for each formulation were immerged into water for four hours before the tests were taken.

49. The results of the water absorbent tests for a total of 12 samples produced with three different formulations were summarized in Table 27.

Table 27. Water Absorbent Test Results (%Volume)

Blowing Agent	**HCFC-141b**		**HFO-1233zd(E)**		**HFO-1336mzz(Z)**	
Dipping period	2 hrs.	24 hrs.	2 hrs.	24 hrs.	2 hrs.	24 hrs.
Sample 1	0.83	2.61	1.01	3.11	1.06	3.11
Sample 2	1	2.34	1.51	4.27	1.55	3.81

50. Foam samples made from the two new HFO formulations demonstrated higher percentage of water absorbent that the HCFC-141b formulated foam samples. The higher water absorbent in the HFO formulations was the results of more opened cells in the foam structure due to the increasing water content in the HFO formulations which was required to compensate for the lower quantity of the blowing agents.

Fire Performance

51. Flame retardant property of foams blown with different blowing agents was conducted by employing two different international standards: (i) UL 94; and (ii) ASTM -568 and ASTM D-635. Foam samples made from the two HFO formulations passed the UL 94 standard V-0 level tests. The foam samples that were subject to a vertical flame stopped within 10 seconds and the foam drips were not inflamed.

52. The ASTM D-568 standard tests confirmed that the foam samples made with the HFO formulations were self-extinguished within 1 – 2 seconds when they were subject to a vertical flame. Moreover, the burn propagated less than 3 mm. Similarly, the ASTM D-635 standard tests for a horizontal flame position also yielded the same results for the samples made from the two HFO formulations. Therefore, these foam samples were considered to meet ASTM D-568 and D-635 standards. The test results based on both standards are summarized in Table 28.

Table 28. Fire Performance Test Results

Table XX. Fire Performance Test Results			
Blowing Agent	**HCFC-141b**	**HFO-1233zd(E)**	**HFO-1336mzz(Z)**
UL 94	V-0	V-0	V-0
ASTM D-568 and ASTM D-635	Self-Extinguished	Self-Extinguished	Self-Extinguished

Field Tests

53. Because of a lower quantity of an HFO blowing agent in order to keep the product cost competitive, the rising of foam had to be compensated by generating CO2 as a co-blowing gas from the additional water content to enhance the water-isocyanate reaction. Therefore, the new HFO formulations, which had a higher water content, consumed more isocyanate. The ratio between the HFO blended polyol and isocyanate was adjusted to about 0.78:1 or 0.82:1 by volume. However, most Thai spray foamers only had spray machines with a fixed ratio at 1:1 by volume. As a result, the field tests were then operated at South City Petroleum's facility.

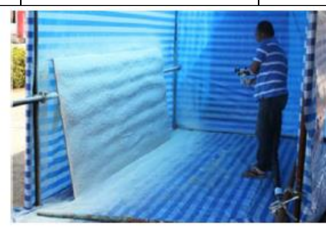
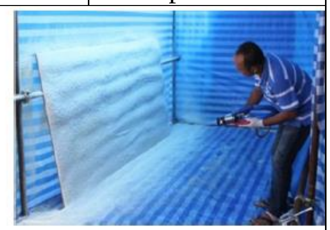
54. Two major spray foam companies in Thailand (Narongrit, and Lohr Trade and Consulting) were invited to participate in the field test on December 11, 2018. Both spray foam companies had opportunities to use South City Petroleum's spray machine funded by the MLF to spray the two new HFO formulations

and to inspect the final foam products. At the end of the field test, both enterprises were asked for their opinions on the following: chemical reaction, foam appearance, foam strength, adhesion performance, and the overall view of the two new HFO formulations. The results of the interviews were included in Table 29.

Table 29. Field Test Interview Results

Filed Test	**HFO-1233zd(E)**		**HFO-1336mzz(Z)**	
	Narongrit	**Lohr Trade and Consulting**	**Narongrit**	**Lohr Trade and Consulting**
Chemical reaction	Little slow	Appropriate	Appropriate	Little fast
Foam cell appearance	Appropriate	Appropriate	Appropriate	Appropriate
Foam strength	Appropriate	Appropriate	Appropriate	Appropriate
Adhesion on substrate	Fair	Good	Fair	Fair
Satisfaction	Reaction time to be improved	Appropriate	Appropriate	Reaction time to be improved



55. Both invited enterprises were confident that the HFO formulations could be used in the Thai industry as a replacement for the HCFC-141b formulation. They were satisfied with the cell size appearance, reaction time, adhesion and foam strength. The only area of improvement suggested by the enterprises was the reaction time. One suggested that the HFO-1233zd(E) formulation should be improved to have faster reaction, while another suggested to slow down the reaction time of the HFO-1336mzz(Z) formulation.

Incremental Capital Cost

56. The demonstration project as approved by the ExCom also provided financial supports to South City Petroleum to acquire one spray foam machine and thermal conductivity testing machine. These pieces of equipment were critical to the development of new foam formulations and for demonstration of the final products. As described in the project proposal, the enterprise anticipated that reduction of the blowing agent in the formulation would require additional water content in the polyol system and that consequently led to the increasing ratio of isocyanate and polyol (different foam index). Therefore, the spray foam machine with adjustable ratios of isocyanate and polyol was acquired by the project. To facilitate development and testing of new formulation, the thermal conductivity testing machine was provided.

57. The spray foam machine purchased by South City Petroleum was made by a Graco machine (Model: Reactor H-VR). The injection rates of isocyanate and polyol could be varied within the range from 1:1 to 2.5:1. The thermal conductivity tester purchased by South City Petroleum are Thermtest Model HFM-100. The approved funding levels for the spray foam machine and thermal conductivity tester were US $40,000 and US $5,000, respectively. The actual costs paid by South City Petroleum were US $41,692 and US $22,253, respectively. Detailed financial information will be provided in the Project Completion Report.

Cost Effectiveness of South City Petroleum's HFO Based Formulations

58. Cost is the major issues in this industry. The new HFO formulations must be price competitive in comparison with the current HCFC-141b formulations. Table 30 provides cost comparison between the HCFC-141b formulations and the two HFO formulations. The following costs of the blowing agents were use in the calculation: US $2.86/kg of HCFC-141b; US $14/kg of HFO-1233zd(E); and US $20/kg of HFO-1336mzz(Z).

Table 30. Cost of Foam Production and Incremental Operating Cost of HFO Formulations

South City Petroleum	141b system			1233zd(E) system			1336mzz(Z) system		
	Parts	Unit Cost (US$/kg)	Price	Parts	Unit Cost (US$/kg)	Price	Parts	Unit Cost (US$/kg)	Price
Polyol Blend	100.00	1.76	175.70	100.00	1.58	158.03	100.00	1.58	158.03
Additives & Catalysts	5.27	9.36	49.32	12.90	12.68	163.54	16.13	6.75	108.88
Other Additives	24.03	1.84	44.16	18.68	1.84	34.42	15.19	2.27	34.42
Blowing Agent	40.27	2.86	115.07	13.16	14.00	184.24	13.13	20.00	262.60
Sub-total	169.57		384.25	144.74		540.23	144.45		563.93
Isocyanate	231.80	1.68	390.44	135.40	1.68	228.07	137.72	1.68	231.97
Sub-total	231.80		390.44	135.40		228.07	137.72		231.97
Total	401.37		774.70	280.14		768.30	282.17		795.91
Price of foam (US$/kg)			1.93			2.74			2.82
IOC (US$/kg 141b)						8.10			8.88

59. For the HFO-1233zd(E) formulation, a new catalyst package was required to overcome the formulation stability. While the cost of HFO-1233zd(E) was significantly lower than the cost of HFO-1336mzz(Z), the cost of the new innovative catalyst package for HFO-1233zd(E) made the overall incremental operating cost of the HFO-1233zd(E) formulation only slightly less expensive than the HFO-1336mzz(Z) formulation.

Summary

60. The results of the demonstration project to develop reduced HFO polyol formulation systems at BIT and South City Petroleum confirmed that the spray foam formulations with HFO blowing agents of about 10% of the polyol weight and proper adjustments on the choice of polyol and the catalyst package could yield the foam properties that were still acceptable to the Thai spray foam market. While the HFO-1233zd(E) formulation demonstrated instability in the formulation, the issue could be solved by introducing a new catalyst package. Spray foams blown with HFOs exhibited adhesion performance that was acceptable to the market.

61. Reactivity time of the new reduced HFO formulations is similar to the HCFC-141b formulation. This was acceptable to the Thai market. Density of spray foam made from the reduced HFO formulations was slightly higher than the baseline HCFC-141b formulation. The slight increase in the compressive strength was also observed. Similarly, the initial K-factors of the reduced HFO formulations were 20 – 30% higher than the HCFC-141b formulation. All properties of HFO blown foams were quite stable over time. Both HFO formulations passed the fire performance tests.

Table 31. Summary of Key Performance of HFO Formulations of BIT and South City Petroleum

	BIT		South City Petroleum	
	-1233zd(E)	-1336mzz(Z)	-1233zd(E)	-1336mzz(Z)
Reactivity				
Cream time (sec)	4	5	4	4

Gel time (sec)	9	9	6	6
Tack-free time	16	16	7	7
Foam Properties				
Foam Density (kg/m^3)	38.77	39.07	39.51	34.64
K-Factor (mW/m.K)	24.20	26.10	24.74	26.88
Compressive Strength (kPa)	188.20	190.59	256.00	206.00
Cost				
Cost of PU System ($/kg foam)	2.61	2.96	2.74	2.82
Incremental Operating Cost ($/kg HCFC-141b)	4.72	8.24	8.10	8.88

62. Reduction of the blowing agents required an additional amount of water to generate CO2 from the water-isocyanate reaction. Consequently, an additional amount of isocyanate which made the polyol and isocyanate ratio by volume deviated from 1:1 was required. Most spray foam enterprises in Thailand would have to either retrofit or replace their existing spray machine to be able to apply these new formulations.

National Ozone Unit (NOU) at Environment Public Authority (EPA) of Kuwait

In cooperation with

UNIDO & UNEP

Comparative Study to Analyse NIK Technologies for Central Air Conditioning Applications in Kuwait

Final Report

October 2018

Project Coordinators:
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UNEP: Ayman Eltalouny
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Comparative Study to Analyse NIK Technologies for Central Air Conditioning Applications in Kuwait

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Introduction

At the 75th EXCOM, UNIDO resubmitted requests for this proposal for feasibility studies, in line with decision 74/29 (originally 72/40), to develop a business model for district cooling in Kuwait and Egypt. UNIDO is the lead implementing agency and UNEP is the cooperating agency for both studies.

The feasibility study objective is to provide a detailed technical, financial as well as environmental and energy assessment / road map for the government of Kuwait, in the development of Central A/C systems. The focus of the feasibility study will be a full comparative analysis of three not-in-kind technologies namely:

I. Deep Sea Water free cooling.
II. Waste heat absorption and
III. Solar assisted chilled water absorption systems

Being considered the most promising for Kuwait.

The deliverables of the feasibility study will be:

1. Assessment of the most suitable not-in-kind technology for Central AC systems
2. Assessment of available renewable energy sources,
3. Assessment of legalization barriers,
4. Assessment of energy saving mechanisms,
5. Assessment of environmental benefits
6. Development of a financial structure and financial scheme for both, governmental co-financing mechanisms, including the possibility of providing incentives for private companies.

The project was approved by the 75th EXCOM in accordance to the following decision:

> *20. For Kuwait, the focus of the feasibility study will be a full comparative analysis of three not-in-kind technologies: deep sea water free cooling, waste heat absorption and solar assisted chilled water absorption systems, to determine which may be the most promising option for central air-conditioning systems.*
>
> *21. The following activities will be implemented:*
>
> *(a) A literature review on the current status of deep sea water free cooling, waste heat absorption, and solar assisted chilled water absorption systems;*
>
> *(b) Analysis of renewable energy sources, legal barriers, energy saving mechanisms, environmental benefits; and*
>
> *(c) Development of a financial structure and financial scheme for both the Government, co-financing mechanisms (including the possibility of reducing energy subsidies), and private energy providers.*

Project Objectives

The focus of the feasibility Study is to comparatively assess three not-in-kind technologies for central AC and DC; and provide technical and economical evidence to be disseminated to government officials as well as private investors. This feasibility study will address:

- Use of not-in-kind technologies
- Central A/C technology options;
- Legalization Barriers;
- Energy saving mechanisms;
- Governmental co-financing mechanism

Project Context

UNIDO and UNEP have been implementing a demonstration project for a detailed technical, financial as well as environmental and energy assessment / road map for the government for

Kuwait, in the development of Central A/C systems. The focus of the feasibility study will be a comparative analysis of three not-in-kind technologies namely deep-sea water free cooling, waste heat absorption and solar assisted chilled water absorption systems that are being considered the most promising for Kuwait.
In addition, the most suitable Not-In-Kind (NIK) cooling technology will be selected to air condition two sites, a school and a mosque. Conceptual designs are prepared, each design shall be governed by the principle of energy conservation, adopting together with conventional In-Kind (IK) cooling other suitable techniques NIK cooling techniques to provide substantial savings in operating costs.

1.0 Selection Criteria for the Two Sites

Questionnaires were prepared, see annex 1, based on a point system to help evaluate selection of the best sites/buildings suitable for application of NIK cooling technologies. Unfortunately, this selection process did not provide tangible results because the best sites selected were not assessable to a deep-seawater source, reject heat sources or downstream natural gas piping network (solar assisted absorption cooling). Eventually, general construction plans were obtained for candidate sites that are to be built by "Kuwait Public Authority for Housing Welfare (KPAHW)" and those satisfied one important NIK cooling technology; Two Stage Direct Indirect (TSDI) evaporative cooling.
Sites that are in the planning stage were preferred also buildings designs that are to be repetitively constructed in future at other sites.
In total four different candidate building sites were proposed by KPAHW.
Those are:

1. ***A school***. The school central air-conditioning system, utilising 5 air cooled chillers, each 200 TR refrigeration capacity, total capacity 1000 TR. The school air conditioning design IK design was provided.
2. ***A Medical Centre.*** Comprising small operating theatres, emergency units and other medical facilities. The Medical Centre has a designed IK central air conditioning system using DX units. Unfortunately, the design documents were not complete, and it proved impossible to obtain enough data to form an accurate idea on refrigeration loads, schedule of equipment and other vital design data on time to consider this selection seriously.
3. ***A small mosque.*** Although the mosque architectural and civil design data were complete, no central air conditioning system was provided. This excluded the use of this mosque because of the time needed to estimate cooling loads and create a central air conditioning design.
4. ***A large central mosque***. A complete central air conditioning IK design was provided. The air conditioning IK design documents were complete and were enough to get a complete and full picture on the IK design.

