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执行蒙特利尔议定书
多边基金执行委员会
第七十六次会议
2016 年 5 月 9 日至 13 日，蒙特利尔

项目提案：泰国

本文件包括基金秘书处就以下项目提案提出的评论和建议：

<u>销毁</u>

• 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示范项目	世界银行

项目评价表 — 多年期项目
泰国

项目名称	双边/执行机构
(a) 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示范项目	世界银行

国家协调机构：	泰国工业部工程建筑司

最新报告的项目所涉消耗臭氧层物质消费数据

A: 第 7 条数据（ODP 吨，2014 年）

氟氯烃			864.45

B: 国家方案行业数据（ODP 吨，2014 年）

HCFC-22	647.04
HCFC-123	2.72
HCFC-141b	174.87
HCFC-124	0.10
HCFC-225	2.75
进口预混多元醇中的 HCFC-141b	11.19

仍符合供资资格的氟氯烃消费量（ODP 吨）	708.56

本年度业务计划分配款		资金 美元	淘汰 ODP 吨
	(a)	不详	不详

项目名称：	
企业所使用的 ODS（ODP 吨）：	38.94*
将淘汰的 ODS（ODP 吨）：	3.88
将使用的 ODS（ODP 吨）：	3.88
项目期限（月）：	12
原申请数额（美元）；	355,905
最终项目费用（美元）：	
增支资金成本:	320,500
应急费用（10 %）：	32,050
增支经营成本:	0
项目总费用:	352,550
地方所有权（%）：	100%
出口成分（%）	0%
申请赠款（美元）：	352,550
成本效益（美元/公斤）：	10
执行机构支助费用（美元）：	24,679
多边基金总共支付费用（美元）：	377,229
对应供资情况（有/无）：	无
所包括项目监测进度指标（有/无）：	有

* 所有用途。喷涂泡沫塑料消费量：4.14 ODP 吨

秘书处的建议：	个别审议

项目说明

背景

1. 在执行委员会第七十五次会议上，世界银行提交了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，原申请总金额为 397,100 美元，外加 27,797 美元的机构支助费用。[1] [2]经秘书处审查后，项目费用调整为 355,905 美元，外加机构支助费用。为审议提交第七十五次会议的所有示范低全球升温潜能值技术的项目成立了联络小组。继联络小组讨论后，执行委员会决定将包括泰国泡沫塑料项目在内的 7 个示范项目的审议推迟到第七十六次会议进行（第 75/42 号决定）。

2. 世界银行代表泰国政府重新向第七十六次会议提交了上述示范项目，总金额为 355,905 美元，外加 24,913 的机构支助费用。所提交项目提案载于本文件的附件一。

项目目标

3. 泰国聚氨酯泡沫塑料行业包括 215 家企业，使用 1,723 公吨[3] HCFC-141b，生产硬质聚氨酯泡沫塑料，包括喷涂用途。泰国氟氯烃淘汰管理计划第一阶段[4] 涉及用于聚氨酯泡沫塑料的 1,517 公吨的 HCFC-141b，但因该项用途没有低全球升温潜能值代用品而不包括 30 家喷涂泡沫塑料企业（即：顶棚、冷藏室、渔船、公共汽车、储罐和绝缘罐）所使用的 349.1 公吨。 目前喷涂泡沫塑料用途的 HCFC-141b 消费量已增加到 585 公吨。

4. 项目建议：

(a) 加强两家本地配方厂家利用氢氟烯烃（即：HFO-1233zd(E) 和 HFO-1336mzz(Z)）为聚氨酯喷涂泡沫塑料行业的中型企业配制、测试和生产预混多元醇的能力；

(b) 验证和优化喷涂泡沫塑料用途中结合使用二氧化碳进行氢氟烯烃发泡用途，以取得在最少增支经营成本情况下与 HCFC-141b 相类似的热性能 （将氢氟烯烃的比例降至 10%）；

(c) 编制一份关于不同的削减氢氟烯烃配方与基于 HCFC-141b 的配方相比的成本分析；以及

(d) 向泰国和其他国家配方厂家散发评估的结果。

5. 实行示范项目所建议的两种氢氟烯烃的主要障碍是其昂贵的单位成本、第 5 条国家可获得的数量有限[5] 以及第 5 条国家情况下经验普遍十分有限。

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[1] UNEP/OzL.Pro/ExCom/75/68。

[2] 为本项目的编制工作所核准供资为 30,000 美元，外加 2,100 美元的机构支助费用，但有一项谅解，即本项核准并不意味着核准提交时的项目或其供资金额（第 74/36 号决定）。

[3] 参考年：根据第六十八次会议核准的氟氯烃淘汰管理计划为 2010 年。

[4] UNEP/OzL.Pro/ExCom/68/41。

[5] 商业可行性已经 HFO-1233zd(E)确定；2014 年年底开始进行 HFO-1336mzz(Z)的试点规模生产，预期将于 2016 年实现全面商业化。

