COUNTRY:	**Turkey**	**IMPLEMENTING AGENCY:**	**UNDP**

PROJECT TITLE: **Validation of the use of HFO-1234ze as Blowing Agent in the Manufacture of Extruded Polystyrene Foam Boardstock (Phase-I)**

PROJECT IN CURRENT BUSINESS PLAN:	**Yes (added, based on ExCom Decision 55/43e i-iii)**
SECTOR:	**Foams**
Sub-Sector:	**Extruded Polystyrene Boardstock Foam**
ODS USE IN SECTOR	
Baseline:	**Not yet determined**
Current (2007):	**923 ODP t HCFCs, as per Government reporting**
BASELINE ODS USE:	**N/A**
PROJECT IMPACT (ODP targeted):	**N/A for this phase**
PROJECT DURATION:	**10 months**
PROJECT COSTS:	**US$ 165,000 (Phase-I only)**
LOCAL OWNERSHIP:	**100 %**
EXPORT COMPONENT:	**0 %**
REQUESTED MLF GRANT:	**US$ 165,000**
IMPLEMENTING AGENCY SUPPORT COST:	**US$ 12,375 (7.5 %)**
TOTAL COST OF PROJECT TO MLF:	**US$ 177,375**
COST-EFFECTIVENESS:	**N/A**
PROJECT MONITORING MILESTONES:	**Included**
NATIONAL COORDINATING AGENCY:	**Ministry of Environment and Forestry**

PROJECT SUMMARY

Turkey is a Party to the Vienna Convention and the Montreal Protocol. It also ratified the London, Copenhagen, Montreal and Beijing amendments to the Protocol. The country is committed to an early phaseout of HCFCs (2015) and willing to take the lead in assessing and implementing new HCFC phaseout approaches to achieve that goal. The objective of this project is to validate the use of a recently industrialized hydrofluoroolefin, HFO-1234ze, in the production of extruded polystyrene foam boardstock. This substance has no ODP and a very low GWP. Turkey hosts 12 local manufacturers of extruded polystyrene boardstock, most using a mixture of HCFC-142b and -22 because of safety (non-flammable) and performance (good thermal insulation). These producers tested already several HCFC replacement options with mixed results and are eager to round off their evaluations with the testing of this HFO that may make the use of high-GWP HFCs unnecessary. The project is divided into two phases:

Phase I: validate on existing equipment the use of HFO-1234ze and determine conditions under which commercial conversion could be implemented.

Phase-II: in case of a positive outcome, conversion of the existing operation to HFO-1234ze

At this stage funding only for Phase-I is requested. The costs of Phase-II cannot be determined at this stage and will be calculated after completion of Phase-I and then submitted for approval.

IMPACT OF PROJECT ON COUNTRY's MONTREAL PROTOCOL OBLIGATIONS

Phase-I of this project is a pilot project and will not directly contribute to the fulfillment of Turkey's Montreal Protocol obligations. However, if successfully validated, the technology will contribute to availability of cost-effective options that are urgently needed to implement HCFC phase-out in extruded polystyrene boardstock. Such options can be applied in all XPS manufacturers in Turkey and world-wide. **Gaining experience through just one project rather than 12 (in Turkey) or in excess of 50 (worldwide A2 countries only) may save millions of dollars on actual phaseout costs compared to just over US$ 200,000 for one pilot project.**

Prepared by: Rappa, Inc. **Date: February, 2010**

60th Meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol

PROJECT OF THE GOVERNMENT OF TURKEY

VALIDATION OF USE OF HFO-1234ze AS BLOWING AGENT IN THE MANUFACTURE OF EXTRUDED POLYSTYRENE (XPS) FOAM BOARDSTOCK (PHASE-I)

1. PROJECT OBJECTIVES

The objective of this project is to validate the use of HFO-1234ze in the manufacture of XPS foam boardstock and, if the outcome is positive, apply the technology subsequently in a sector phaseout project. Lessons learned may be of use for similar manufacturing plants worldwide.

