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EXECUTIVE COMMITTEE OF
THE MULTILATERAL FUND FOR THE
IMPLEMENTATION OF THE MONTREAL PROTOCOL
Seventy-fifth Meeting
Montreal, 16-20 November 2015

PROJECT PROPOSAL: THAILAND

This document consists of the comments and recommendation of the Fund Secretariat on the following project proposals:

Foam

- Demonstration project at foam system houses in Thailand to formulate pre-blended polyol for spray polyurethane (PU) foam applications using low-GWP blowing agent — The World Bank

PROJECT EVALUATION SHEET – NON-MULTI-YEAR PROJECT

THAILAND

PROJECT TITLE(S)	BILATERAL/IMPLEMENTING AGENCY
(a) Demonstration project at foam system houses in Thailand to formulate pre-blended polyol for spray polyurethane (PU) foam applications using low-GWP blowing agent	The World Bank

NATIONAL CO-ORDINATING AGENCY	Department of Industrial Works, Ministry of Industry Federation of Thailand Industries

LATEST REPORTED CONSUMPTION DATA FOR ODS ADDRESSED IN PROJECT

A: ARTICLE-7 DATA (ODP TONNES, 2014)

HCFCs			863.32

B: COUNTRY PROGRAMME SECTORAL DATA (ODP TONNES, 2014)

HCFC-22	647.04
HCFC-123	2.72
HCFC-141b	174.87
HCFC-124	0.10
HCFC-225	2.75
HCFC-141b in imported pre-blended polyol	11.19

HCFC consumption remaining eligible for funding (ODP tonnes)	708.56

CURRENT YEAR BUSINESS PLAN ALLOCATIONS		Funding US $ million	Phase-out ODP tonnes
	(a)	n/a	n/a

PROJECT TITLE:	
ODS use at enterprises (ODP tonnes):	38.94*
ODS to be phased out (ODP tonnes):	3.85
ODS to be phased in (ODP tonnes):	3.85
Project duration (months):	12
Initial amount requested (US $):	397,100
Final project costs (US $):	
Incremental capital cost:	323,550
Contingency (10 %):	32,355
Incremental operating cost:	0
Total project cost:	355,905
Local ownership (%):	100%
Export component (%):	0%
Requested grant (US $):	355,905
Cost-effectiveness (US $/kg):	10
Implementing agency support cost (US $):	24,913
Total cost of project to Multilateral Fund (US $):	380,818
Status of counterpart funding (Y/N):	N
Project monitoring milestones included (Y/N):	Y

*All applications. Consumption in spray foam: 4.14 ODP tonnes

SECRETARIAT'S RECOMMENDATION	Individual consideration

PROJECT DESCRIPTION

1. On behalf of the Government of Thailand, the World Bank as the designated implementing agency has submitted to the 75th meeting a request for funding a demonstration project to validate the use of two hydrofluoroolefins (HFOs) (HFO-1233zd(E) and HFO-1336mzz(Z)) for spray foam through formulation development by two system houses, technical replication and dissemination of the results, at the amount of US $397,100, plus agency support costs of US $27,797.

2. In line with decision 72/40[1], the Executive Committee approved funding for the preparation of this project in the amount of US $30,000, on the understanding that its approval did not denote approval of the project or its level of funding when submitted (decision 74/36[2]). The proposal submitted is contained as Annex I to the present document.

Project objective

3. The project proposes:

(a) To strengthen the capacity of two local system houses to formulate, test, and produce pre-blended polyol using HFOs for small and medium-sized enterprises (SME) in the polyurethane (PU) spray foam sector;

(b) To validate the use of HFOs co-blown with CO_2 as foam blowing agents for spray foam, to optimize the HFC[3]/HFO ratio to get a similar thermal performance to that of HCFC-141b with minimum incremental operating costs, and to validate reduced formulations at 10 per cent of HFC/HFO;

(c) To prepare a cost analysis of the different HFC/HFO reduced formulations versus the currently used HCFC-141b-based systems; and

(d) To disseminate the results of the assessment to systems houses in Thailand and other countries.

Sector background and justification

4. The PU foam sector in Thailand comprises 215 enterprises using 1,723 metric tonnes (mt)[4] of HCFC-141b (most of which is contained in locally blended polyols), in the manufacturing of rigid foam, (including spray applications) integral skin and flexible foam. Fifty-three of these enterprises are considered “microenterprises” given that their consumption is less than one mt of HCFC-141b per year.

5. Stage I of the HPMP addressed 1,517 mt of HCFC-141b in all PU foam applications, excluding a consumption of 349.1 mt of HCFC-141b used by 30 enterprises in spray foam due to the absence of low-GWP alternatives for this application. Between 2010 and 2015 this consumption has increased to 585 mt. The main applications for spray foam include roofs, cold-storage rooms, fishing boats, passenger buses, storage tanks, and insulated tankers.