项目执行情况

6. 项目将在两家配方厂家的帮助下予以执行，它们是：Bangkok Integrated Trading Co., Ltd（BIT 公司）和 South City Polychem Co., Ltd.（SCP 公司），它们将多元醇（大多数使用 HCFC-141b）供应给多种聚氨酯泡沫塑料用途，包括喷涂泡沫塑料。这两家配方厂家都拥有执行示范项目的基本设备。

7. BIT 公司将配制高密度喷涂泡沫塑料（50 公斤/立方米），SCP 公司将配制普通密度的喷涂泡沫塑料（35 公斤/立方米）。每家配方厂家都将编制并测试至少 110 种以下赋形剂的配方：HFO-1233zd(E)和 HFO-1336mzz(Z)；五种氢氟烯烃/二氧化碳比例（即：100:0、75:25、50:50、25:75 和 0:100）；基于不同聚醚、聚酯和胺醇比例的五种周期。将使用一种新的泡沫塑机（Graco）来使用所得出的配方，其最大压力为 3,500 磅/平方英尺，聚氨酯与异氰酸盐的比例可以调整。将对初期阶段的结果进行分析，以确定多元醇的最佳组合。

8. 将对 30 种最佳泡沫塑料配方进行测试（每个配方出三种采样），并将泡沫塑料的临界性能（即维度稳定性、不同底面粘合性不佳、热传导以及可加工性）与典型 HCFC-141b 配方的特性进行比较。将对特定的配方进行实地测试。

9. 将举办一次技术讲习班推广所取得的结果。将为配方厂家和聚氨酯供应商提供获得专家和技术供应商的机会，以便转让知识和加强其配方研发的技术能力。

10. 预期项目将在 12 个月内完成。

项目费用

11. 如表 1 所示，估计项目的总费用为 355,905 美元。

表 1. 按活动分列的项目费用

项目	数量	单位成本（美元）	共计（美元）
泡沫塑料设备:			
喷涂泡沫塑料机（工作压力为3,500磅/平方英尺，聚氨酯与异氰酸盐比例可调整）	2 套	40,000	80,000
实验室设备:			
热传导测试器	2 套	5,000	10,000
配制研发和测试:			
配制研发	2	45,000	90,000
经认可的实验室进行的外部测试（可燃性、压缩系数）	110	250	27,500
实地测试	20	500	10,000
聚氨酯测试材料（包括运输）			
多元醇	1,100	US $ 3.0/kg	3,300
计量吸入器	1,100	US $2.5/kg	2,750
技术援助			
技术援助包括旅行	1	80,000	80,000
技术传播讲习班	2	10,000	20,000
小计			**323,550**

项目	数量	单位成本（美元）	共计（美元）
应急费用（10%）			32,355
共计			**355,905**

秘书处的评论和建议

评论

12. 提交第七十五次会议的项目提案所包括的高全球升温潜能值的氢氟碳化合物配方，是为市场上无法购到氢氟烯烃的情况设想的。但是，这一配方已从提交第七十六次会议的项目中撤除；因此，现示范项目完全侧重于减量氢氟烯烃的配方。

13. 为便于参阅，现将秘书处与世界银行就提交第七十五次和第七十六次会议的示范项目的讨论结果归纳如下：

(a) 世界银行对项目费用进行了合理化，由第一次提交第七十四次会议的 1,046,000 美元，[6] 调整为提交第七十五次会议的 397,100 美元。最初提交第七十六次会议的项目提案费用进一步合理化为 355,905 美元。此外，由于自示范项目中撤除了氢氟烯烃配方，测试次数为 100 次（而不是 110 次），因而节省了 3,355 美元。因此，示范项目总费用为 352,550 美元；

(b) 世界银行解释说，为了在 12 个月内实施该项目，将在两家配方厂家的协助下执行该项目（一家测试顶棚隔热喷涂泡沫塑料，另一家测试冷藏室和建筑喷涂泡沫塑料）。如果仅利用一家配方厂家，便需要研发和测试两倍数字的配方，可能需要较长时间；

(c) 氟氯烃淘汰管理计划第一阶段期间，向 BIT 公司提供了资金支持，用于所有次级行业的小企业转型为水发技术，但其中不包括喷涂泡沫塑料行业，示范项目中涉及该行业；

(d) 鉴于泰国喷涂泡沫塑料企业目前使用 585 公吨的 HCFC-141b，所使用特定技术可能的可复制性很大。该地区其他国家的情况也是如此：中国（7,100 公吨）、印度尼西亚（5.5 公吨）以及越南（60 公吨）。尽管菲律宾喷涂泡沫塑料用途将于 2015 年停止使用 HCFC-141b，但它仍将从项目中受益；

(e) 项目实施要求进行集中的配方研发，原因是这将是第一次根据第 5 条国家的情况对减量氢氟烯烃进行评价。需要一名国家泡沫塑料专家进行参与，以便在整个过程中同这两家配方厂家进行合作。为加快执行该项目，可将示范项目纳入泰国氟氯烃淘汰管理计划第一阶段的现有赠款协定；以及