2. INTRODUCTION

2.1 GENERAL

Extruded polystyrene foams can be categorized into sheet and boardstock. Sheet is mostly used for food applications and thermal insulation requirements are modest. For boardstock, however, which is mostly used for construction applications, good thermal insulation is critical. Therefore, while virtually all CFC use in sheet has been converted to hydrocarbons, boardstock has initially been converted to HCFCs and then later, where forced by regulations, to a mixture of options that all are less than desired from a performance point of view. The UNEP Foams Technical Options Committee (FTOC) mentions that the phaseout of HCFCs in non-A5 countries ***ñ****has been***ð** *and continues to be***ð** *a problem***ò**. North American XPS boardstock producers are on course to phaseout HCFC use by the end of 2009. Phaseout choices will be HFC blends, CO_2 (LCD) and hydrocarbons. The significant variety in products required to serve the North American market (thinner and wider products with different thermal resistance standards and different fire-test-response characteristics) require different solutions than in Europe and Japan, who have already phased out HCFCs with HFC-134a, HFC-152a and CO_2 in Europe and significant use of hydrocarbons in Japan. However, recently introduced so called F-Gas regulations in Europe may change the scenario in that region as HFC-134a will have to be phased out.ò With so many uncertainties in non-A5 countries, it is a challenge to provide guidance to A5 countries.

The manufacture of XPS boardstock has been traditionally an A2 market. There has been minor production in A5 countries but the FTOC states that recently production took off in China and Turkey. In addition, there is production in Argentina, Egypt and Saudi Arabia, while Kuwait, Brazil and Mexico are starting up new production lines. This increase in prominence, combined with the urgency caused by Turkeyôs decision to early HCFC phaseout, requires a close look at HCFC phaseout options.

Blowing agent manufacturers are working diligently on a new generation of blowing agents that aim to combine zero ODP and good thermal insulation properties with low GWP. However, the horizon for industrialization in industrialized countries is 2-4 years which would imply that any phaseout efforts in A5 countries would not contribute to the period through 2016 (ñfreeze + 10 %ò). There is one exception and that is HFO-1234ze. This chemical which is produced by Honeywell is already industrially applied in one component PU foam (OCF) manufacturers in Europe which were struck by a ban on the use of HFC-134a in July 2008 and needed a replacement urgently. The properties of this chemical as well as preliminary trials show promise for use in XPS boardstock but there has been no formal validation so far. If the MLF desires a full range of HCFC phaseout options for XPS boardstock that are not sub-standard in performance or unwanted in climate impact, evaluation of HFO-1234ze will be needed. This substance appears to offer the same climate impact advantages as hydrocarbons without the fire risk and to promise improved insulation value compared with other HCFC replacements.

But, with no diffusion data available, this is a very preliminary statement. UNDP is in contact with its manufacturer, Honeywell, which has agreed to support a validation project.

Technology validation is a global task. Experience gained can be applied in all MLF project dealing with XPS (estimated to exceed 50) and could save in this way millions of dollars in addition to making costs more transparent. Past experience in CFC phaseout has shown this. However, it has to be executed in one particular country. Because of the global impact, deduction of the first phase, which deals with development, optimization and validation from the national aggregate HCFC consumption would not be considered fair and it is requested to treat phase-1 in this way.

2.2 THE USE OF HCFCs IN XPS BOARDSTOCK APPLICATIONS IN TURKEY

The XPS Boardstock industry in Turkey consumed in 2008 about 4,100 t blowing agents from which ~70% (2,860 t) consisted of HCFCs. Growth in this industry has been impressive as the following overview shows:

Table-1: production of XPS Boardstock in Turkey

	2006	**2007**	**2008**	**2009**
XPS Boardstock Capacity (m^3)	1.200.000	1.900.000	2.200.000	2.400.000
Capacity Use (%)	75	75	75	
XPS Boardstock production	900,000	1,425,000	1,650,000	
Average Density (kg/m^3)	~31	~31	~31	
Annual production (t)	28,000	44,200	51,000	
Blowing Agent (%)	8	8	8	
Blowing agent use	2,240	3.540	4,080	
HCFC Share (%)	100	80	70	
HCFC Consumption (t)	**2,240**	**2,830**	**2,860**	

The industry is under pressure from the Governmentð that wants to phaseout the use of HCFCs by the end of 2015ð and has been testing alternatives with the following outcome:

- HFC-134a trials have been successful but the high GWP makes it less attractive
- HFC-152a most trials have been in combination with dimethylether (DME) and have been Successful, albeit with a penalty in insulation value of around 10%. There is current commercial production using this approach
- Hydrocarbons trials are imminent, pending the finalization of safety measures
- CO_2 trials have been so far unsuccessful (inconsistent product)

See paragraph 5 below for a detailed discussion of these options.