It was decided to select site 1 and 4 as the two designated sites for changing their air conditioning design from IK to NIK or NIK assisted by IK.
It is important to note that the selection of the sites fulfilled two important criteria:

I. Sites are important to the country's construction policy represented by Kuwait Public Authority for Housing Welfare (KPAHW) building program.
II. Construction plans are well developed but not too far developed that NIK cooling cannot be integrated into it.

The two buildings selected were ideally suited for Two Stage Direct Indirect (TSDI) evaporative cooling. This is especially important given the importance of the recommendations of increasing fresh air (outdoor air) in those applications of schools and public gathering areas.

2.0 Compilation of Technical Solutions

The relevant technical solutions chosen for the demonstration of cooling systems are examined such as fluorocarbon chillers (In- Kind cooling technology), non-fluorocarbon chillers (Not-In-Kind cooling technology), distribution piping network, load interface techniques and energy calculation methods. The compilation of technical information on relevant technical solutions chosen for the demonstration of NIK cooling systems encompass the following solutions compiled:

- Systems utilising In-Kind cooling technologies or fluorocarbon chillers.
- Systems using Not-In-Kind cooling technologies or non-fluorocarbon chillers.
    - Systems operating by deep sea cooling or cooling/heating.
    - Reject exhaust heat or flue gas streams fired absorption systems.
    - Solar assisted chilled water absorption systems.
    - Natural gas fired double effect absorption chillers/heaters systems.
    - Steam or hot water indirect fired absorption systems.
- Distribution piping networks pumping arrangements.
- District cooling for a city using reject heat in power stations
- Load interface techniques and energy calculation methods.
- Daily cooling load profile curves, diversity factors and Thermal Energy Storage (TES).

Details on each solution and suitability for the case is described in detail in annex-2.

3.0 Kuwait Climatological Conditions and the Concept of Two-stage Direct/Indirect (TSDI) evaporative cooling.

The two sites suggested by "Kuwait Public Authority for Housing Welfare (KPAHW)" were not within easy access to the Gulf for a Deep-Sea Cooling system use, nor were they near an exhaust heat source or a downstream natural gas pipeline to use with a solar assisted cooling system. The two sites were however most suited for using an NIK system, a two stage direct/indirect evaporation system. Kuwait being a low humidity country, especially in summer, makes it ideal for using the system at high efficiency when most needed. The system was adopted for both sites, as shown later.

3.1 Kuwait Climatological Conditions.

Kuwait enjoys remarkably low relative humidity conditions during summer, which makes it ideally suited for the use of TSDI evaporative cooling. Table 3.1 below shows basic Climatological readings in Kuwait, for 2002.

The year was arbitrally chosen according to information made available. The date stated is the one at which the highest dry bulb temperature occurred for the designated month. Coincident dew point, wet bulb and relative humidity are shown.

Table 3.1 Kuwait Highest monthly dry bulb, coincident dew point, wet bulb and relative humidity.

Kuwait Date, 2002	Hour	Highest T_{db}, °C	Coincident		
			Dew point, °C	T_{wb}, °C	Relative Humid. %
09.01	14:00	23.5	6.6	13.970	33.652
14.02	15:00	25.6	-0.3	12.499	18.154
31.03	15:00	31.8	3.5	15.975	16.691
22.04	15:00	36	13.8	21.298	26.537
22.05	15:00	44.2	1.8	19.663	7.56
29.06	15:00	47.9	4.7	21.513	7.684
06.07	16:00	45.7	3.8	20.624	8.066
14.08	15:00	49.7	4	21.851	6.686
02.09	14:00	46.6	4.5	21.079	8.093
01.10	15:00	38.8	11.2	20.997	19.213
06.11	15:00	32.5	14.3	20.492	33.302
14.12	15:00	21.9	10.3	14.983	47.663

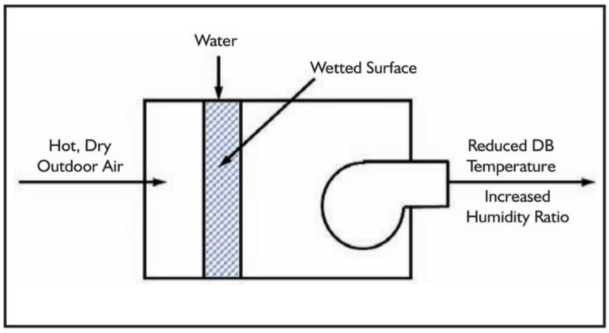
The table shows that during November, December and January the high humidity ratio shall not provide enough TSDI cooling, if needed, and IK cooling may be needed. Otherwise, in March, April May, June, July, August, September and October TSDI cooling will operate well because of the low relative humidity (19.2 % to 6.7 %). This study is based on this criterion.

The two sites/buildings are redesigned to operate primarily on TSDI evaporative units with IK chilled water or DX units assisting in times when humidity is highest, providing the bulk of the cooling capacity needed during those eight months.

Furthermore, if Thermal Energy Storage (TES) tanks of the stratified type can be added to the system in order to reduce further the installed IK capacity. TES tanks stores cooling enthalpy at off-peak times and release it at on-peak time. This helps reducing installed capacity because energy is produced at night-time, when climatic temperatures are milder, saving energy further in the order of 10 to 20 %. However the scope of the study did not permit the exploration of this novel feature.

3.2 The Concept of Two Stages direct/Indirect (TSDI) evaporative cooling

Direct evaporative cooling is an old technology, useful in low wet bulb ambient temperature regions, since it relies on reducing the conditioned air temperature by evaporating water in the stream and using the water latent heat to reduce air temperature. Indirect evaporative cooling allows cooling the air stream without raising its humidity and allow using the system in hybrid arrangements with other cooling systems. This expands the use of indirect evaporative cooling; improving its efficiency while reducing water consumption



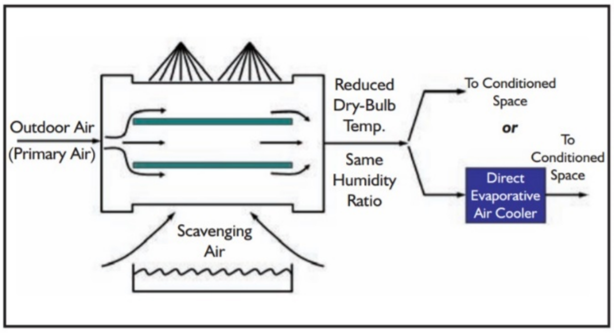


Figure 3.1: Basic direct evaporative cooler Indirect or indirect-direct evaporative cooler.

Figure 3.1 shows a schematic diagram of both systems. Indirect evaporative cooling using a secondary stream, not in directly contact with the primary stream, cools the outdoor air. The humidity of the primary stream thus does not rise. By combining both direct and indirect evaporative cooling air cooling quality improves.

In figure 3.1 the primary air is cooled in the first stage using an air heat exchanger. Primary air, which flows inside the heat exchanger, is cooled without raising its humidity. It is then cooled again by direct evaporative cooling in the second stage and its humidity is raised. Another direct/ indirect cooling system cools the water (not the primary air) in the first stage. The cooled water flows to a fin and tube heat exchanger cooling another stream of outdoor air reducing its temperature and humidity. The second stage cools the air by evaporative cooling.

Figure 3.2: An Indirect Evaporative Cooling module.

In Figure 3.2, shows a modular indirect evaporative cooling module comprising the heat exchanger section. Figure 3.3 shows the airflow pattern in and around the heat exchanger.

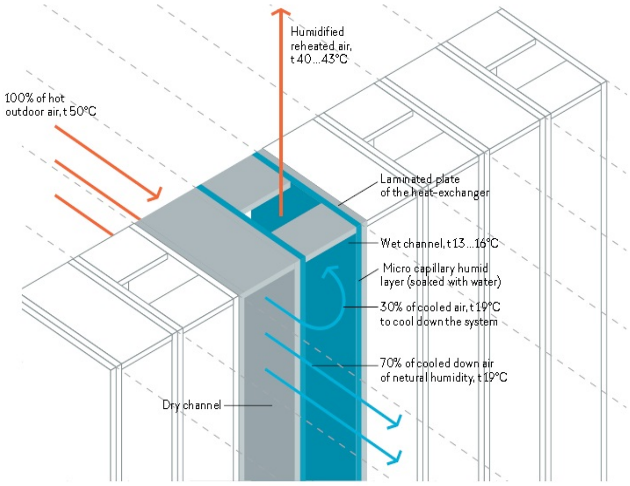


Figure 3.3: Details of air flow in and around an indirect evaporative cooling heat exchanger

Manufacturers of commercially available units claim to provide supply air at the following temperatures at 50º C conditions:

	Ambient Conditions	
	Condition 1 **50ºC dry bulb/28ºC wet bulb**	**Condition 2** **50ºC dry bulb/19ºC wet bulb**
Supply air		
Achieved conditions:		
Dry bulb, ºC	25.7	13.8
Wet bulb, ºC	21.7	3.8

The higher wet bulb temperature in the initial condition one (t db= 50 ºC, t wb=28 ºC), resulted in supply air at a higher t db (25.7 ºC) compared to initial condition 2 (t db= 50 ºC, t wb=19 ºC) where supply air t db dropped to 13.8 ºC.
Water consumption at those conditions is about 1.2 l/hr per kW. Water consumption may rise to about 2.5 l/hr per kW at maximum elevated dry bulb temperatures at Kuwait extreme summer conditions, when outdoor wet bulb temperatures are over 28ºC, in certain climate zones, a hybrid system is used utilizing a mechanical vapour compression, an IK system, to assist until those harsh conditions are not prevailing. The system then switches back to Indirect Evaporative Cooling.

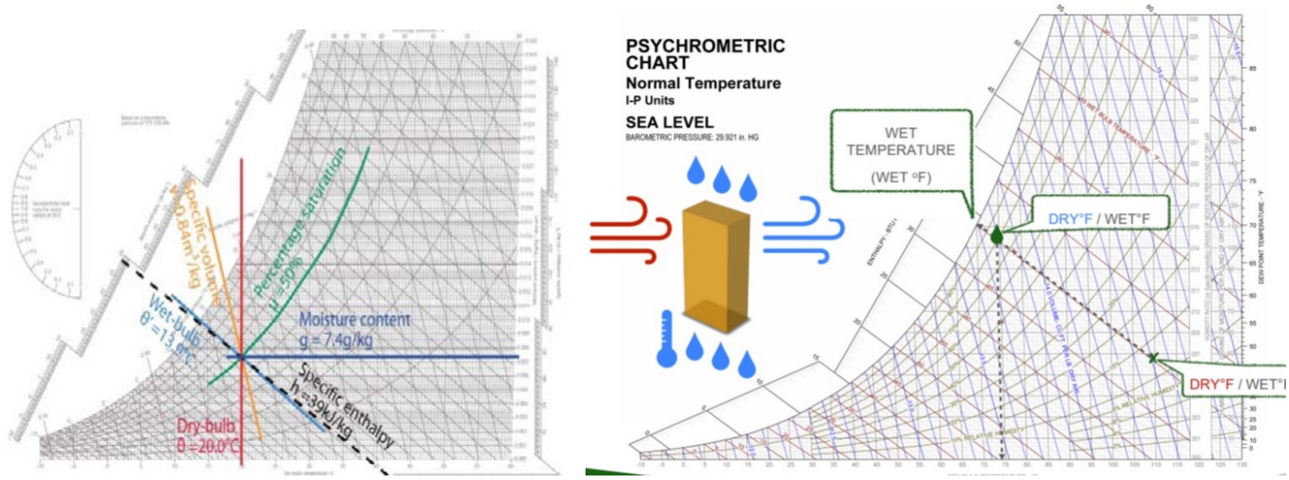
4.0 Energy Consumption comparison: TSDI evaporative cooling versus IK cooling.

4.1 Expected operational Savings of a 5000 cfm (30 TR, 106 kW) TSDI evaporative cooling unit

In sections 4.0 and 5.0 it is shown that the saving in operational cost for the two-sited selected. To demonstrate these savings, the following case study was made:

Two Stage Evaporative Cooling:

A 5000 cfm 100% outside air (Full Fresh Air) air handling unit is considered, the refrigeration capacity saving using a NIK evaporative system assisted by an IK system is calculated and compared to a full IK mechanical DX vapour compression system. Figures 4.1 and 4.2 shows the thermodynamic processes on a psychometric chart. Figure 4.3 and 4.4 shows an isometric view of the unit, a cross section plan and the thermodynamic processes on a psychometric chart. Figure 3.8 and 3.9 shows energy saving for Kuwait conditions in August, see table 3.1, the highest dry bulb temperature during the whole year.



Figures 4.1 and 4.2: Thermodynamic processes on psychometric chart.