(f) 正如世界银行解释的，采用替代技术的潜在风险与泡沫塑料新配方粘度增加有关，也与现阶段无法确定氢氟烯烃的最终费用和市场上可获得与否有关。

14. 世界银行报告称，泰国政府承诺从剩余的符合资助条件的氟氯烃消费量中淘汰 35.3 公吨 HCFC-141b。

[6] UNEP/OzL.Pro/ExCom/74/48。

结论

15. 秘书处认为，项目遵守了第 72/40 号决定规定的标准，因为项目增加了对于当前在行业内（喷涂泡沫塑料）应用减量氢氟烯烃配方（低全球升温潜能值技术）的知识，鉴于在使用易燃发泡剂方面的局限性，几个第 5 条国家认为该行业内存在挑战。在两家配方厂家的支持下，通过优化减量氢氟烯烃配方，预期将减少中型企业的经营费用，特别是在氢氟烯烃减量 25%或 10%的配方的情况下。此外，对示范做法作了明确的说明，该做法也与泰国的氟氯烃淘汰管理计划相联系；对于在该国和该地区进行复制的可能性也作了说明。秘书处注意到，三个其他项目也建议对喷涂泡沫塑料或其他用途中的氢氟烯烃进行示范。[7]

建议

16. 谨建议执行委员会考虑：

(a) 在讨论关于项目审查期间所查明问题概览的文件（UNEP/OzL.Pro/ExCom/76/12）所述氟氯烃全球升温潜能值代用品的示范项目提案时，审议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；

(b) 根据第 72/40 号决定，核准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，金额为 352,550 美元，外加给世界银行的 24,679 美元的机构支助费用；

(c) 自符合资助条件的剩余氟氯烃消费量中扣除 3.88 ODP 吨氟氯烃；以及

(d) 敦促泰国政府和世界银行按计划在 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终报告。

[7] 哥伦比亚（UNEP/OzL.Pro/ExCom/76/26）；印度（UNEP/OzL.Pro/ExCom/76/35）；以及沙特阿拉伯（UNEP/OzL.Pro/ExCom/76/46）。

Annex I

THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER

PROJECT COVER SHEET

COUNTRY:	Thailand	
PROJECT TITLE:	Demonstration project at foam system houses in Thailand to formulate pre-blended polyol for spray polyurethane foam applications using low-GWP blowing agent	
SECTOR COVERED:	PU Foam	
ODS USE IN SECTOR:	349 MT HCFC-141b in 2010 (spray foam)	
PROJECT IMPACT:	N/A	
PROJECT DURATION:	One year	
TOTAL PROJECT COST:	Incremental Capital Costs (Incl. 10% contingencies)	355,905 USD
	Incremental Operating Costs	0 USD
	Total Project Cost	355,905 USD
PROPOSED MLF GRANT:		355,905 USD
SUPPORT COST:		24,913 USD
TOTAL COST:		380,818 USD
COST-EFFECTIVENESS:	N/A	
IMPLEMENTING ENTERPRISE:	1. Bangkok Integrated Trading Co., Ltd 2. South City Polychem Co., Ltd	
IMPLEMENTING AGENCY:	The World Bank	
COORDINATING AGENCY:	Department of Industrial Works, Ministry of Industry Federation of Thailand Industries	

PROJECT SUMMARY

This is a demonstration project to validate the use of two Hydrofluoroolefins (HFOs): HFO-1233zd(E) and HFO-1336mzz(Z) for spray foam applications in Thailand. These are low GWP and non-flammable blowing agent being developed to replace HCFC and HFC blowing agents.

The project consists two main components. The first component is the formulation development with participating system houses. Two local system houses are participating under this component, one to develop formulations at 35kg/m^3 density and another at 50kg/m^3 density in order to cover most spray foam applications in Thailand. The second component is technical replication and dissemination of results.

The development process consists the following steps: planning, experimental laboratory, formulation development, foam samples preparation and testing. An international expert will be engaged to provide

support during the planning and implantation of the project, analyze cost/performance, and participate in technical dissemination seminar.	
Prepared by:	
Reviewed by:	OORG

1. PROJECT OBJECTIVE

The Article 5 parties will address in the short term the second phase of the HPMP (2016-2020) in the foam sector. One of the most critical subsectors that still uses HCFC-141b and accounts for a significant market portion is the production of spray foam for different applications such as construction, refrigerated transportation, tanks insulation, etc. The sector is characterized by a great number of "micro" small enterprises without the sufficient knowledge and discipline to handle flammable substances, which prevents the adoption of hydrocarbons as HCFC replacement. In addition the introduction of high GWP alternatives such as HFCs (HFC-245fa, HFC-365mfc, etc.) would result in a negative climate impact.

This projects proposes the validation of the Hydrofluoro Olefins (HFOs), a low GWP and non flammable option, for spray foam applications in the scenario of the Article 5 parties through the development of polyurethane (PU) formulations with reduced HFO contents that have CO2, derived from the water-isocyanate reaction, as co-blowing gas. The aim is to optimize the cost/performance balance while achieving a similar foam thermal performance to HCFC-141b based formulations.