3. RECIPIENT INFORMATION

This pilot project has been prepared around B-Plas, a Turkish manufacturer of extruded polystyrene foam boardstock. Contact information is as follows:

Company: B-Plas Bursa Plastic, Metal ve Turizm San. Ve Tic. A.S.
Contact: Levent Ceylan
Address: Yeni Yalova Yolu 5. km No: 365 Bursa, Turkey
Ph/Fx: +90-224-261-0900/+90-224-261-0918
Email: leventc@bplas.com.tr

B-Plas was established in 1987 and is owned by Celal and Memduh Gökçen, both Turkish nationals and residents of Osmangazi/Bursa. The XPS plant is located in Bursa, about 170 km from the port of Istanbul and 25 km from the port of Gemlik. It employs 36 and produces XPS on three twin screw extruders. Production has developed as follows:

Table 2: XPS Boardstock Production at B-Plas

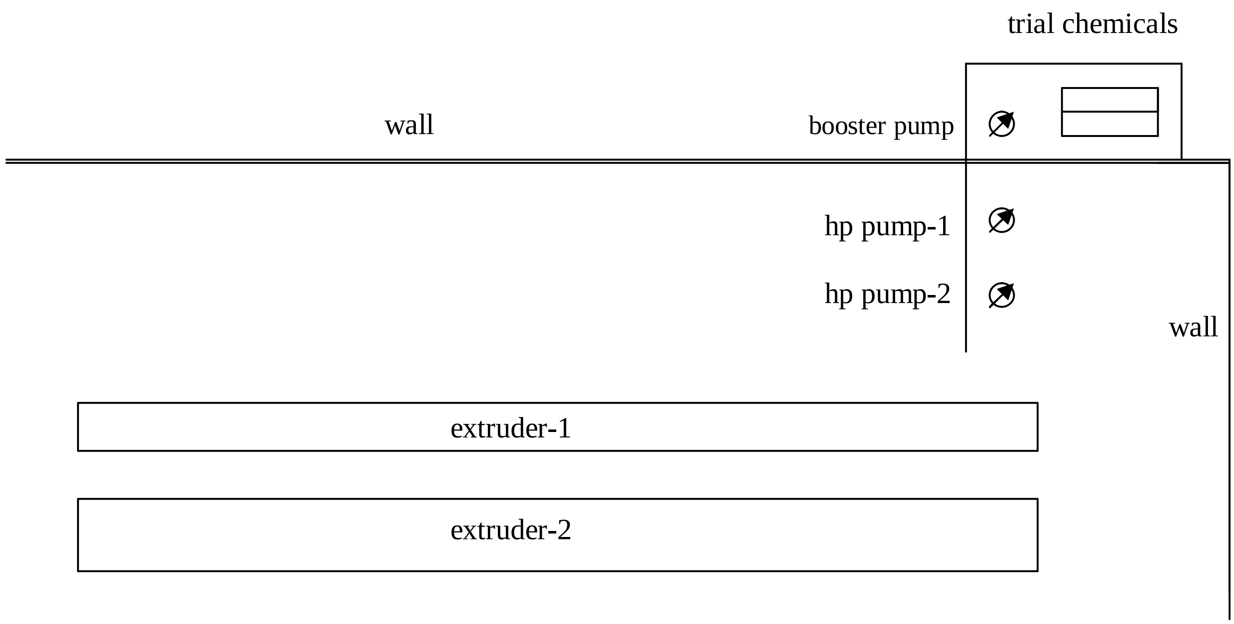
	2006	2007	2008	Comments
Production (m^3)	38,000	44,000	79,000	Increase through higher sales and lower density
Sales (m^3)	38,000	44,000	75,000	
Resin use (kg)	1,550,000	1,600,000	2,350,000	
Blowing agent use (kg)	220,000	240,000	369,000	

There is no export to other countries. The operation belongs to the B-Plas Bursa Plastic Group which employs about 1,600, had in 2007 sales of over US$ 200 million.