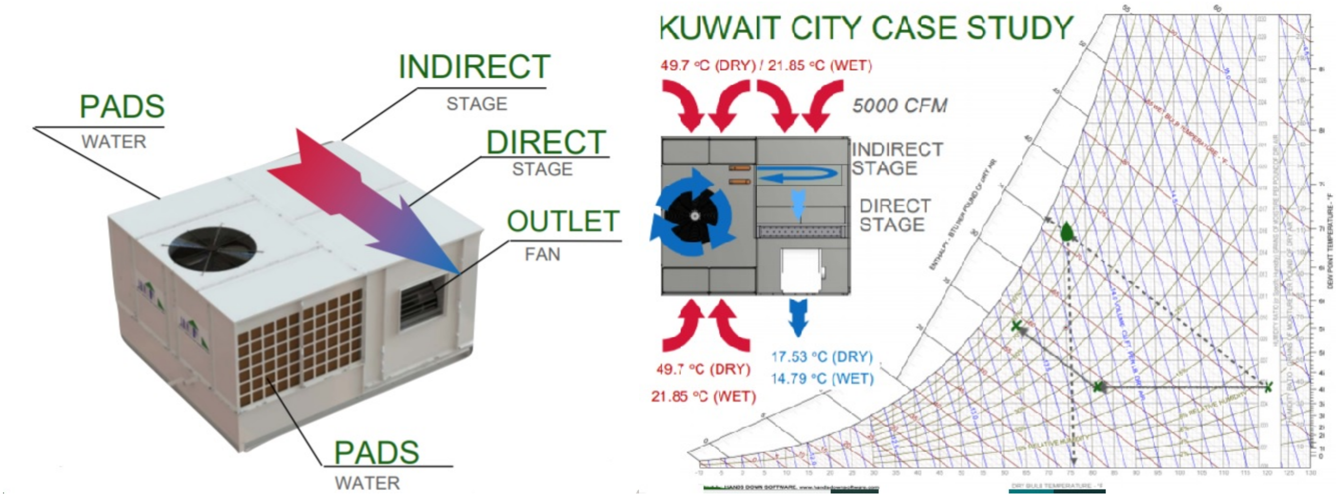


Figure 4.3 and 4.4: Isometric view of TSDI evaporative cooler and the thermodynamic processes on the psychometric chart

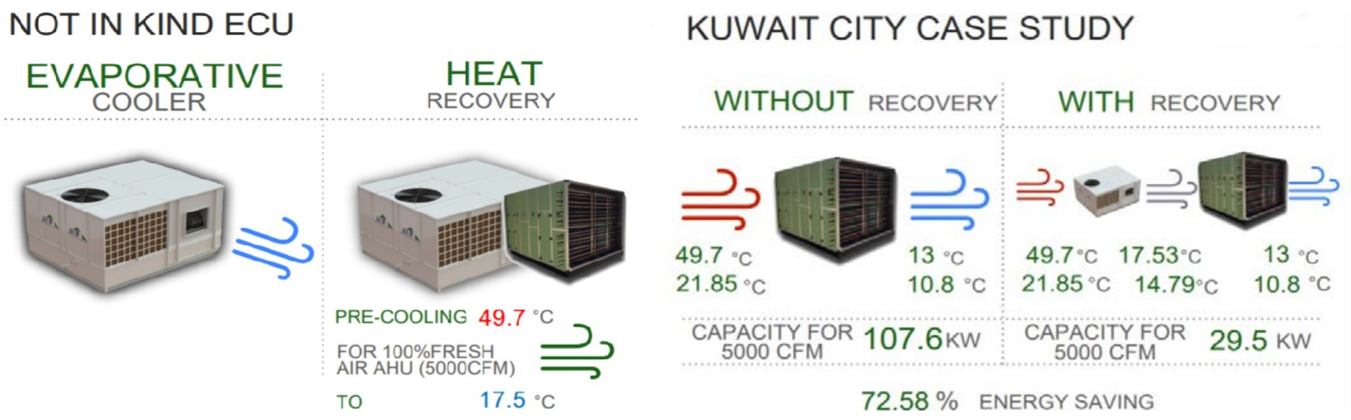


Figure 4.5 and 4.6: Energy saving for Kuwait maximum summer conditions, August 2002.

In this TSDI evaporative cooling system the first stage cools water located in the LHS of the unit in figure 3.6. Cooled water flows to the indirect stage, the RHS of the unit, in turn cools outdoor air passing through this second stage. Evaporative cooling then cools the air at the last stage. Figures 3.8 and 3.9 show the outdoor air conditions:

- Initial Kuwait conditions, August 14 th at 15:00: t db= 49.7 °C, t wb= 21.851 °C and RH= 6.686 %.
- Conditions exiting NIK TSDI unit : t db= 17.53 °C, t wb= 14.79 °C
- Conditions exiting IK DX unit : t db= 13 °C, t wb= 10.8 °C.
- Refrigeration capacity saved by using TSDI evap. Cooling: 78.1 kW or 72.58 % saving.

Savings for a 5000 cfm DX unit, with a refrigeration capacity of 107.6 kW (30.6 TR) are calculated to be about 73 % compared to a full IK cooling system. Refrigeration capacity of the IK DX unit drops to 29.5 kW (8.5 TR) or about 27.5 % of original IK capacity.
Total water Consumption is 178.16 l/hr total or 178.17/ 78.58 = 2.28 l/hr per kW at maximum dry bulb conditions of the year, 14th of August 2002.

4.2 Outdoor Air (Fresh Air) as opposed to Recirculated Air.

The IK central air conditioning design was based on limited fresh air requirements, about 15 % of air supply. This is to limit the necessity to cool outdoor air from design conditions (48 ^{0}C) to return air conditions, which can constitute a sizable load. This is specially so given the outdoor air requirements for a public assembly place where over 1000 worshipers may be attending at one time, during important religious occasions.
Alternatively, the advantages of air conditioning with full outdoor air for a public gathering place are several: outdoor air will provide better Indoor Air Quality (IAQ) and help reduce possible diseases cross contamination as well as help get rid of bacterial odour.
Given these conditions, it was thought that a full fresh air (outdoor air) TSDI evaporative cooling hybrid system would have an important advantage compared to a recirculated air system. This system was thus adopted.

4.3 Weather Data for Kuwait for the whole year, hour by hour.

Table 4.1 Supply air temperature spread chart for an entire year and Weather data.

Location: Kuwait City - Kuwait
Hourly Weather Data Source: EnergyPlus
Based on SAT Formulae for WBT Calculation on 27.11.2015

	VENTILATION		DIRECT EVAPORATIVE COOLING (DEC)		INDIRECT EVAPORATIVE COOLING (IEC)		INDIRECT - DIRECT EVAPORATIVE COOLING (IDEC)	
SUPPLY AIR TEMP IN °C	Ambient Air (No coooling)		Adiabatic Cooling		Sensible Cooling		Two Stage Cooling	
	No of Hrs	in %	No of Hrs	in %	No of Hrs	in %	No of Hrs	in %
S A Temp ≤ 14	1171	13%	2704	31%	2142	24%	5507	63%
S A Temp 14.01 - 16.00	474	5%	1068	12%	892	10%	1596	18%
S A Temp 16.01 - 18.00	618	7%	1038	12%	1040	12%	830	9%
S A Temp 18.01 - 20.00	576	7%	1224	14%	914	10%	401	5%
S A Temp 20.01 - 22.00	528	6%	1712	20%	1198	14%	226	3%
S A Temp 22.01 - 24.00	463	5%	770	9%	1535	18%	146	2%
S A Temp 24.01 - 26.00	480	5%	213	2%	857	10%	52	1%
S A Temp 26.01 - 28.00	545	6%	31	0%	166	2%	2	0%
S A Temp 28.01 - 30.00	524	6%	0	0%	16	0%	0	-----
S A Temp 30.01 - 32.00	514	6%	0	0%	0	0%	0	-----
S A Temp 32.01 - 34.00	518	6%	0	-----	0	0%	0	-----
S A Temp 34.01 - 36.00	482	6%	0	-----	0	-----	0	-----
S A Temp 36.01 - 38.00	429	5%	0	-----	0	-----	0	-----
S A Temp 38.01 - 40.00	368	4%	0		0		0	-----
S A Temp 40.01 - 42.00	333	4%	0		0		0	-----
S A Temp≥ 42.01	737	8%	0	-----	0	-----	0	-----
	8760		8760		8760		8760	

Table 4.1 shows the supply air temperature spread chart for an entire year weather data. These data were obtained from EnergyPlus™. The U.S. Department of Energy's (DOE) Building Technologies Office (BTO) funds EnergyPlus. The National Renewable Energy Laboratory (NREL) manages it.
EnergyPlus is developed in collaboration with NREL, various DOE National Laboratories, academic institutions, and private firms. EnergyPlus™ is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings.
To highlight the operational saving of a hybrid TSDI evaporative cooling unit compared to a DX unit for Kuwait, complete average hourly data for a whole year of IK cooling system and TSDI evaporative cooling system were calculated:

1- Complete average hourly daily data for Kuwait, for a whole year, compiled from 30 years period. These are:

- Ambient air conditions : T_{db}, T_{wb}, moisture, enthalpy.
- Conditions of air after TSDI evaporative cooler: WBD 9wet bulb depression), WBE (wet bulb efficiency- WBE= 13.63 ln (WBD) + 42), T db after Dry Air Moist Air heat exchanger.
- Load on cooling coil: with or without evaporate cooling per cfm for an entire year.

2- A worked example for energy consumption of a 5 TR TSDI evaporative cooling unit compared to a DX unit of the same capacity.

These data were obtained with the kind assistance of reference 9. References 10 and 11 offered data and assistance in producing this report.
Figure 4.7 shows a screen shot of the excel sheet showing the energy consumption results.

Date: 16.04.2017

Analysis of TR/CFM for Kuwait - only for AC hours, when IDEC can't meet comfort needs

Abbreviations:	
DBT	Dry Bulb Temp in °C
WBT	Wet Bulb Temp in °C
Moisture	Specific Humidity in [kgWater/kgDryAir]
Enthalpy	in kJ /kg

SUPPLY AIR - OFF COIL CONDITIONS	
DBT	14.57 °C
WBT	13.71 °C
Moisture	0.00946 kg/kg
Enthalpy	38.566 kJ/kg

WBD= wet bulb depression

WBE= wet bulb efficiency WBE=13.63 ln(WBD)+42

S. No.	Month	Date	Time	Ambient Air conditions				Condition of Air after IEC					Load on cooling coil	
				DBT	WBT	Moisture	Enthalpy	WBD	WBE	DBT-DAMA	Moisture	Enthalpy	Without IEC or ERW	With IEC
8485	12/20 13:00:00			20.23	16.00	0.00960	44.722	4.23	50%	18.12	0.010	42.457	6.156	3.890
8486	12/20 14:00:00			20.46	15.57	0.00904	43.526	4.89	50%	18.02	0.009	40.931	4.960	2.364
8490	12/20 18:00:00			18.74	15.06	0.00917	42.096	3.68	50%	16.90	0.009	40.122	3.529	1.556
8491	12/20 19:00:00			17.27	15.15	0.00986	42.337	2.12	50%	16.21	0.010	41.165	3.770	2.598

DAMA= Dry Air-Wet Air= IEC

	Without IEC or ERW	With IEC
Total: Load on Coil for 1 Year (kJ/kg)	61999.727	23867.147
Load on coil in Btu/lb	26655.11	10261.04
Load on coil in Btu/CFT	1996.12	768.42
Load on Coil in Btu/Hr	119767.27	46105.09
Load on coil per CFM for an entire year (TRH)	**9.98**	**3.84**
Savings by using IEC		**6.14**

Notes:

Conversion: 1 kJ/kg = 0.429923 btu/lb	*For 1 CFM*	*3.84*
P.S: Density of air @ STP = 0.074887 lb/cft	*For 2500 CFM*	*9605.2*
Air flow rate taken as 1 CFM, hence per hour qty of air = 60 CFT		

Figure 4.7: Screen shot of results.

4.4 Energy Consumption Comparison.

Table 4.2 shows the energy consumption comparison between two systems both nominally at 5 TR capacity: a DX system and a TSDI evaporative cooling system assisted by a DX cooling coil and condensing unit.

The reason this energy consumption is made is to demonstrate the energy savings given the operational conditions for Kuwait over a whole year.

The comparison shows a considerable saving when using a Hybrid TSDI unit compared to a DX unit, air-cooled. However, certain assumption were made.

Assumptions:

- The system operates on Full Fresh Air, except for 683 hrs. (Of 8670 hrs. - 7.8 % of total operational hrs.) when more cooling is needed than the nominal 5 TR DX coil installed, see note 1 and 2 below.

- If a Full fresh air model is used, during the 683 hrs. there will be a need for a larger DX coil- up to 16.9 TR. This system has not been contemplated. It was thought that reverting to a recirculated air during those 683 hrs. is justifiable, given the added expenses needed if a full fresh air system was used at all hrs.

- Even with a larger coil, 16.9 TR, there are some 5 hrs. when the refrigeration capacity is larger than 16.9 TR. Those five hours (0.057 % of the years) are not considered since we shifted to a recirculated system at the critical 683 hrs.
- The cost of the control system that switches to recirculated air for 683 hrs. is taken into consideration when comparing capital costs.

Table 4.2: Energy Consumption Comparison - 5 TR DX recirculated vs. A Hybrid TSDI evap. cooling

s. n	IK System	Cap., TR	Energy Consumption, kW.hr/yr.	NIK evaporative Hybrid System	Cap., TR	Energy Consumption, kW.hr/yr.
1	***System Description:*** System 1: Recirculated Air Re-circulation rooftop packaged AC unit. 2500 cfm.	5		***System Description:*** System 2: 100 % FA TSDI evaporative system with DX coil. DX hybrid operates when supply air temperature is above 14.6 ^{0}C and dew point is above 12.9 ^{0}C, to meet room conditions of 23.9 ^{0}C & 50 % RH.	Up to 16.9 TR	-16.9 TR for Full Fresh Air Or -5 TR and Recirculated DX air for 683 hrs per year.(2)
2	***Energy Consumption hours:*** - All year except 65 days (1560 hrs), winter season. 8760 – 1560 = 7200 hrs. - 300 operational days and 80 % diversity			***Energy Consumption hours:*** Hour's analysis shows: - 3892 hrs. needed with DX hybrid cooling. - 4868 hrs. with TSDI evap. Cooling will fulfil T_{db}= 14.6 ^{0}C and T_{dp} = 12.9 ^{0}C.	Note (1)	
3	***Unit's own energy consumption:*** Included in 1.5 Kw/TR			***Unit's own energy consumption:*** *For TSDI operation hours, without cooling, with* 0.6 kW/1000 CFM and 90% diversity -0.6 x (2500/1000) x 4868 x 0.9		6,572
4	***Energy consumption:*** 7200 x 5 x 1.5x 0.8 Hr x TR x kW/hr		43,200	***Energy consumption for DX Hybrid operating hours*** - 3.84 x 2500 x 1.5		14,400
5	***Total Energy Consumption:***		43,200	***Total Energy Consumption:*** 3 + 4		20,972
6	***Total Energy Saving:***		***22,228***	***(51.4 % saving)***		

Note (1): **Cooling Mode, Operational Hours and Tonnage.**

Operational Hours per Year.			
TSDI unit operational without cooling	TSDI unit operational & DX coil, max 5 TR	TSDI unit operational & DX coil, > 5 TR	Total
4868	3209	683 (2)	8760

Note (2): **Operational Hours and Tonnage over 5 TR**

Operational Hours per Year.				
16.0 – 16.9 TR	12.1 – 16.0 TR	8.1 – 12.0 TR	5.1 – 8.0 TR	Total
5	81	244	353	683

Table 4.3: Budgetary Cost, Electric and Water Consumption of all Air Handling Unit Types.