Therefore the objectives of the project would be:

1. To strengthen capacity of selected local system houses to formulate, test, and produce pre-blended polyol using low-GWP alternatives. This would lead to increased supply of cost-effective low-GWP pre-blended polyol to small and micro-enterprises.
2. The validation of the use as foam blowing agents of the recently developed HFOs in blends with CO2 for the production of spray foam in Thailand. The aim is to develop and optimize reduced HFO formulation to get a similar thermal performance to HCFC-141b at a minimum incremental operating cost.
3. To make a cost analysis of the HFO reduced formulations versus the currently used HCFC-141b based system.
4. To disseminate the technology to interested system houses in Thailand and other countries.

2. SECTOR BACKGROUND

Based on HPMP, the foam sector in Thailand is the largest manufacturing sector of Thai-owned enterprises with a 2010 consumption of HCFC-141b of 1,723 metric tonnes, most of it in the form of domestically blended polyol. There are 215 foam manufacturing enterprises active in manufacturing PU rigid foam, integral skin, flexible foam and extruded polystyrene. The majority uses pre-blended polyol that is supplied by the different polyol suppliers. Out of the 215 enterprises, 53 have a consumption of less than 1 ODP MT of HCFC-141b and can consequently be considered as "micro-enterprises."

Table 1: Breakdown of HCFC Consumption in Foam Sector (MT)[1]

Sector/Application	No. of Enterprises	HCFC-141b Consumption (MT)

[1] Source: Thailand HCFC Phase-out Management Plan

		2007	2008	2009	2010
Rigid Polyurethane					
Box Foam	4	44.7	61.4	70.2	60.1
Commercial Refrigeration	14	110.4	136.6	132.8	147.5
Steel/Fiberglass door	6	29.0	32.6	32.5	28.5
Ice Box	44	592.3	604.4	634.1	602.8
Pipe Section/Pipe-in-pipe Insulation	6	41.3	39.3	50.4	62.7
Pipe Section and Sandwich Panel***	3	32.8	38.3	40.6	38.4
Refrigerated Truck, Reefer, Fishery vessel	13	43.2	59.3	59.7	70.3
Sandwich Panel	25	242.7	275.4	246.9	332.2
Spray Foam	30	295.9	330.1	298.6	349.1
Thermoware	7	46.6	54.5	47.9	45.7
Wood Imitation	6	27.6	32.2	39.2	49.0
Others	44	41.8	58.4	66.2	48.0
Sub-total Rigid Polyurethane Foam	202	1,548.2	1,722.6	1,719.1	1,834.4
Flexible Polyurethane	5	21.6	25.0	27.9	25.1
Integral Skin	8	19.3	28.0	24.3	24.1
Total Foam Sector	215	1,589.1	1,775.6	1,771.3	1,883.6

Under Stage I HPMP, the foam sector conversion will phase-out a total quantity of 1,517 MT of HCFC-141b used in bulk, in domestically pre-blended and imported pre-blended polyol. Of which, 639.6 MT of HCFC-141b will be replaced by cyclo-pentane and 844.6 MT of HCFC-141b will be replaced by a 50% reduced formulation with HFC-245fa as a blowing agent. The balance will be phased out by water blown technology. Thailand Stage I HPMP does not include spray foam application in 30 enterprises which consumed 349.1 MT of HCFC-141b in 2010. The reason for not including spray foam in Stage I was due to limited alternatives for spray foam either because of the capacity of enterprises needed to adequately apply the technology and the technology's maturity (CO2), or because of the environmental impact of other commercially available alternatives (HFCs).

2.1 System House Background

Thailand's foam industry comprises not only polyol suppliers and manufacturers, but also system houses that both supply pure polyol to, as well as blend polyol and prepare formulations for the foam industry. In addition to direct supply by system houses, local polyol distributors authorized by the system houses also supply pure polyol and pre-blended polyol to foam enterprises across the country. Thailand has thirteen PU system houses and polyol suppliers. The local system houses/suppliers cater to small/micro enterprises (SME) with PU material, while international PU chemical manufacturers (BASF, Bayer, Dow and Huntsman) are represented and concentrate on the larger users.

To reach these small and micro-sized enterprises, the project will provide foaming equipment to two local system houses and assist in developing and supplying pre-blended polyol using low-GWP alternatives to spray PU foam to their customers. The two participating local system houses are:

2.1.1 Bangkok Integrated Trading Co., Ltd

Bangkok Integrated Trading (BIT) was established in 1989. It began as the sole distributor of PU foam of Dow Chemical in Thailand. They began to provide their own pre-blended polyol in 2009. Its products are widely used in the production of foam for appliances, sandwich panels, automotive, furniture, reefer container, cold store, pipe insulation, imitation wood and imitation ceramic, spray foam, etc. It is supplying polyols to customers all over the Thailand. The estimated HCFC-141b in system sales and spray foam from 2010 to 2015 are shown in Annex 1. Most of the products are pre-blended polyol with HCFC-141b blowing agents.