6. In non-Article 5 countries, HFC-245fa (GWP: 1,030) is the prevailing technical option to replace HCFC-141b as a blowing agent for spray foam. Reduced HFC-245fa formulations at 7.5 to 10 per cent

[1] The Executive Committee decided *inter alia* to consider at its 75th and 76th meetings proposals for demonstration projects for low global-warming potential (GWP) alternatives to HCFCs within the framework established, and provided criteria for such projects.
[2] At the 74th meeting, the Executive Committee considered requests for the preparation of projects to demonstrate low-global-warming potential (GWP) technologies and feasibility studies on district cooling.
[3] At this stage, HFC-245fa is included as a transitional solution to control costs, as price and availability of HFOs is uncertain.
[4] Reference year: 2010 as per the HPMP approved at the 68th meeting.

were developed to lower climate impact and cost, but the viscosity of the pre-blended polyol has been increased, which could pose a problem for spray foam machines in operation.

7. HFO-1233zd(E) and HFO-1336mzz(Z) are non-flammable; have low climate impact and enhanced energy efficiency; have better thermal performance in rigid PU foam applications and spray than the high GWP HFCs, and their application may not require the retrofit of existing foaming equipment. Commercial availability has been established for HFO-1233zd(E) and a pilot scale production of HFO-1336mzz(Z) has commenced in late 2014, with full commercialization expected in 2016. The three main obstacles for the introduction of these substances are their high unitary cost, the limited availability in Article 5 countries and the lack of experience in using this technology in prevailing Article 5 country conditions.

Systems houses included

8. Of the 13 systems houses and polyol suppliers in Thailand, the following two would be participating in the project:

(a) *Bangkok Integrated Trading Co., Ltd (BIT):* Supplies polyols (mostly using HCFC-141b) to customers with a varied range of PU foam applications including spray foam. The BIT facility includes a laboratory that performs chemical tests (reaction and cream/string tests and foam water content) while physical tests are outsourced. BIT received assistance during stage I of the HPMP; and

(b) *South City Polychem Co., Ltd. (SCP):* Supplies polyols (mostly using HCFC-141b) to customers with a varied range of PU foam applications including spray foam. The SCP plant includes blending tanks, and a laboratory to perform basic tests (i.e., cream time and tack free time).

Project implementation

9. BIT will formulate high density spray foam (50 kg/m^3) and SCP will formulate normal density spray foam (35 kg/m^3). Each system house will prepare and test a minimum of 150 formulations based on HFO-1233zd(E) and HFO-1336mzz(Z); five HFC-245fa and HFO ratios (100:0, 75:25, 50:50, 25:75, and 0:100); five cycles based on different ratios of polyether, polyester and amine polyols; and three identical tests on each formulation. The resulting formulations will be applied using a Gusmer (Graco) type dispenser with an adjustable isocyanate/polyol volume ratio. The results of the initial phase will be analysed to identify the best combinations of polyols.

10. In the second phase, the optimal 30 foam formulations would be tested (three samples from each formulation). The critical foam properties, (i.e., dimensional stability, adhesion to different substrates, thermal conductivity, and processability) would be determined and compared to those of a typical HCFC-141b formulation. A field test with selected formulations would be carried out.

11. Given that the new reduced formulations would likely be more viscose than HCFC-141b formulation, a spray foam machine with a maximum pressure at 3,500 psi and adjustable polyol to isocyanate ratio would be provided to each systems house to carry out the test accurately. Other additional laboratory equipment will be included.

12. A technical workshop will be organized to disseminate the results. Access to experts and technology suppliers will be given to system houses and polyol suppliers to transfer knowledge and strengthen their technical capacity in formulation development.

13. The project is expected to have a duration of 12 months.

Project cost

14. The estimated cost of the project is US $397,100 as detailed in Table 1.

Table 1. Project cost by activity

Items	Qty.	Unit Cost (US$)	Total (US$)
Foam equipment:			
Spray foam machine (working pressure at 3,500 psi and 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	50,000	100,000
External test by accredited laboratory (flammability, compressibility)	200	250	50,000
Field test	20	500	10,000
PU material for testing (including transportation)			
Polyol	US $ 3.0/kg	2,000	6,000
MDI	US $2.5/kg	2,000	5,000
Technical assistance			
Technology assistance including travel	1	80,000	80,000
Technology dissemination workshop	2	10,000	20,000
Sub-total			**361,000**
Contingencies (10%)			36,100
Total			**397,100**

SECRETARIAT'S COMMENTS AND RECOMMENDATION

COMMENTS

15. The Secretariat noted the World Bank's efforts to rationalize the cost of the project from the original cost of US $1,046,000 in the proposal submitted to the 74th meeting to US $397,100.

16. Upon a Secretariats' request, the World Bank clarified that in order to be able to complete the project within 12 months; it required to work with two systems houses, one of which will focus on spray foam roof insulation and the other on cold storage rooms and buildings. Using only one systems house, would need to develop and test twice the number of formulations which would take considerably longer time.