AHU Description			Utility requirement			Budgetary price CIF Kuwait Port / CFM
SN	Type	Cooling Description	Power (kW/ 1000 CFM)	Water (Annual average) LPH/ 1000 CFM	Water (Peak time consumption) LPH/ 1000 CFM	
1	TSDI evap. Cooling.	1. Indirect cooling stage 2. Direct (adiabatic) stage	0.6 kW	8 LPH	13 LPH	USD 2 / CFM
2	One Stage Indirect Evap. Cooling Only.	1. Indirect cooling stage	0.45 kW	6 LPH	11 LPH	USD 1.6 / CFM
3	TSDI evap. Cooling with cooling coil (CW or DX)	1. Indirect cooling stage 2. Cooling & dehumidification with CW/DX coil	0.8 kW (CW or DX coil press drop considered)	6 LPH	11 LPH	USD 3 / CFM
4	Typical AHU with cooling coil (CW or DX).	Cooling & dehumidification with CW/DX coil	0.6 kW (CW or DX coil press drop considered)	none	none	USD 1.5 / CFM

Table 4.4: Official Prices of Electricity and Water- Kuwait (Published in Arabic)

أولاً: تُحدد تعرفة وحدة الكهرباء على النحو الآتي:

سعر التعرفة لكل كيلو وات . ساعة (فلس)	القطاع
(25) فلس	الحكومي
(5) فلس	الإستثماري و التجاري
(5) فلس	الصناعي و الزراعي
(3) فلس	الصناعي والزراعي المنتجين (المنشآت ذات العلاقة)
(12) فلس	الأخرى (باستثناء قطاع السكن الخاص)
(3) فلس لكل (ك.فار)	الطاقة غير الفاعلة للقطاعات الصناعية والتجارية والحكومية

ثانيـــاً: تُحدد تعرفة وحدة المياه العذبة على النحو الآتي:

سعر التعرفة لكل الف جالون إمبراطوري شهرياً (دينار)	القطاع
(4) د.ك	الحكومي
(2) د.ك	الإستثماري و التجاري
(2) د.ك	الأخرى (باستثناء قطاع السكن الخاص)
(1.250) د.ك	الصناعي و الزراعي
(750) فلس	الصناعي والزراعي المنتجين (المنشآت ذات العلاقة)
(500) فلس	محطات تعبئة المياه

The First Site

5.0 TSDI evaporative cooling system for a Direct Expansion (DX) central A.C. system of a Mosque

5.1 Estimated cooling load.

The Kuwait Public Authority for Housing Welfare (KPAHW) provided IK design drawings for a major mosque in the Capital, Kuwait City. The design provided, was a central air conditioning system made utilizing roof top DX air cooling packaged units.

In that original IK design, the nominal cooling load of the building is 81 TR. The hybrid system envisaged includes both two stage direct Indirect (TSDI) evaporative cooling assisted by a DX cooling coil to operate when the relative humidity is high to the extent that the TSDI system cannot reach the off coil design conditions.

Eventually the hybrid TSDI evaporative cooling system assisted by the DX system will provide much less energy consumption than a DX system. This is shown in the financial study.

There was no need to increase the installed DX coil capacity, to deal with the critical 683 hrs., when the TSDI system cannot deal with the load. In these hrs., the system reverted to a recirculated air system during those 683 hrs., as opposed to a full fresh air system for the all other operating hrs.

5.2 Modified Conceptual Design of the Plant Incorporating TSDI evaporative cooling system.

Figure 5.1 shows a schematic diagram of the Hybrid TSDI evaporative cooling system assisted by a DX cooling coil system.

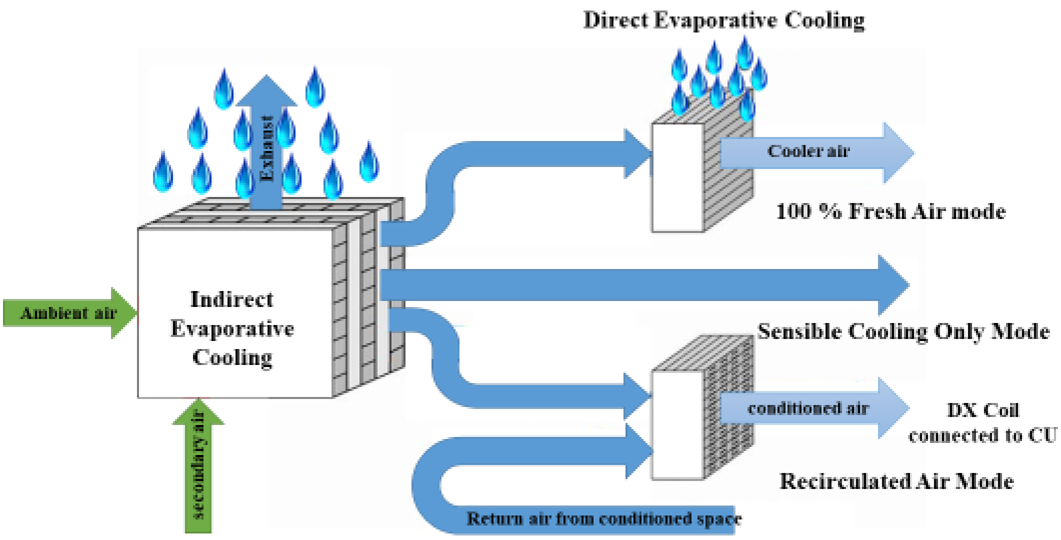


Figure 5.1: Schematic diagram of a hybrid TSDI evaporative cooling system assisted by a DX cooling coil

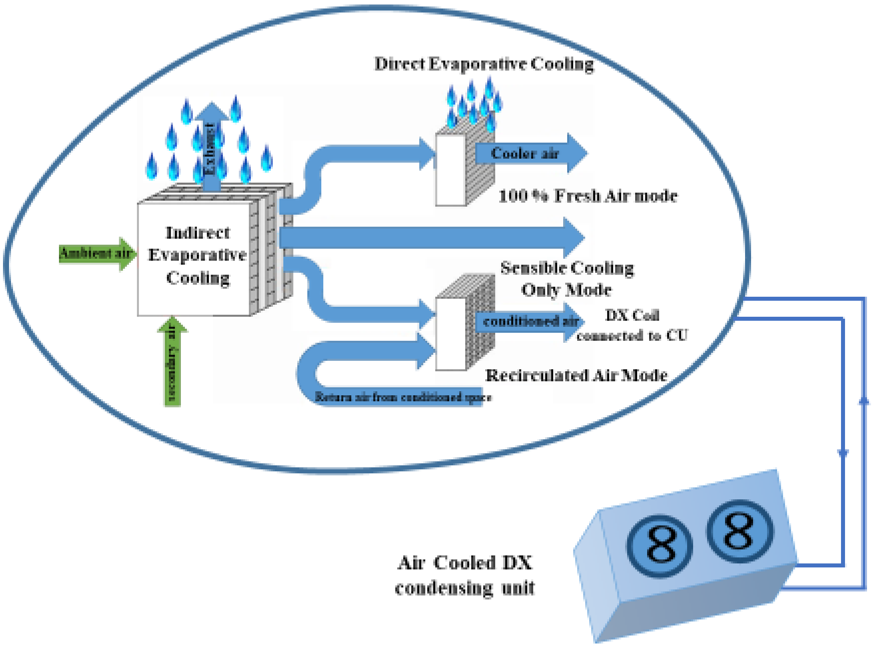


Figure 5.2: Schematic diagram of a hybrid TSDI evaporative cooling system with DX coil connected to air cooled condinsing unit

5.3 Operational savings of the Hybrid NIK assisted by IK system.

Table 5.1 for the mosque cooling energy comparison, compares both IK cooling system and NIK TSDI cooling system assisted by DX coils.
The reason energy consumption is made is to demonstrate the energy savings given the operational conditions for Kuwait over a whole year.

The comparison shows a considerable saving when using a Hybrid TSDI unit compared to a DX unit, air-cooled. However, certain assumptions were made.

Assumptions:

- The system operates on Full Fresh Air, except for 683 hrs. (Of 8670 hrs. - 7.8 % of all operating time) when more cooling is needed than the nominal 800 TR DX coil installed, see note 1 and 2 below.
- If a Full fresh air model is used, during the 683 hrs. Then a much larger need TSDI system would be needed - This system has not been contemplated because of its added unjustified extra expenses. It was assumed that air was recirculated during those 683 hrs. only.
- The cost of the control system that switches to recirculated air for the 683 hrs. is taken into consideration when comparing capital costs.

Table 5.1: Energy Consumption Comparison - 81 TR DX recirculated vs. A Hybrid TSDI evap. cooling for a mosque.

s. n	IK System	Cap., TR	Energy Consumption, kW.hr/yr.	NIK evaporative Hybrid System	Cap., TR	Energy Consumption, kW.hr/yr.
1	***System Description:*** System 1: Recirculated Air Re-circulation rooftop packaged AC unit. Total cfm 40,500.	81		***System Description:*** System 2: 100 % FA TSDI evaporative system with DX coil. DX hybrid operates when supply air temperature is above 14.6 ^{0}C and dew point is above 12.9 ^{0}C, to meet room conditions of 23.9 ^{0}C & 50 % RH.	81	- 81 TR and Recirculated DX air for 683 hrs per year.(2)
2	***Energy Consumption hours:*** - All year except 65 days (1560 hrs), winter season. 8760 – 1560 = 7200 hrs. - 300 operational days and 80 % diversity			***Energy Consumption hours:*** Hour's analysis shows: - 3892 hrs. needed with DX hybrid cooling. - 4868 hrs. with TSDI evap. Cooling will fulfil T_{db}= 14.6 ^{0}C and T_{dp} = 12.9 ^{0}C.	Note (1)	
3	***Unit's own energy consumption:*** Included in 1.5 Kw/TR			***Unit's own energy consumption:*** *For TSDI operation hours, without cooling, with* 0.6 kW/1000 CFM and 90% diversity -0.6 x {(500X 81)/1000} x 4868 x 0.9		106,463
4	***Energy consumption:*** 7200 x 81 x 1.5x 0.8 Hr x TR x kW/hr		699,840	***Energy consumption for DX Hybrid operating hours*** - 3.84 x 500 X 81 x 1.5		233,280
5	***Total Energy Consumption:***		699,840	***Total Energy Consumption:*** 3 + 4		339,743
6	***Total Energy Saving: kW.hrs/year***			***360,097 (51.5 % saving)***		

Note (1) & (2): **Cooling Mode, Operational Hours and Tonnage.**

Operational Hours per Year.			
TSDI unit operational without cooling	TSDI unit operational & DX coil, max 81 TR	TSDI unit operational & DX coil, > 81 TR	Total
4868	3209	683 (2)	8760

The Second Site

6.0 TSDI evaporative cooling system for a Chilled Water system air conditioning of a School.

The first site selected is a school. The school air conditioning original IK design was completed, and utilised an air cooled chilled water system connected to a chilled water-piping network to air handling units and fan coil units. The system incorporates a small number of split units (3) and one packaged unit

.

6.1 Estimated Cooling Load of the system.

About 800 TR (4 x 200 TR chillers + 1 x 200 TR stand-by chiller).

6.2 Modified Conceptual Design of the Plant Incorporating TSDI evaporative cooling system.

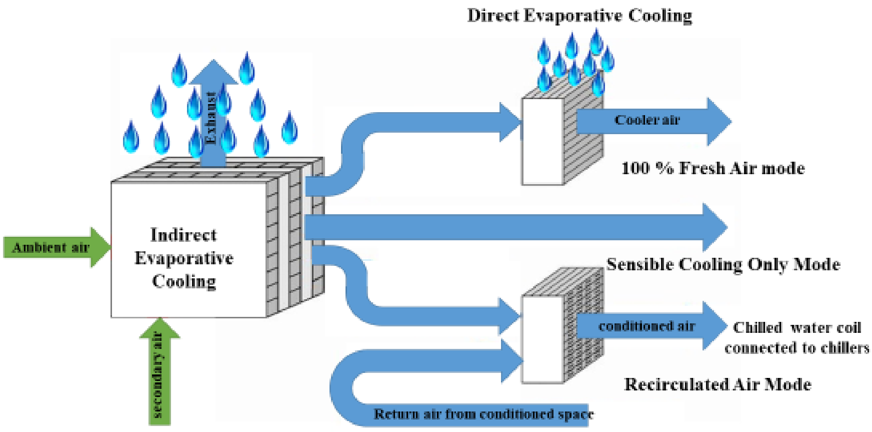


Figure 6.1: Schematic diagram of a hybrid TSDI evaporative cooling system assisted by a chilled water cooling coil

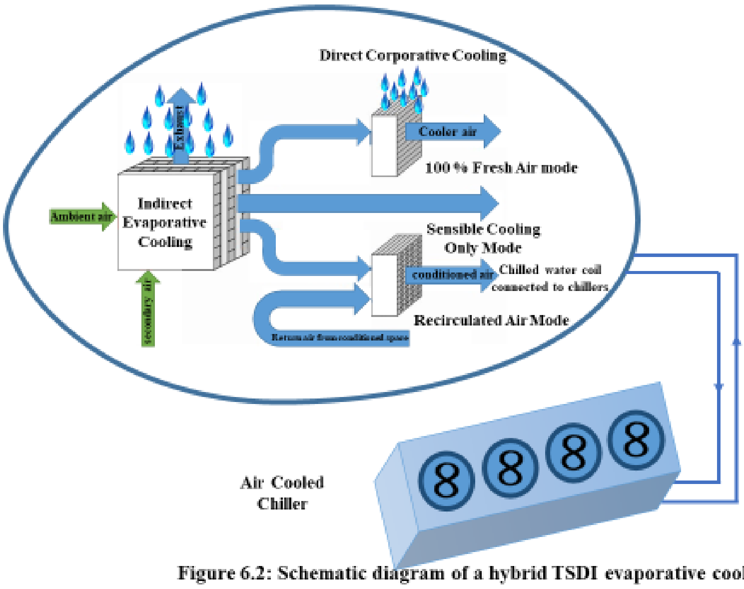


Figure 6.2: Schematic diagram of a hybrid TSDI evaporative cooling system assisted by chilled water coil connected to air cooled chiller

6.3. Operational savings of the Hybrid NIK assisted by IK system.

Table 6.1 for the energy consumption of the school air conditioning systems, compares both NIK cooling system assisted by the air cooled chilled water system IK cooling system with the original design of an IK air cooled chilled water system only.
The reason this energy consumption is made is to demonstrate the energy savings given the operational conditions for Kuwait over a whole year.
The comparison shows a considerable saving when using a Hybrid TSDI unit compared to a DX unit, air-cooled. The financial study shows these savings in detail. However, certain assumption were made.