BIT facility includes a laboratory that performs chemical tests: reaction and cream/string tests, and foam water content (water titration). Physical tests are performed by external accredited laboratory either in Thailand and Singapore according to relevant national and international standards. The company has a 5-MT insulated blending tank to produce pre-blended polyol. BIT technical personnel consist a chemist with more than 17-year experiences in foam formulation and production.

2.1.2 South City Polychem Co., Ltd

South City Polychem (SCP) was founded in 1996, located in Rayong Province. SCP is the sub-company under South City Group. There are 3 people are working on polyol system development and production. Head of R&D has more than 20-year experience in PU foam development. South City Polychem has one 1-ton and one 5-ton blending tank. They also have a laboratory to perform basic tests (i.e., cream time, and tack free time). Their products are widely used in the production of foam for appliances, sandwich panels, automotive, furniture, reefer container, cold store, pipe insulation, imitation wood and imitation ceramic, etc. It is supplying polyols to customers all over the Thailand. Most of the products are pre-blended polyol with HCFC-141b blowing agents.

2.2 Spray Polyurethane foam (SPF)

Spray PU foams are closed-celled, air tight, resistant to mildew and fungal attack, provide no food value to rodents and have good vapor barrier properties. They find utility as an in situ applied insulation in applications where irregular shapes or the need for a monolithic layer of foam exists. These applications include building envelope, pipe insulation, tank insulation, rail cars, residential roofing and floors. Sprayed foam is now finding increasing applications in retrofitting/refurbishing roofs, walls, floors and windows of existing buildings as well as in new constructions such us commercial offices, industrial factories and warehouses, agricultural pig and chicken farms.

There are approximately 30 enterprises that provide spray foam services to their customers in Thailand. Main applications for spray foam in Thailand include the followings: roof, cold-storage room (including floor), fishing boat, passenger bus, storage tank, and insulated tanker. These enterprises either buy blowing agent and mixing it themselves with pre-blended polyol systems or purchase pre-blended polyol systems with HCFC-141b. Their baseline HCFC-141b consumption in 2010 was estimated to be 349.1 MT and increasing to 585 MT in 2013.

For normal applications, desired density is 35kg/m^3 for optimal insulation. For flooring applications that need high compressive strength, the desired density is 50 kg/m^3. Current SPF formulation in Thailand uses 20-30% HCFC-141b in pre-blended polyol. The system house can adjust the ratio of HCFC-141b in pre-blended polyol depending on the density requirement of the users. Foam systems used in SPF applications need to have fast reaction time (cream time: 3 sec. and tack-free time: 5-7 sec.). Other considerations include low odor.

For developed countries, the proven technical options to replace HCFC-141b as blowing agent for spray PU foam are exclusively limited to high GWP HFCs, specifically, HFC-245fa, which has a GWP of 1,030 (100yr ITH, IPCC 4th Assessment Report 2008). This constitutes a major drawback for developing countries, as this is an application with comparatively high emissions and having in mind Decision XIX/6, which promotes selection of alternatives that minimize environmental impacts, in particular impacts on climate. Reduced HFC-245fa formulation at 7.5-10% could reduce the climate impact but will increase the viscosity of the pre-blended polyol. This could pose problem for current crop of spray foam machines, with maximum working pressure up to 1600 psi, whether they can cope with higher viscosity polyol. The barrier for hydrocarbon technology in this application is safety during foaming because of their flammability.

2.3 Low-GWP alternatives

The unsaturated HFCs and HCFCs (commonly called HFOs), 1233zd(E) and 1336mzz(Z), marketed under the trademarks Forane (Arkema), Formacel (Chemours) and Solstice (Honeywell) and recently commercialized, have shown in rigid PU foam applications such as domestic refrigeration and spray a better thermal performance that the high GWP-saturated HFCs currently used in the developed countries. Their general properties are shown in **Table 2** along with HCFC-141b, HFC245fa and HFC-365mfc. They offer a unique opportunity for introducing safe non-flammable technologies that while enhancing energy efficiency will have a positive effect on climate change in terms of greenhouse emissions. Based on the physical properties of these substances (non flammability and relatively high boiling points) it is anticipated that their application does not require the retrofit of the foaming equipment currently in use. This is particularly true and important at the level of small and medium enterprises. Commercial availability has already been established for HFO-1233zd(E). Pilot scale production of HFO-1336mzz(Z) commenced in late 2014, with full commercialization expected in 2016. Although for these options availability is likely to be targeted mostly in markets within Article 2 parties where the requirement for improved thermal efficiency is best identified, the demand to leapfrog high GWP alternatives to HCFCs could accelerate distribution to Article 5 regions. There are not legal or commercial barriers for the introduction of these products.