17. With regard to the reason to include HFC-245fa in the demonstration project, the World Bank clarified that the demonstration includes reduced HFC/HFO formulations required as a transition while the supply of HFOs are limited and the prices are high. In order to minimize the use of HFCs, the World Bank proposed keeping only one HFC formulation, in case HFOs are not commercially available. This alternative approach would reduce the number of formulations to be tested from 150 to 110 and the revised cost would be US $355,905.

18. Upon request, the World Bank confirmed that the conversion of the end-users would be part of stage II of the HPMP. However, the World Bank committed to phasing out 35.6 mt of HCFC-141b with the implementation of the project (at a cost-effectiveness of US $10/kg).

19. It was concluded that in this case there is no overlap between this project and the funds already approved to BIT under stage I, as those funds were for technical assistance to micro enterprises for conversion to water-blown technology in all sub-sectors except spray foam.

20. As indicated by the World Bank, the potential replicability in the use of the selected technology in Thailand is large, given that 585 mt of HCFC-141b are consumed by the spray foam enterprises; it is also the case in other countries in the region: China (7,100 mt), Indonesia (5.5 mt) and Viet Nam (60 mt). While the Philippines will stop using HCFC-141b in spray foam applications in 2015, it could also benefit from the project.

21. On the potential risks associated to adopting the technology, the World Bank indicated that the new formulations could result more viscous and require new spray foam machines. In this case, stage II of the HPMP would need to consider an investment component to equip new spray foam machines to eligible enterprises. The second risk is the cost and commercial availability of HFOs which cannot be determined at this point. This risk is being mitigated by the proposal to include a similar series of tests in the event that HFC may need to be used as a transition blowing material for a short period of time until a commercial scale supply of HFOs is available in Article 5 countries.

22. The World Bank informed the Secretariat that in order to expedite the implementation of the project, it could be included under the existing Grant Agreement for stage I of the HPMP.

23. In justifying the costs requested, in particular on the “technology assistance including travel” line, the World Bank explained that the project implementation requires an intensive formulation development as it is the first time that HFOs will be evaluated under Article 5 countries’ conditions. Involvement of an international foam expert is required to work with the two systems houses throughout the process.

24. The Executive Committee may wish to consider approval of this project in light of the guidelines and other projects being considered under the allocated window of US $10 million for this purpose.

RECOMMENDATION

25. The Executive Committee may wish to consider:

(a) The demonstration project at foam system houses in Thailand to formulate pre-blended polyol for spray polyurethane (PU) foam applications using low-global-warming potential (GWP) blowing agent, in the context of its discussion on proposals for demonstration projects for low-global warming potential (GWP) alternatives to HCFCs as described in the document on the overview of issues identified during project review (UNEP/OzL.Pro/ExCom/75/27);

(b) Approving the demonstration project at foam system houses in Thailand to formulate pre-blended polyol for spray PU foam applications using low-GWP blowing agent, in the amount of US $355,905, plus agency support costs of US $24,913 for the World Bank, in line with decision 72/40; and

(c) Deducting 3.91 ODP tonnes of HCFCs from the starting point for sustained aggregate reduction in HCFC consumption.

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)	397,100 USD
	Incremental Operating Costs	0 USD
	Total Project Cost	397,100 USD
PROPOSED MLF GRANT:		397,100 USD
SUPPORT COST:		27,797 USD
TOTAL COST:		424,897 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 optimize the HFC/HFO ratio in the cell gas to get a similar thermal performance to HCFC-141b at a minimum incremental operating cost.
3. To make a cost analysis of the different HFC/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)			
		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

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

Sector/Application	No. of Enterprises	HCFC-141b Consumption (MT)			
		2007	2008	2009	2010
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 . 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. 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, 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

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.

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. Based on chosen independent variables, each system house will prepare and test a minimum of 150 formulations.

- 2 abovementioned HFO molecules; HFO-1233zd(E) and HFO-1336mzz(Z)
- 5 HFC-245fa and HFO ratios – 100:0, 75:25, 50:50, 25:75, and 0:100. At this stage, HFC-245fa is included as transitional to control cost while price and availability of HFOs are uncertain at the moment.
- 5 cycles based on different ratios of polyether, polyester and amine polyols
- 3 identical tests on each formulation

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% HFC/HFOs.

iv. Formulation development.

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 150 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 will use a Gusmer (Graco) type dispenser to spray 30 foam formulation and 3 samples from each formulation will be tested.

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.

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	50,000	100,000	
• External test by accredited laboratory (flammability, compressibility)	200	250	50,000	
• Field Test	20	500	10,000	
PU material for testing (including transportation)				
• Polyol	$3.0/kg	2,000	6,000	
• MDI	$2.5/kg	2,000	5,000	
Technology assistance including travel	1	80,000	80,000	
Technology dissemination workshop	2	10,000	20,000	
Sub-total			361,000	
Contingencies (10%)			36,100	
Total			397,100	

5. PROPOSED MULTILATERAL FUND GRANT

The proposed grant request is US$ 386,100, 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			X									

Activity	Month after approval											
	1	2	3	4	5	6	7	8	9	10	11	12
testing												
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

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