Assumptions:

- The system operates on Full Fresh Air, except for 683 hrs. (Of 8670 hrs. - 7.8 % of the whole operating time) when more cooling is needed than the nominal 800 TR DX coil installed, see note 1 and 2 below.

- If a Full fresh air model is used, during the 683 hrs. Then a much larger need TSDI system would be needed - This system has not been contemplated because of its added unjustified extra expenses It was assumed that air was recirculated during those 683 hrs. only.

- The cost of the control system that switches to recirculated air for the 683 hrs. is taken into consideration when comparing capital costs.

Table 6.1: Energy Consumption Comparison - 800 TR CW recirculated vs. Full FA Hybrid TSDI evap. cooling for a school.

S. n	IK System	Cap., TR	Energy Consumption, kW.hr/yr.	NIK Evap. Hybrid System	Cap., TR	Energy Consumption, kW.hr/yr.
1	***System Description:*** System 1: Recirculated Air Re-circulation rooftop AHU, Chilled water unit. 500 X 800 cfm.	800		***System Description:*** System 2: 100 % FA TSDI evaporative system with DX coil. DX hybrid operates when supply air temperature is above 14.6 ^{0}C and dew point is above 12.9 ^{0}C, to meet room conditions of 23.9 ^{0}C & 50 % RH.	800	-800 TR and Recirculated DX air for 683 hrs per year.(2)
2	***Energy Consumption hours:*** - All year except 65 days (1560 hrs), winter season. 8760 – 1560 = 7200 hrs. - 300 operational days and 80 % diversity			***Energy Consumption hours:*** - Hour's analysis shows: -3892 hrs needed with DX cooling. - 4868 hrs with TSDI evap. Cooling will fulfil T_{db}= 14.6 ^{0}C and T_{dp} = 12.9 ^{0}C.		
3	***Unit's own energy consumption:*** Included in 1.5 Kw/TR Diversity 80 %			***Unit's own energy consumption:*** 0.6 kW/TR, Diversity 90 %. -0.6 x {(500 x 800)/1000)} x 4868 x 0.9		1,051,488
4	***Energy consumption:*** 7200 x 800 x 1.5x 0.8 Hr x TR x kW/hr		6,912,000	***Energy consumption for DX Hybrid operating hours:*** - 3.84 x 500 x 800 x 1.5		2,304,000
5	***Total Energy Consumption:***		6,912,000	***Total Energy Consumption:*** *3+4*		3,355,488
6	***Total Energy Saving: kW.hrs/year***			***3,556,512 (51.5 % saving)***		

Note (1) & (2): **Cooling Mode, Operational Hours and Tonnage.**

Operational Hours per Year.			
TSDI unit operational without cooling	TSDI unit operational & DX coil, max 800 TR	TSDI unit operational & DX coil, > 800 TR	Total
4868	3209	683 (2)	8760

7.0 Capital Costs, Operating Costs for the Financial Analysis and Summary Technical Results.

7.1 Assumptions for the breakdown of capital and operational costs of the Mosque and School.

This section is devoted to obtaining the following two items:

- Capital and operating parameters needed for the financial analysis part of the study in order to obtain the basic financial indicators to prove whether the system is viable or not for Kuwait, from a financial economic point of view.
- Provide an overall summary of technical results obtained, in order to simplify access to information regarding the technical part of the study.

In order to reach the first point, certain assumptions were made. Those are listed below:

The Mosque

- The IK central air conditioning system consists of seven packaged roof top direct expansion (DX) units. Those incorporate seven air handling unit section with a DX coil and a condensing unit section
- The capacities of the packaged units are between 5 and 20 TR.
- All packaged units are designed with 15 % fresh air and 85 % recirculated air.
- The packaged units are connected to a ductwork, both supply, return and an air distribution grilles and diffusers.
- The total installed capacity of the system is 81 TR.
- A small number of split units, exhaust fans and electric heaters will remain as they are in the NIK design.
- The proposed NIK design is to replace the packaged units with a Two Stage Direct Indirect (TSDI) evaporative cooling air handling units quipped with a DX coil connected to condensing units.
- The individual and aggregated capacity of the NIK system remains the same at 81 TR.
- The NIK system will be a full fresh air system to improve indoor air quality inside the mosque, except for 683 hrs. a year when humidity is too high, the system will then automatically shift to recirculated air with 15 % fresh air.

The School

- The IK central air conditioning system consists of several air handling unit sections equipped with a chilled water-cooling coil connected to five air-cooled chillers (4 +1 stand-by).
- The total aggregated capacities of the air-handling units is 800TR.
- All AHU are designed with 15 % fresh air and 85 % recirculated air.
- The AHUs are connected to a ductwork, both supply, return and an air distribution grilles and diffusers.
- The total installed capacity of the system is 1000 TR.
- A small number of split units, exhaust fans and electric heaters will remain as they are in the NIK design.
- The proposed NIK design is to replace the AHUs with a Two Stage Direct Indirect (TSDI) evaporative cooling air handling units quipped with a chilled water coils connected to the air cooled chillers.
- The individual and aggregated capacity of the NIK system remains the same at 800 TR.
- The NIK system will be a full fresh air system to improve indoor air quality inside the school, except for 683 hrs. a year when humidity is too high, the system will then automatically shift to recirculated air with 15 % fresh air.

7.2 **Breakdown of Capital and Operating Costs of the Mosque.**

Table 7.1: Breakdown of Capex and Opex for the Mosque-Kuwait.

Sn.	Item	As indicated	US $	Remarks
A	**Major Data for Not-In-Kind technology using TSDI evaporative cooling system.** **System Description:** 100 % FA, except 683 hrs when system shift to recirculated air. TSDI evaporative system with DX coil. DX hybrid operates when supply air temperature is above 14.6ºC and dew point is above 12.9 ºC, to meet room conditions of 23.9 ºC & 50 % RH			
	Total Aggregated AHUs Installed Capacity, TR	81		Comprises all AHUs capacities. According to table 4.5
	Unit's own electric energy consumption, kW.h/year: *For TSDI operation hours, without cooling, with* 0.8 kW/1000 CFM and 90% diversity -0.8 x {(500X 81)/1000} x 4868 x 0.9	141,950		500 cfm per TR. According to table 5.1
	Electric Energy consumption for DX Hybrid operating hours, kW.h/year: - 3.84 x 500 X 81 x 1.5	233,280		According to table 5.1
	Total Electric Energy consumption yearly: kW.h/yr.	375,230		
	Water Consumption, litre per year: 6 x { (500 x 81)/1000} x 3209	779, 787		Table 4.5
I	**Capital Costs Breakdown**:			
1	***Cost of AHUs with TSDI evaporative cooling and DX coils:*** 3 x 500 x 81		121,500	Table 4.5
2	***Automatic control system to switch to recirculated mode during hours when full fresh air will need for than 81 TR aggregated capacity- 683 hr***. 81 x 500 x 0.2		8,100	See note (2), table 4.5 and USD 0.2 / cfm
	Total Capital Cost		**129,600**	
II	**Operating Costs**			
	Cost of Electric Energy Consumption per year: {(375,230 x 25)/1000} x 3.27		30, 675	Based on 1 kW.h= 25 Fils. 1 K.D= 1000 Fils

				1 K.D =1 USD3.27
	Cost of water consumption per year: {(779, 787 / 4.54609) /1000} x4x3.27		2,244	4 KD /1000 Imp. Gallon 1 Imp. Gallon= 4.54609 l.
	Total Yearly Operating Costs		**32,919**	
SN	**Item**	**As indicated**	**US $**	**Remarks**
B	**Major Data for In-Kind DX System.** **System Description:** Recirculated Air Re-circulation rooftop packaged AC unit. Total 40,500 cfm.			
	Total Aggregated AHUs Installed Capacity, TR:	81		
	Unit's own electric energy consumption, kW.h/year: - All year except 65 days (1560 hrs), winter season. 8760 – 1560 = 7200 hrs. - 300 operational days and 80 % diversity 7200 x 81 x 1.5x 0.8 Hr x TR x kW/hr	699,840		
I	**Capital Cost:**			
	Cost of AHUs with DX coils: 81 x 500 x 1.5		60,750	From Table 4.5
	Total Capital Costs		**60,750**	
II	**Operating Cost:**			
	Cost of electric energy consumption per year, hr x TR x kW/hr x diversity x rate and 80 % diversity : 7200 x 81 x 1.5x 0.8 x 25/1000 x 3.27		57,212	See Table 5.1
	Total yearly operating costs		**57,212**	

7.3 Breakdown of Capital and Operating Costs of the School.

Table 7.2: Breakdown of Capex and Opex for the School-Kuwait.

Sn.	Item	As indicated	US $	Remarks
A	**Major Data for Not-In-Kind technology using TSDI evaporative cooling system. System Description:** 100 % full fresh air TSDI evaporative system with chilled water coil. Chilled Water hybrid operates when supply air temperature is above 14.6 ^{0}C and dew point is above 12.9 ^{0}C, to meet room conditions of 23.9 ^{0}C & 50 % RH.			- 800 TR and Recirculated chilled water cooled air for 683 hrs per year.(2)
	Total Aggregated AHUs Installed Capacity, TR	800		Comprises all AHUs capacities. According to table 4.5
	Unit's own electric energy consumption, kW.h/year: 0.8 kW/TR, Diversity 90 %. -0.8 x {(500 x 800)/1000)} x 4868 x 0.9	1,401,984		500 cfm per TR. table 6.1 and table 4.5
	Electric Energy consumption for chilled water Hybrid operating hours, kW.h/year: -3.84 x 500 x 800 x 1.4	2,150,400		According to table 6.1
	Total Electric Energy consumption yearly: kW.h/yr.	3,552,384		
	Water Consumption, litre per year: 6 x { (500 x 800)/1000} x 3209	7,701,600		Without 682 hrs when CW coil operational. 3892-683=3209 Tables 4.5 and 6.1
I	**Capital Costs Breakdown**:			
1	***Cost of AHUs with TSDI evaporative cooling and chilled water coils:*** 3 x 500 x 800		1,200,000	Table 4.5
2	***Automatic control system to switch to recirculated mode during hours when full fresh air will need for than 81 TR aggregated capacity-683 hr***. 800 x 500 x 0.2		80,000	See note (2), table 4.5 and USD 0.2 / cfm
	Total Capital Cost		**1,280,000**	
II	**Operating Costs**			
	Cost of Electric Energy Consumption per year: {(3,552,384 x 25)/1000} x 3.27		290, 407	Based on 1 kW.h= 25 Fils. 1 K.D= 1000 Fils

				1 K.D =1 USD3.27
	Cost of water consumption per year: { (7,701,600 / 4.54609) /1000} x4x3.27		22,159	4 KD /1000 Imp. Gallon 1 Imp. Gallon= 4.54609 l.
	Total Yearly Operating Costs		**312,566**	
SN	**Item**	**As indicated**	**US $**	**Remarks**
B	**Major Data for In-Kind Chilled Water System.** **System Description:** Recirculated Air, Re-circulation rooftop AHU, Chilled water unit. 500 X 800 = 400,000 cfm.			
	Total Aggregated AHUs Installed Capacity, TR:	800		
	Unit's own electric energy consumption, kW.h/year: - All year except 65 days (1560 hrs), winter season. 8760 – 1560 = 7200 hrs. - 300 operational days and 80 % diversity (Hr x TR x kW/hr) 7200 x 800 x 1.4x 0.8	6,451,200		
I	**Capital Cost:**			
	Cost of AHUs with chilled water coils: 800 x 500 x 1.5		600,000	From Table 4.5
	Total Capital Costs		**600,000**	
II	**Operating Cost:**			
	Cost of electric energy consumption per year, hr x TR x kW/hr x diversity x rate and 80 % diversity : 7200 x 800 x 1.4x 0.8 x 25/1000 x 3.27		527,386	See Table 6.1
	Total yearly operating costs		**527,386**	

7.4 Summary Technical Results.

The aim of the study is to analyse Not-In-Kind (NIK) cooling technologies for central air conditioning applications for Kuwait that have low GWP as well as provide significant energy efficiency savings.
Questionnaires were prepared to choose two sites where the air conditioning systems of buildings are designed for central system application by traditional electric system once for direct expansion (DX) and another for chilled water (CW) application.
The Kuwait EPA, the official entity that commissioned the study, has been providing guidance and assistance to us in filling questionnaires through information received from "Kuwait Public Authority for Housing Welfare" (KPAHW). General construction plans were obtained from KPAHW for candidate sites that are to be built by them and were to be centrally air conditioned by either a DX or a CW system. Four building sites were used to fill the questionnaires, those are:

1. ***A school.*** The school central air-conditioning system, utilising 5 air cooled chillers, each 200 TR refrigeration capacity, total capacity 1000 TR. The school air conditioning design IK design was provided.
2. ***A Medical Centre***. Comprising small operating theatres, emergency units and other medical facilities. The Medical Centre has a designed IK central air conditioning system using DX units. Unfortunately, the design documents were not complete, and it proved impossible to obtain enough data to form an accurate idea on refrigeration loads, schedule of equipment and other vital design data on time to consider this selection seriously.
3. ***A small mosque***. Although the mosque architectural and civil design data were complete, no central air conditioning system was provided. This excluded the use of this mosque because of the time needed to estimate cooling loads and create a central air conditioning design.
4. ***A large central mosque.*** Complete with central air conditioning IK design was provided. The air conditioning IK design documents were complete and were enough to get a complete and full picture on the IK design.