Table 2: HCFC, HFC and HFO Foam Blowing Agent Properties

Common name	HCFC-141b	HFC 245fa	HFC 365mfc	HFC1336mzz-Z	HCFC 1233zd	HCFC 1233zd
Manufacturer	Various	Honeywell	Solvay	DuPont	Honeywell	Arkema
Trade name		Enovate®	Solkane®	Formacel®	Solstice™ LBA	Forane®
Formula	CH_3CCl_2F	$CF_3CH_2CHF_2$	$CF_3CH_2CF_2CH_3$	Cis-CF_3-CH=CH-CF_3	Trans-ClCH=CH-CF_3	Trans-ClCH=CH-CF_3
Molecular Weight	116.9	134	148	164	130.5	130.5
Boiling Point (°C)	32.1	15.3	40.2	33	19	19
GWP (100yr ITH)*	725	1,030	794*	2	1	<7
Gas Thermal Conductivity (mW/mK, 10°C)	9	12.5	10.6	10.7	10.6**	9
LFL / UFL (vol % in air)	6.5-15.5	None	3.8-13.3	None	None	None

The formulation science associated to the PU technology and the excellent foam thermal characteristics provided by HFOs open the door for the development of PU formulations with reduced HFO contents that have CO_2, derived from the water-isocyanate reaction, as co-blowing agent. The aim is to optimize the cost/performance balance of these substances, achieving a similar foam thermal behavior to HCFC-141b at the lowest possible cost, and, simultaneously, to carry out a comprehensive assessment of the HFO performance at developing countries conditions.

These alternatives could provide a long-term solution for spray PU foam applications as well as for other application. However, there are two main obstacles for the introduction of these substances:

1. Their high unitary cost that is reflected in the final cost of the PU formulation.
2. The minimum experience with these products in developing country conditions. This technology

has not been demonstrated in conditions prevailing in Article 5 parties.

3. PROJECT DESCRIPTION

Currently, pre-blend polyol for SPF applications in Thailand contain 20-30% of HCFC-141b while the best reduced formulation used in developed countries can reach 7.5% of HFC-245fa. In this demonstration project, the goal is to validate reduced formulations at 10% HFOs. The project consists of two main components. The first component is the reduced formulation development with participating system houses. The second component is technical replication and dissemination of results.

3.1 Reduced Formulation Development with System House

Two local foam system houses (Bangkok Integrated Trading Co. Ltd. and South City Co. Ltd.) will be participating in the project. Bangkok Integrated Trading will focus their formulation on high density SPF (50kg/m^3) while South City will focus on normal density SPF (35kg/m^3). Based on their past experience in formulation development, the development process will be as followed:

i. Planning.

Definition of the independent variables: type of HFO, type of polyols, proportion of HFOs in the cell gas, and density. Definition of the dependent variables: Lambda value, compression strength, flame retardant, and dimensional stability. A commercial HCFC-141b based formulation will be used as control.

ii. Selection of polyol candidates based on solubility.

SPF uses a combination of polyether, polyester and amine polyols based on different requirements: dimension stability, flame retardant, and cell size. At this stage, candidates from each type of polyol will be shortlisted based on their solubility with the two HFOs. Different ratios of polyether, polyester and amine polyols will also be considered during formulation development.

iii. Test options.

Different spray foam applications require different combinations of polyol, surfactant, catalysts, fire retardant and other additives. With technical support from the international expert, one foam system house will develop formulations for under-roof application while another will develop formulations for cold storage room.

To reach 10% HFO reduced formulation, each system house will need to conduct different CO2 formulation for each HFO in order to get the characteristic curve. An additional formulation will be needed for matching the point where the characteristic curve intersects with the baseline HCFC-141b performance. Therefore, each HFO will need five formulations. For statistical purposes, three sets of tests are required for each HFOs. The total test will be equal to 30 tests plus 3 test for baseline HCFC-141b formulation. Three specimens for each test will be prepared and sent for laboratory testing. The total number of specimens and laboratory tests is about 100 (33 * 3). Three tests will be needed and additional 9 – 10 specimens will be sent for laboratory test.

iv. Formulation development.

Spray foam must meet a number of customer, government and specifier’s criteria. The baseline for critical properties such as dimensional stability, adhesion to different substrates, thermal conductivity, processability will be determined to compare the values currently observed with the HCFC-141b based systems. The foams will be tested for reactivity, foam surface quality, density with and without skins, closed cell content, thermal performance, compressive strength, dimensional stability and on selected samples for flammability via standard test methods. The critical immediate and aged foam properties for these applications (Lambda value, compression strength, dimensional stability) will be tested following ASTM or ISO standard procedures and DIN for flammability.

The resulting formulations will be prepared at laboratory scale and then applied using a Gusmer (Graco) type dispenser with an adjustable isocyanate/polyol volume ratio.

The initial phase will be at laboratory scale testing minimum of 110 formulations Catalysis and overall blowing agent amount will be adjusted to have among formulations a similar reactivity, free-rise density, and dimension stability. The results of initial phase will be analyzed in order to identify best combinations of polyols before the next phase. The second phase, the system house will use a Gusmer (Graco) type dispenser to spray selected foam formulations to simulate real-world application. Three samples from each formulation will then be subjected to comprehensive tests.