Selection number 1 and 4 proved best specially since their IK design was completed and could be modified to NIK as well as both were provided with either DX or CW systems design and were soon to be constructed.

Several NIK system were considered such as: deep sea cooling, cooling by the use of reject heat, natural gas fired absorption chiller and solar assisted absorption chiller cooling. Lastly Two Stage Direct Indirect (TSDI) evaporative cooling was considered. The latter NIK system was chosen because the unusual climatological conditions of Kuwait. Analysis of the climatological data over the last 30 years revealed that the relative humidity in Kuwait throughout summer is remarkably low. This dry summer ambient made TSDI evaporative ideally positioned for air conditioning. The system does not utilize refrigerants except water (no GWP) and is known for its low energy consumption.

The technical study looked at both sites and changed the original IK designs to a TSDI evaporative system assisted by the original IK system. Energy consumption was calculated throughout the year and design schematic diagram were made for the new systems.

The preliminary results made for the calculation of energy consumed by the technical study shows there are savings for the NIK assisted by IK system of about 52 % when compared to a traditional electric IK system.

The technical study shows also that the NIK system assisted by IK improves the Indoor Air Quality (IAQ) for occupants by using primarily full fresh air in both mosque and school thus enhancing greatly the way of life reducing cross contamination and renewing air reducing unwanted odours as well as reducing greatly the carbon footprint.
The technical study explains in detail the steps taken and justify the energy savings obtained. The study then made a cost breakdown of capital and operating cost to be used in the financial part of the study to calculate with a high degree of accuracy the energy savings and capital cost, cost break even, return on investment and other financial parameters.
The financial study justified the additional capital cost needed to adopt a TSDI evaporative system assisted by the original IK system and calculated more accurately those savings. In the financial study the system not only recoup its additional expenses in a limited short number of years but also shows the system can be adopted for other central system applications.
Further work will be needed to check empirically these results by building two prototypes: one DX and another CW, and monitor the operational results to disseminate the new technology in Kuwait.

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From the Industry:

9 Mr Sunil Tiwari, GM A.T.E. Enterprises.

10 Eng. Y. Barakat, DCM enterprises.

11 Eng. M. Manzalawi, Tiba enterprises.

Annex-1

Criteria and Questionnaire for sites locations -Kuwait NIK Project

No	Item	Criteria	Points	Score
1	New developed city/district.	New City = 20 New District in existing City = 15 Existing District = 5	20	
2	Minimum Cooling Capacity	< 5,000 TR = 5 5,000 – 10,000 TR = 7 10,000 – 30,000 TR = 8 > 30,000 TR = 10	10	
3	Proximity to: a. Sea side b. Waste Heat Source (elect. power station)	Within or less than 5Km = 30 5-10 Km = 20 More than 10 Km = 10	20	
4	Proximity to NG downstream line	Within connected proximity	10	
5	Current status of city/district development	Concept phase = 20 Design phase = 10 Contract phase = 5	20	
6	Type of application (residential, commercial, governmental, industrial, mixed)	Governmental = 20 Residential = 5 Commercial =15 Industrial = 15 Mixed Use = 20	20	
		Total	100	

Technical Information Survey

No.	Item	Details
1	Sites Parameters:	
A	Sites for District Cooling Plants under consideration.	- Name of sites: - Site 1: --------- - Site 2: ---------- - Site 3: ---------- - Site 4: ---------- (Chose two sites.)
B	Cost of Land: - Purchasing. - Renting.	Site 1: Site 2: Site 3: Site 4:
C	Cost of plant building construction:	For a masonry building: -----/square meter. For a steel structure building: ------/square meter.

No.	Item	Details
D	Additional Information you may think is important to list:	
2	Energy and Water.	
A	Electric Power Prices: - Low Voltage. - Medium Voltage. - High Voltage.	Residential: --- Commercial: ---- Industrial: ----- (Link to internet site- prices of electric power cost.)
B	Natural Gas Prices:	Site1: , Site 2: , Site3: , Site 4: Is it piped to site?
C	Is there a source of reject heat near the site? (Refinery, steel mill, glass factory, thermal desalination plant, electric power station, etc.…)	Site 1: Site 2: Site 3: Site 4:
D	- Is there a Refuse Processing Plant near the site? - Is there a Refuse Derive Fuel (RDF) available?	Site 1: Site 2: Site 3: Site 4:
E	Price of fresh water, brackish water and drain:	
F	Additional Information you may think is important to list:	
3	Salaries	
A	Salaries structure for: - Qualified Graduate engineers (5 to 10 years exp.): - Qualified Graduate engineers (1 to 5 years exp.): - Skilled Technician: - Technician: - Labourer:	
B	Additional Information you may think is important to list:	
4	Taxes and Custom Duties	
A	Rate of Income Taxes: - On individuals: - On Corporations:	
B	Taxes on Services: - On electric power supply: - On district Cooling Services. - Other.	
C	Custom Duties on imported Equipment:	

No.	Item	Details
D	Value Added taxes on Imported goods and services:	

Financial Information Survey

No.	Item	Details
1	Sites Parameters:	
A	Sites for District Cooling Plants under consideration.	- Name of sites: - Site 1: --------- - Site 2: ---------- - Site 3: ---------- - Site 4: ---------- (Chose two sites.)
B	Cost of Land: - Purchasing. - Renting.	Site 1: Site 2: Site 3: Site 4:
C	Cost of plant building construction:	For a masonry building: -----/square meter. For a steel structure building: ------/square meter.
D	Additional Information you may think is important to list:	
2	Energy and Water.	
A	Electric Power Prices: - Low Voltage. - Medium Voltage. - High Voltage.	Residential: --- Commercial: ---- Industrial: ----- (Link to internet site- prices of electric power cost.)
B	Natural Gas Prices:	Site1: , Site 2: , Site3: , Site 4: Is it piped to site?
C	Is there a source of reject heat near the site? (Refinery, steel mill, glass factory, thermal desalination plant, electric power station, etc.…)	Site 1: Site 2: Site 3: Site 4:
D	- Is there a Refuse Processing Plant near the site? - Is there a Refuse Derive Fuel (RDF) available?	Site 1: Site 2: Site 3: Site 4:
E	Price of fresh water, brackish water and drain:	
F	Additional Information you may think is important to list:	
3	Salaries	

No.	Item	Details
A	Salaries structure for: - Qualified Graduate engineers (5 to 10 years exp.): - Qualified Graduate engineers (1 to 5 years exp.): - Skilled Technician: - Technician: - Labourer:	
B	Additional Information you may think is important to list:	
4	Taxes and Custom Duties	
A	Rate of Income Taxes: - On individuals: - On Corporations:	
B	Taxes on Services: - On electric power supply: - On district Cooling Services. - Other.	
C	Custom Duties on imported Equipment:	
D	Value Added taxes on Imported goods and services:	

Annex-2

Compilation of Technical Solutions

The relevant technical solutions chosen for the demonstration of cooling systems are examined such as fluorocarbon chillers (In- Kind cooling technology), non-fluorocarbon chillers (Not-In-Kind cooling technology), distribution piping network, load interface techniques and energy calculation methods.
The compilation of technical information on relevant technical solutions chosen for the demonstration of NIK cooling systems encompass the following subjects:

1. Systems utilising In-Kind cooling technology or Fluorocarbon chillers

The definition of Not-In-Kind DC cooling technology is technology that mostly utilize electric power to produce cooling. Not-In-Kind DC cooling technology is technology that mostly do not utilize electric power to produce cooling. The aim of this study is the dissemination of Not-In-Kind cooling technologies, to help introducing these technologies in Kuwait.
Fluorocarbon chillers are In-Kind cooling technology, since they are mechanical vapour compression machine operated by electric power. Fluorocarbon chillers have real (not subsidized) operating costs relatively higher than these of Not-In-Kind cooling technologies. Therefore, they are not used in this study as the main producers of cooling capacity, but to assist in the cooling process when needed.
Sometimes Not-In-Kind technologies or non-fluorocarbon chillers are not able to bring down the chilled water supply temperature to low design levels efficiently and economically. In this case, In-Kind technologies may be needed to assist the cooling process. When design supply chilled water temperatures are set at 3 to 4 °C, In-Kind technology can be included. For this reason, sometimes electric chillers are included in the design of chilled water plants in-series arrangement with non-fluorocarbon chillers such as absorption chillers.
Distribution piping network designed with large delta T requires low supply chilled water temperature. This is to help reduce the diameter of the chilled water piping, thus reducing cost. This is especially important in large and long networks. Those temperatures are not reachable with current commercially available second-generation absorption chillers, since they can provide chilled water temperatures down to 5 to 6 ^{o}C safely. Lower chilled water temperatures, 3 to 4 ^{o}C, are available with new generation absorption chillers expected commercially in the near future. Thus, fluorocarbon chillers can be included in-series design arrangement to achieve those low temperatures.
This is also the case in applications when ice or ice-slurry are used for thermal energy storage system (TES), since negative chilled water supply design conditions are required to produce ice or ice- slurry and those temperatures are not achievable with current generations absorption chillers.
However, when used the major portion of cooling capacity will be borne by Not-In-Kind cooling technology resulting in low operating costs for the system, while fluorocarbon chillers, electrically operated, will provide a small fraction of the operating costs to achieve lower supply design chilled water temperatures, when needed.

2. Systems using Not-In-Kind cooling technologies or Non-fluorocarbon Chillers

The main NIK cooling technology systems are:

A. Systems operating by deep sea cooling (DSC) or cooling/heating

Deep Sea Cooling is a new technology that uses cold-water temperature of the seas, at great depths, to cool chilled water of a district cooling system. The main advantage of this technique is that may consumes down to a tenth energy consumption compared to In-Kind technologies.
This technique is well developed in Scandinavian countries and in island states such as Hawaii and others. Stockholm City has used its unique location on the shore of the Baltic Sea and at the mouth of Lake Malaren

(the largest lake in Sweden) to build a deep source cooling system for its downtown buildings. Another large project is planned for Dubai in the United Arab Emirates. Toronto City, Canada has the largest deep-source cooling project yet it is not the first city to plumb the depths of North America's glacial lakes.
Four years ago, Cornell University inaugurated a US $ 57 million lake-source cooling plant. The system cools university buildings and a nearby high school in Ithaca, New York.

The plant draws 3.9 ^{o}C (39 F) water from 70 meters (250 feet) below the surface of Cayuga Lake, a glacially carved lake that is 132.6 meters (435 feet) deep at its lowest point The Natural Energy Laboratory of Hawaii Authority (NELHA), a state research facility located on the Big Island of Hawaii, runs its own deep-source cooling plant. The system cools buildings on the agency's campus, which overlooks the Pacific Ocean. The plant draws 6 ^{o}C (42.8 F) seawater from depth of 610 meters (2,000 feet). "NELHA saves about US $3,000 a month in electrical costs by using the cold seawater air-conditioning process," said Jan War, an operations manager. Makai Ocean Engineering, a private company based in Honolulu, is also developing plans to cool all of the city's downtown using a similar system.

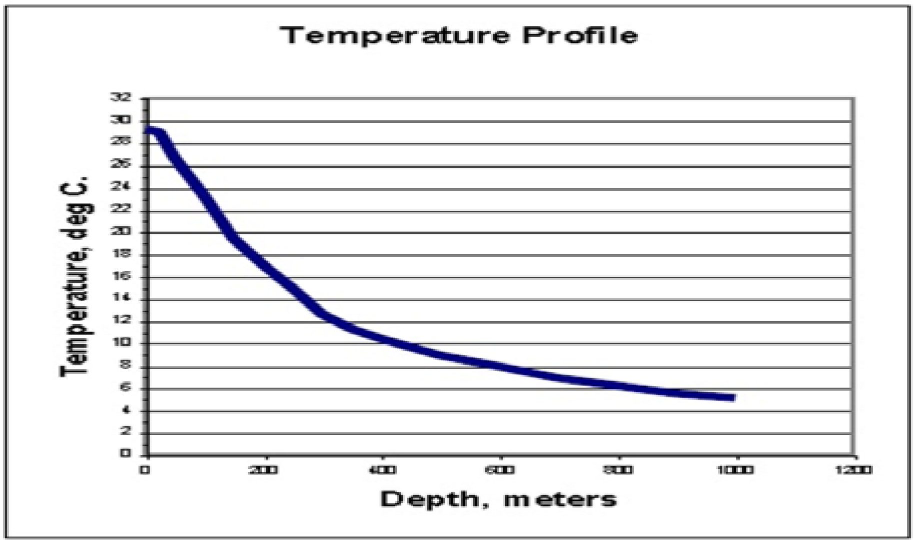

Figure 2.1: Seawater temperature drop versus depths of the Sea.

The graph shows the general trend of the downward decrease of seawater temperature as depth increase. This trend differs from summer to winter and with the location of the point where it is measured.
Oceanographers divide the ocean into categories by depth. The broadest category is the upper part of the ocean known as the —photical zone. This is generally regarded as the upper 200 meters of the ocean where sun light penetrates, and photosynthesis takes place. The bottom part of the ocean is called the —aphotical zone where sunlight does not add heat and cold temperatures are present. Bathymetry and oceanography studies suggest that at an ocean depth of at least 1000 meters, 4°C water temperature is assured. It should be noted that 4^{o}C temperature might also be available at depths of 500 to 900 meters. Diligent temperature studies for the Gulf need to be conducted as part of the study preceding a proposed project [(1)].
For a specific location, measurements that are more accurate are available at the US National Oceanic and Atmospheric Administration (NOAA). At NOAA, the National Centres for Environmental Information (NCEI) hosts and provides access to one of the most significant archives, with comprehensive oceanic, atmospheric, and geophysical data. NCEI is the US leading authority for environmental information [(3)]. Once the Egyptian government approves the location of the plant, temperatures of the seawater at the location can be assessed.

Deep Sea Cooling and Horizontal Directional Drilling (HDD) Techniques

There are several problems associated with laying a pipe to access cold water from shore to the required depth. The tide action might dislodge anchoring blocks of the piping, especially with high seas. Coral Reefs and seabed marine life may also be affected. Because of that, environmental permits may be difficult to obtain. Returning seawater to the sea should be made so that it is returned to the depth strata where the seawater temperature is the same as that of the returning water. This assures conservation of the sea microorganisms without disruption.