Given that the new reduced formulations will most likely be more viscose than HCFC-141b formulation, the project will provide a spray foam machine with maximum working pressure at 3,500 psi and adjustable polyol to isocyanate ratio to each system house in order to carry out the spray foam test accurately. Other equipment will include additional laboratory equipment. The participating system houses will receive budget for testing different formulations and for cost of raw materials for the trial production and testing that they will develop with their customers.

v. Analysis of results.

A detailed analysis of the resulting foam properties at different HFO levels and the associated formulation cost will be carried out. A typical HCFC-141b formulation will be used as standard.

vi. Field test

A field test with selected formulations will be done.

3.2 Technical Replication and Dissemination of Results

Based on results from the first component, technical workshop will be made available to all system houses and polyol suppliers to share the results from the testing of foam formulations using low-GWP alternatives. Foam system houses and polyol suppliers will be given support in the form of access to experts and suppliers of alternative technologies to bring them up to speed on short and longer term options for a sector characterized by small users with capacity limitations. The technical assistance will transfer knowledge and strengthen technical capacity of the system house in formulation development. Foam properties depend on the interaction of all components: polyols, blowing agents, surfactants, catalysts, and isocyanate.

3.3 IMPACT ON GWP

There is no impact on GWP at this stage. The impact will occur when the system houses produce and commercialize the new low-GWP formulations.

4. PROJECT BUDGET

4.1 Technical Assistance

Cost for international expert is included. The expert is expected to provide technical advices for preparation, monitoring and reviewing of project, and recommendation on extension to other foam industry in the country. Three full one-week visits are needed. The first visit is to carry out detailed planning of the project implementation (experimental laboratory planning, formulation development, foam samples preparation and testing). The second visit is planned during the middle of the implementation to do a detailed project follow-up. Finally the third visit is to discuss the final report preparation including support on the cost/performance analysis and, in parallel, participate in the dissemination seminar.

4.2 Provision of equipment

The project plans to provide one full set spray foam machine (maximum working pressure 3,500 psi. The equipment consists of ordinary spray foam dispenser, super-critical CO2 module as well as water introduction module for PIR application. By this arrangement, any of potential difficulty to connect all modules can be avoided, so that fast implementation is ensured.

4.3 Laboratory tests

Some of essential properties of the foam are to be done by outsourcing (Flame retardancy and aging tests, SEM). Fundamental laboratory equipment for testing such as a thermal conductivity tester and are provided to the participating system houses. For the foam application, minimum amount of formulated polyol is to be provided from suppliers both for PUR and PIR applications.

4.4 Dissemination workshop

Cost to organize the dissemination workshops is included. Two workshops will be organized in Thailand to system houses in Thailand and support to interested system houses from countries in the region.

4.5 Incremental operating cost

According to the supplier, the cost of the low-GWP foam blowing agent material will be much higher than HCFC-141b. Though with reduced HFO PU formulation that have CO_2, derived from the water-isocyanate reaction, as co-blowing agent, the cost/performance balance of these substances, achieving a similar foam thermal behavior, could be slightly higher than HCFC-141b. Amount of PU material is nearly same as the HCFC-141b foams for almost all application, since the density is same and required thickness is same.

However, IOC is not requested for end users in the present demonstration project.

The summary of the project cost is as follows:

ITEMS	Qty.	Unit Cost (US$)	Total (US$)	Remark
Foaming equipment				
• Spray foam machine (maximum working pressure at 3,500 psi & adjustable polyol/isocyanate ratio)	2 sets	40,000	80,000	
Laboratory equipment				
• Thermal conductivity tester	2 sets	5,000	10,000	
Formulation development and testing				
• Formulation development	2	45,000	90,000	
• External test by accredited laboratory (flammability, compressibility)	110	250	27,500	

ITEMS	Qty.	Unit Cost (US$)	Total (US$)	Remark
• Field Test	20	500	10,000	
PU material for testing (including transportation)				
• Polyol	1,100 kg	3.0	3,300	
• MDI	1,100 kg	2.5	2,750	
Technology assistance including travel	1	80,000	80,000	
Technology dissemination workshop	2	10,000	20,000	
Sub-total			323,550	
Contingencies (10%)			32,355	
Total			355,905	

5. PROPOSED MULTILATERAL FUND GRANT

The proposed grant request is US$ 355,905, the calculated cost based on actual situation of all participants.

6. PROJECT IMPLEMENTATION

The project will be implemented under the supervision of the Department of Industrial Woks in coordination with Federation of Thai Industries. The following proposed schedule will be effective after the proposed MLF grant approved:

Activity	Month after approval											
	1	2	3	4	5	6	7	8	9	10	11	12
Project approval	X											
GSB appraisal	X											
Sub-project agreement		X										
Planning for system development and verification testing			X									
Specification of foaming equipment and site preparation			X									
Procurement and installation of equipment at the system houses				X								
Trials/testing/analysis				X	X	X	X	X	X			
Report and Review meeting.									X	X		

Technology dissemination workshop											X	
Completion report												X

7. PROJECT IMPACT

Not applicable.