Horizontal Directional Drilling (HDD) is a mature technology used in the Oil and Gas field. This technique enables directional drilling under the surface to access deep cold water with a horizontal displacement of up to eleven kilometres from shore. A rig could also drill a diagonal tunnel of suitable diameter to bring cold seawater to the surface. Using heat exchangers between the cold seawater and a chilled water system, temperatures of 5.5°C to 6.5°C could be achieved at the fresh chilled water network. Similarly, the rig would also drill suitable tunnel to return heated water to a suitable depth. This is the drilling technique suggested for the study.

Figure 2.2 shows the position of the supply and return tunnels and piping and the DC station.

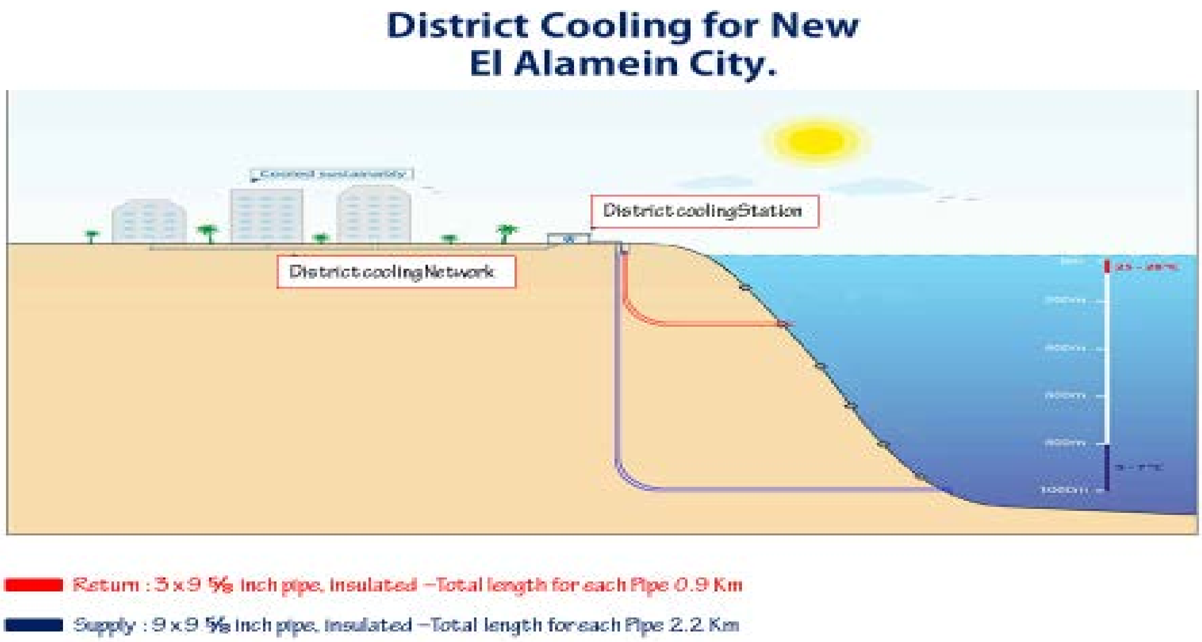

Figure 2.2: Example of Deep Sea Cooling or Free Cooling for a City.

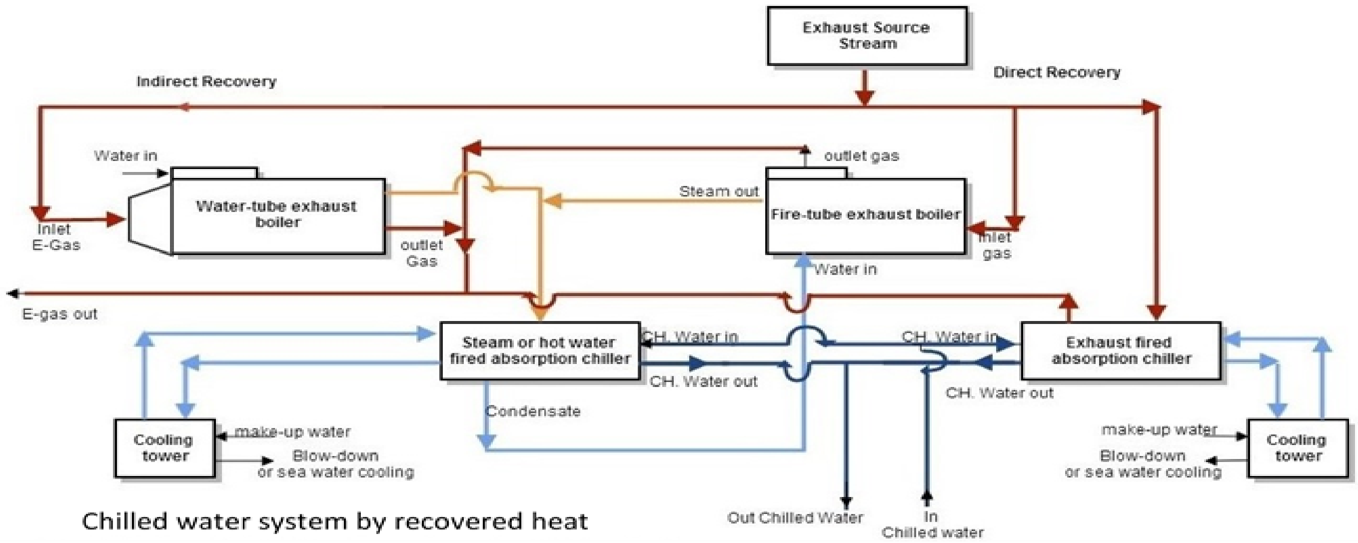

Figure 2.3: Schematic diagram of Exhaust and steam fired absorption chiller.

Figure 2.3 shows a schematic diagram of exhaust and steam fired absorption chiller. When the exhaust stream is relatively clean, with small amount of Sulphur oxides (SOx) and Nitrogen oxides (NOx) in the stream, it is possible to use the stream to fire directly an exhaust fired absorption chiller. Sulphur oxides and Nitrogen oxides when combined with condensate create acids that attack the generator of the absorption chiller and reduces its lifetime considerably. Therefore direct-fired exhaust absorption chillers have to be used with great caution and only when the exhaust stream composition is relatively free of these oxides. When the stream is not clean, a heat recovery boiler is recommended, either a water tube exhaust type or fire tube exhaust type depending on ease of cleaning the tubes from the inside or the outside. The system economics are excellent because of the negligible cost of the exhaust.

B. Solar assisted chilled water absorption cooling systems.

Solar assisted chilled water absorption cooling systems utilises vacuum tube solar collectors or concentrated collectors to heat up water in a closed loop. This heated water fires hot water fired absorption chillers producing chilled water. The capital cost of vacuum or concentrated collectors constitute a large part of the system capital investment. This is why, despite the low operating cost of the system it is not economically feasible to construct the entirety of a chilled water system using solar-fired absorption system. Systems are constructed using 10 to 20 % of the total capacity produced by solar-fired absorption chiller. Systems of total capacities around 500 TR with 50 to 100 TR operating with solar collectors have been constructed and operate successfully. Larger capacities are not be economical. Figure 2.4 shows the schematic diagram of such a system.

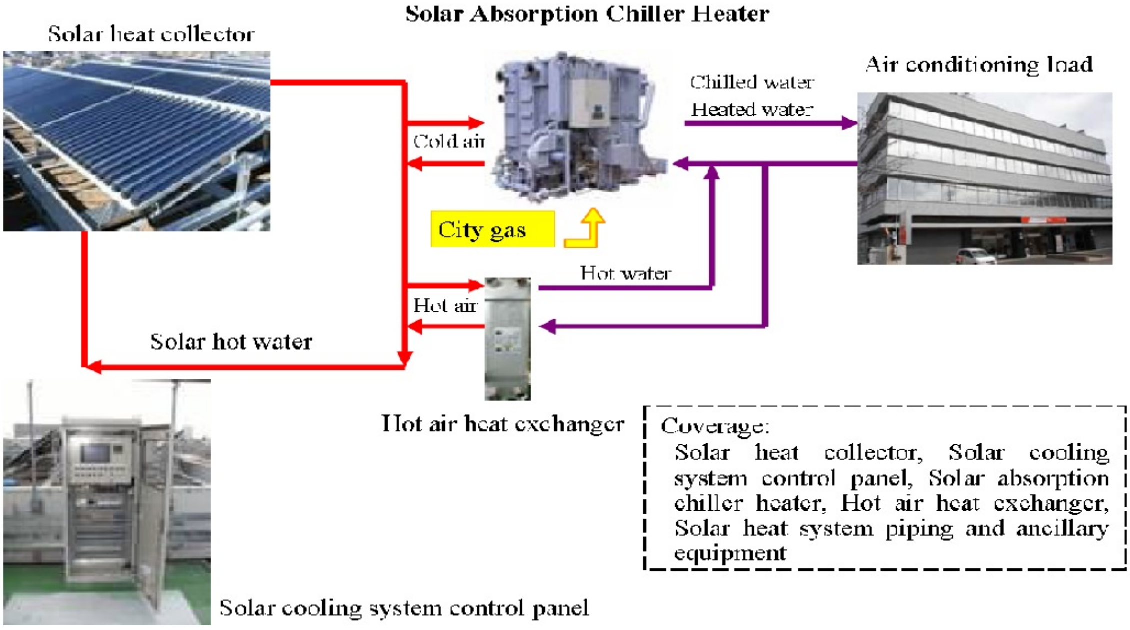

Figure 2.4: Solar assisted chilled water absorption cooling system.

C. Natural gas fired double effect absorption chillers/heaters systems.

This system can be economically advantageous if the price of natural gas in a country is cheaper than that of electric power, which is usually the case. The system is not dependent on electric supply irregularities at on-peak periods; hence, it helps shave and stabilizes electric power demand. Furthermore, when it is responsible for taking care of on-peak surges in a system, it limits use of electric power in those peak periods and reduces power demand surcharges. Figure 2.5 shows an 8,000 TR DC plant with gas fired absorption chillers. There are three generations of absorption chillers. The most common are the Double Effect second-generation units with a heat ratio (efficiency) of 1.2 to 1.45

8 000 TR gas fired absorption chiller plant

Figure 2.5: DC plant with 8000 TR gas fired absorption chiller/heaters.

2.2.5 Steam or hot water indirect fired absorption systems.

Indirect fired absorption systems operate with steam or hot water from industrial processes or from reject heat. Some of the most important examples are Turbine Inlet Cooling System (TIC) used to increase the efficiency of gas turbine power plants. In summer, the turbine efficiency deteriorate due to high ambient temperatures. Cooling combustion air inlet to turbine from ambient conditions to ISO conditions (15 ^{o}C) increases turbine efficiency thus increasing output up to 20%.
Figure 2.6 shows a typical schematic diagram for a TIC system utilizing steam or hot water from the Heat Reject Steam Generators (HRSG) of the power station.

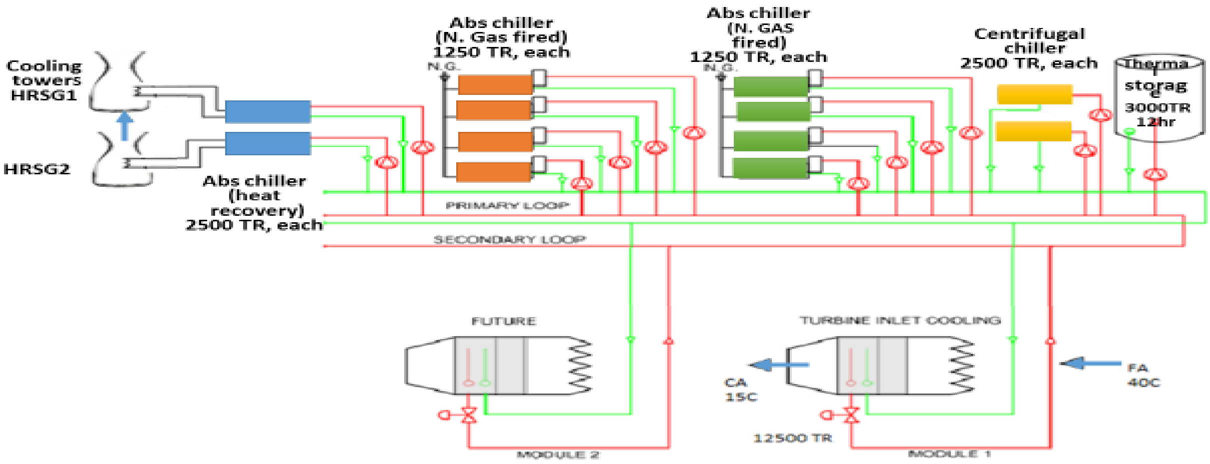

Figure 2.6: Turbine Inlet Cooling -TIC- in a power station using steam or hot water fired absorption chillers.

Figure 2.7 shows the TIC cooling coil installed at air inlet of the gas turbine. Other combination of natural gas fired absorption chillers, electric centrifugal chillers and Thermal Energy Storage (TES) tanks are used to optimize cooling techniques depending on availability of energy at demand.

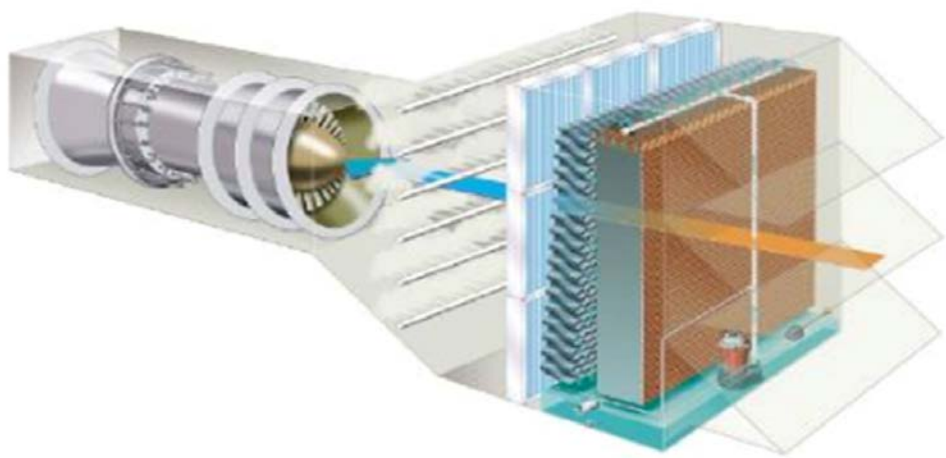

Figure 2.7: TIC cooling coil installed at the air inlet of the gas turbine.