8. ANNEXES

ANNEX-1: Information on system house consumption

ANNEX-2: OORG Review

Annex 1: HCFC-141b Consumption Summary

A. Bangkok Integrated Trading System Sales and HCFC-141b consumption

YEAR	2011	2012	2013	2014	2015 (forecast)
HCFC-141b Consumption (Total)	250	274	271	204	276
HCFC-141b Consumption (spray foam)	19.2	12.9	8.0	7.6	30

B. South City System Sales and HCFC-141b consumption (MT)

YEAR	2011	2012	2013	2014	2015 (forecast)
HCFC-141b Consumption (Total)	129	120	140	150	180
HCFC-141b Consumption (spray foam)	26	24	28	30	36

Annex 2: OORG Review

THAILAND – REVIEW OF SPRAY FOAM DEMONSTRATION PROJECT

INTRODUCTION

This project involves the validation of low GWP unsaturated HFCs (hereinafter referred to as "HFOs") as replacements for HCFC-141b in polyurethane rigid foam in the spray foam sub-sector. In particular, it involves the development of polyol formulations based on HFOs, in conjunction with two local system houses, which supply local SMEs and micro enterprises who are engaged in the application of spray foam systems in the Thailand market.

TECHNICAL ASSESSMENT

The replacement of HCFC-141b in the spray foam sub-sector has been particularly challenging. The main HCFC replacement technology for the global rigid polyurethane foam industry have been hydrocarbons (pentanes). These offer cost-effective low GWP solutions but the high flammability of these hydrocarbons (HCs) prohibit the use in spray foams on safety grounds. Further, the safety engineering modifications would be prohibitive for SMEs and the necessary safety management capacity would be beyond the resources of SMEs.

In developed countries the main replacements for HCFC-141b for spray foams have been one of the two saturated HFCs HFC-245fa or HFC-365mfc (note that HFC-365mfc is not mentioned in Section 2.2 where the use of HFCs is discussed – please rectify). These two HFCs offer excellent foam properties but their high GWPs indicate that they may not be long term solutions, particularly where compliance with Decision XIX/6 is required or is desirable. In addition, these HFCs do not, in themselves, offer cost effective solutions in comparison with HCFC141b and "reduced HFC" formulations involving co-blowing with CO2(water) is one approach to cost effectiveness being applied in developing countries.

The comparatively recent development of HFOs offer low GWP, non-flammable, alternatives to HFCs. These are HFC136mzz-Z (DuPont) and HCFC1233zd (Honeywell and/or Arkema). Their evaluation in developed countries and in applications such as appliances in developing countries are subject to intensive activity but the evaluation in SME-related applications such as spray foam is not being followed in the same time scale. However, their early evaluation in these applications indicates a significant improvement in insulation properties in comparison with the HFCs. It should be noted that the commercial availability of these new blowing agents is improving as new production facilities are built and commissioned.

The proposed project addresses the evaluation of these HFOs in a comprehensive manner. A key step is the partnership with two local systems houses in the development of suitable formulations for spray foams. These system houses are very experienced in polyurethane rigid foam technology. A further key step is the development of "reduced" formulation using HFOs in conjunction with partial co-blowing with CO2(water). This is covered in Section 1 (Project Objective) but is not further covered in Section 3.11 (iii) which concentrates on blend rations with HFC-245fa. It should be made clear to the reader that "reduced" formulations are used.

The development and evaluation of formulations involves a range of polyol types and this approach is fully supported. The formulations will be designed to give foam densities at two levels. These will be at ca 35 kg/m3 and ca 50 kg/m3 to cover optimum insulation and walls and floor/roof applications, respectively.

Another key step is involvement and the enhancement of the capabilities of the two system houses. This step includes a new spray foam dispenser and a thermal conductivity tester for each systems house. The dispensers are chosen to be capable of working with higher viscosity polyol formulations.

The reviewer queries the decision to have only one workshop to disseminate the results and learning from the study. Will this be enough to ensure the necessary attendance of SME foam manufacturers from different regions within and outside Thailand?

ENVIRONMENTAL, HEALTH AND SAFETY CONSIDERATIONS

The main environmental consideration is that HFO technology is of low GWP (and extremely low/negligible ODP) and represents a long-term option. The climate/energy impact (benefit) via the project results is low but may not be negligible, depending on whether or not improved insulation values are achieved in comparison to HCFC-141b. However, long term use of HFCs, even in blends, would have a negative impact

There are no health considerations due to the project per se but the opportunity should be taken during the technology dissemination workshop to emphasise, particularly to micro/SMEs, the importance of avoiding exposure to MDI vapour.

PROJECT COSTS

The proposed capital cost items are necessary and are supported.

In terms of operating costs, these will be higher than for HCFC-141b despite the measures such as the "reduced" HFO approach taken. However, it is noted that incremental operating costs are not requested.

The development of a comparative cost analysis will be a challenging target until market prices are known.

IMPLEMENTATION TIMEFRAME AND MILESTONES

The timetables should be feasible and are supported.

RECOMMENDATION - Approval (Please note points made\\0

Dr M Jeffs

17/09/2014