3. **Distribution Piping Networks Pumping Arrangements.**

There are five chilled water distribution network-pumping arrangements. Those are

A. Constant Flow Arrangement.
B. Variable flow systems
C. Variable Speed Primary Pumping.
D. Primary-Secondary Pumping Arrangement.
E. Primary-Secondary-Tertiary Pumping Arrangement.
F. Primary-Secondary Distributed Pumping Arrangement.

Pumping arrangements differ depending of the cooling application chosen. There could be more than one arrangement suitable for a single application, although this is rare, usually one arrangement will be most economical to build and operate for a certain air conditioning system. The following text is a short description on the suitability of each pumping arrangement:

i. *Constant flow arrangement*

Applied to small capacity district cooling systems where the advantages of variable flow systems are not appreciable. Those advantages are primarily saving in electric energy with frequency inverters.

ii. Variable Flow Arrangements

The primary advantages of those arrangements are their reduced consumption of pumping energy and use of distribution system diversity, saving pumping energy. Those systems are used in relatively larger air conditioning systems.

iii. Variable Speed Primary Pumping

In this system, the primary pumping regulates chilled water flow according to load demand. Pumping energy consumption is reduced compared to constant speed. This system is suitable when the plant pumps can satisfy building's pressure drops, otherwise buildings with larger pressure drops may not be served adequately.

iv. Primary-secondary pumping arrangement.

This system is used when the chilled water distribution system is long, and the variable primary system cannot cope with flows and pressure drops. This arrangement is flexible when an expansion scheme is not clear at inception, and additional buildings may be added at a later stage.

v. Primary-secondary-tertiary pumping arrangement.

It may be necessary, when supply and return chilled water distribution lines become too long with heavy loads in building, to add in-building pumps to provide necessary flow and pressure for each building. These systems are also commonly used in district cooling systems.

vi. Primary-secondary distributed pumping arrangement.

Some systems may have a very large cooling load. It is possible for this system to use a primary-secondary distributed pumping arrangement. This system is probably the most suited system for large applications, because it eliminates secondary pumps in central plants. Reduction in total chilled water pump power of 20%–25% is possible**.** Although this system is highly attractive, it is not suitable when additional buildings may be added at a later stage. The chilled water supply gradient pressure is lower than the return gradient in those systems. Pipes are oversized compared to other systems, which increases the initial capital cost. The operational savings mitigate all those factors in large systems.

4. District Energy for a city using reject heat in power stations.

Figure 2.8 is a Sankey diagram [4] that shows two scenarios to provide heating, cooling, and electricity to a city. One scenario uses a traditional coal-fired power station, business as usual (BAU) scenario, whereas the second scenario uses natural gas in a modern combined heat and power (CHP) station.
In the first scenario with a conventional power station, the typical average thermal efficiency of this simple cycle power station is around 35%. More advanced power stations with combined cycles have thermal efficiencies around 45%. Natural gas-fired CHP stations that recover exhaust gases have overall thermal efficiencies of 80%–90%, and sometimes even higher.
This is why the total primary energy utilized in BAU scenarios shown in Figure 2.6 is 601.6 GWh compared to a primary energy utilization of 308.2 GWh with a CHP station. This is a savings of 293.4 GWh or 48.8% compared to BAU, although in both cases the same energy is produced and taken up by end users: 100 GWh of heat, 100 GWh of cooling, and 100 GWh of electricity.
High thermal efficiencies were obtained because recovered heat was used to fire absorption chillers and assisted by wind and geothermal heat. District heating and cooling technology is utilized with this modern CHP station.
This is why district cooling [5], [6], [7], [8] and heating is such an important technology. It reduces carbon footprint, increases efficiency of power stations especially when coupled with recovered process heat, and makes use of diversity factors in reducing overall heating and cooling needs. However, district cooling and heating can also be applied at a district level, not only at the power station level.

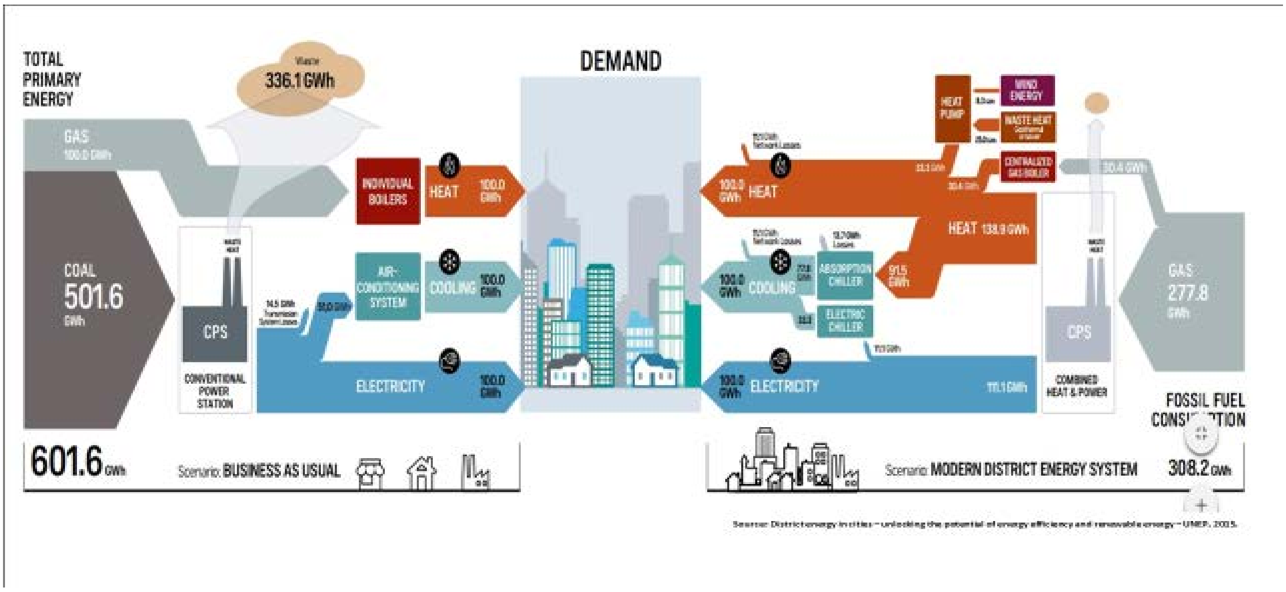

Figure 2.8: The economic and environmental benefits of district cooling in a modern power station for a city.

5. Load Interface Techniques and Energy Calculation Methods.

District cooling systems are connected to distribution networks through load interfaces. These in turn are connected to end users by one of the two methods:

- Direct connections.
- Indirect connections.

Both types of connections are used successfully. The type of connection used depends on the nature and application of the district cooling system.

Direct connections:

The same chilled water produced circulates in the DC plant and the distribution network. Therefore, there is no interface between the chilled water of the plant and in-building distribution network, and hence no separation of chilled water between the production, distribution, and in-building HVAC system. Some insurance companies' demand that direct connection not be used in large DC systems because of the DC provider liabilities in case flooding occurs due to chilled water leaks, which may result in buildings being flooded.

Indirect connections:

In indirect connection, an interface is used, usually a plate heat exchanger. Plate heat exchangers are the preferred heat exchangers in DC systems because traditional shell and tube or shell and coil heat exchangers are bulkier when they are designed to operate at the small approach temperatures in use in DC systems. Those are normally 0.5 to 2°C. In addition, traditional heat exchangers are often more costly. Space is limited in DC buildings' mechanical rooms and
is at a premium, especially in commercial and administrative applications. Rent is often considerable.

Metering and energy meters:

To measure the energy used by end users, energy meters are installed at the building's mechanical rooms. Energy meters utilize equipment for measuring flow, temperature differences between supply and return of chilled water, time duration between two readings and an energy calculator. There are two types of energy meters: dynamic and static.

Collection of DC meter readings:

Collecting energy meter data is done either at the meter or remotely. Local reading of meter uses a handheld terminal that connects to the meter. Remote energy meter reading is made wirelessly by a radio signal from a device in the meter, via the telephone network, or via an Internet connection. In energy meters fitted with radio frequency modules, RF concentrator connected to a central computer uploads the data, and bills can be produced for each end user. In meters connected via the Internet, meters are fitted with a TCP/IP module and can be read by a central computer. Often there is a need for submetering, when a building is rented to more than one end user. In this case, a secondary sub meter is needed or the use of water meters at end users to measure flow rates and allocate sub meter reading proportionally according to water flow meter readings. This method is more economical than using sub meters and is cost effective. Another method used by some DC providers is to calculate individual consumption by floor area of the space instead of submetering. This method does not provide incentives for end user to conserve energy.

6. Daily Cooling Load Profile, Diversity Factors and Thermal Energy Storage (TES).

Daily Cooling Load Profile:

Several important factors must be clearly defined when designing a district cooling system. Some of the most important factors are the daily cooling load demand curve and peak loads. A customer design engineer or consultant usually defines a building's cooling load. Those buildings could be administrative, shopping malls, hotels, schools, and other types of buildings. Cooling load estimates of those buildings will usually vary a great deal from building to building. An administrative building's cooling load estimate will probably include loads attributed to the prevalent weather, loads of occupants, electrical and electronic appliances, lighting and other loads. Those cooling load estimates will differ from those of a shopping mall, where the occupant's load will probably constitute the major part. The same applies to other buildings as well where the loads will vary a great deal. Shopping mall loads peak at a different time of the day compared to administrative loads or residential loads. Deciding how large also when those loads occur is of crucial importance in calculating the total design load of a district cooling plant. In estimating the cooling load of buildings for a certain district, it is possible to use computerized simulation programs and thus obtain an accurate understanding of peak loads' occurrence and their magnitude.

Diversity Factors:

Individual buildings peak at different times. This is why the coincident overall peak demand of a district cooling system depends on the sum of each individual building peak demand at certain time of the day.
Diversity factors are used to calculate the overall peak load of a district cooling system. Those diversity factors may be as low as 0.6 or 0.7 of the sum of individual building peak demands, in applications where there is a great diversity of use. There are different types of diversity factors. Diversity factors inside a building are dependent on the actual use pattern of a building. Diversity factors between one building and the other in a district depend on each building's function, orientation, use, and diversity factors between district cooling plants that may be serving a single
district's distribution network. Chilled water-piping networks are also subject to diversity factors between distribution loops serving different buildings in parallel. All those diversity factors must be taken into account when calculating the overall peak demand of a district cooling system and when designing chilled water distribution networks.

Thermal Energy Storage (TES):

Thermal energy storage (TES) stores cooling enthalpy during off-peak times to use during on-peak times. A specially constructed insulated tank stores the cooling energy at off-peak times and uses it at on-peak times. This technique allows using fewer chillers at on-peak times than those necessary to cope with peaks in the daily cooling load demand curve.
The rating of TES is based on its ability to hold a certain refrigeration capacity for so many hours. For example, a 20,000 TR.h capacity TES will hold 10,000 TR for 2 h or 5,000 TR for 4 h or other combinations totalling 20,000 TR.h. District cooling systems have incorporated successfully TES systems for many years. TES is accepted as an integral part of all air conditioning systems.
Applications range from universities, colleges, airports, museums, sport complexes, and hospitals to leisure centres and administrative buildings; military facilities use TES as do many other applications. The most widely used TES system is the stratified tank type.

附件七

菲律宾政府与多边基金执行委员会根据氟氯烃逐步淘汰管理计划第二阶段计划就削减氟氯烃消费量所达成的最新协定当中将会包含的文本

（为便于参考，相关变更部分以黑体显示）

9. 就管理与实施本协定以及该国为履行本协定规定的义务而开展或以其名义开展的所有活动而言，该国同意对此全面负责。**联合国工发组织**已同意作为该国根据本协定开展活动的牵头执行机构（“牵头执行机构”）。该国对评估工作表示同意，评估可根据多边基金的监测及评估工作方案或参加本协定的牵头执行机构的评估方案开展。

17. 在第八十三次会议上，世界银行已不再是该国根据本协定开展活动的牵头执行机构。因此，世界银行根据本协定所承担的责任仅延伸至第八十二次会议。本项更新后的协定取代菲律宾政府与执行委员会在执行委员会第八十次会议上所达成的协定。

附录 **2-A**：目标及供资

行	细目	**2017 年**	**2018 年**	**2019 年**	**2020 年**	**2021 年**	总量
1.1	《蒙特利尔议定书》附件 C 第一类物质的削减时间表（ODP 吨）	187.56	187.56	187.56	135.46	135.46	暂缺
1.2	附件 C 第一类物质的最大允许消费总量（ODP 吨）	129.52	129.52	129.52	105.87	82.56	暂缺
2.1	牵头执行机构（**联合国工业发展组织**）商定供资额（美元）	1,010,023	0	1,450,029	0	290,005	2,750,057
2.2	牵头执行机构的支持费用（美元）	70,702	0	101,502	0	20,300	192,504
3.1	商定供资总额（美元）	1,010,023	0	1,450,029	0	290,005	2,750,057
3.2	支持费用总计（美元）	70,702	0	101,502	0	20,300	192,504
3.3	商定费用总计（美元）	1,080,725	0	1,551,531	0	310,305	2,942,561
4.1.1	根据本协定商定实现逐步淘汰的 HCFC-22 总量（ODP 吨）						23.44
4.1.2	先前核准的项目中实现逐步淘汰的 HCFC-22 数量（ODP 吨）						2.00
4.1.3	符合资助条件的 HCFC-22 剩余消费量（ODP 吨）						83.88
4.2.1	根据本协定商定实现逐步淘汰的 HCFC-123 总量（ODP 吨）						0.00
4.2.2	在先前核准的项目中实现逐步淘汰的 HCFC-123 数量（ODP 吨）						0.00
4.2.3	符合资助条件的 HCFC-123 剩余消费量（ODP 吨）						1.70
4.3.1	根据本协定商定实现逐步淘汰的 HCFC-141b 总量（ODP 吨）						1.15
4.3.2	在先前核准的项目中实现逐步淘汰的 HCFC-141b 数量（ODP 吨）						43.00
4.3.3	符合资助条件的 HCFC-141b 剩余消费量（ODP 吨）						7.70