4. PROJECT DESCRIPTION

The aim of the trials proposed under this pilot project will be to validate the use of HFO-1234ze and in this way to determine processability and cost impact when replacing current HCFC-142b/-22 blends. It is expected that such trials can be conducted with unchanged production equipment. However, a separate storage/feed operation for the trial chemical will have to be installed, because the existing feed system is too remotely located and would incur substantial contamination if used (see layout below).

FIG-1: B-PLAS TRIAL CONFIGURATION



It is emphasized that this trial configuration is unique for this being a pilot project that needs to keep the existing flow of blowing agents to other extruders than the one used for the trial to avoid costly business interruption. It will not need to be repeated in other XPS conversions. Apart from using HFO-1234ze as sole blowing agent, combinations with co-blowing agents will be tested as well.

During the trial, process conditions will be checked against baseline. Boards with several thicknesses will be produced. The baseline and the trial material will be tested for:

- board density
- appearance
- compression strength
- thermal performance
- water absorption
- diffusivity

Properties testing will be conducted at B-Plas and the HFO-1234ze manufacturer, Honeywell. However, final validation testing will be certified through an independent testing laboratory in Turkey. Honeywell and an independent expert recommended by Honeywell will attend and advise with the trials. A report will be prepared for the ExCom, outlining the quality of the product, changes recommended to equipmentð if anyð for future commercial production and cost analyses. Based on these trials and other trials conducted by the Turkish XPS manufacturersð independently and on their own costsð a phase-II proposal for the entire Turkish XPS boardstock industry (12 plants) will be prepared for commercial conversion from HCFCs to non ODP/low GWP alternatives ï if agreed with by the Government.

5. TECHNICAL OPTIONS FOR HCFC REPLACEMENT IN XPS FOAMS

5.1 GENERAL INFORMATION

Extruded polystyrene foam can be categorized into sheet and boardstock applications. In virtually all sheet applications CFCs have been replaced by hydrocarbonsð butane, isobutane, LNG or LPG. In boardstock, most of the replacement has been a blend of HCFC-142b and HCFC-22 in a 70-80%/30-20% ratio. The use of HCFC-22 was aimed at countering HCFC-142bôs (modest) flammability. With the prices of HCFC-22 ever decreasing, many manufacturersð mainly in Chinað converted to HCFC-22 alone. This had its toll on product quality as the use of HCFC-22 only is prone to shrinkage.

The FTOC 2006 report offers following overview of past and expected conversions:

Table-3: Past and expected Blowing Agents for XPS Boardstock

XPS Type	CFC Alternatives		
	Currently in Use (2005/2006)	Anticipated in 2010-2015 period	
		Developed Countries	Developing Countries
Sheet	Primarily hydrocarbons, HCFCs are not technically required for this end use	CO_2 (LCD), hydrocarbons, inert gases, HFC-134a, -152a	Hydrocarbons, CO_2 (LCD)
Boardstock	CO_2 (LCD) or with HC blends, hydrocarbons (Japan only), HFC-134a, HFC-152a, HCFC-22, HCFC-142b	CO_2 (LCD) or with HC blends, hydrocarbons (Japan only), HFC-134a, HFC-152a and HC blends	HCFC-142b, HCFC-22

As already mentioned in the introduction, the 2008 FTOC update reports that *ñthe phaseout of HCFCs in non Article 5 countries has beenð and continues to beð a problemò*. North American XPS boardstock producers are scheduled to phaseout HCFC use by the end of 2009 through HFC blends, CO_2 (LCD) and hydrocarbons. The significant variety in products required to serve the North American market (thinner and wider products with different thermal resistance standards and different fire-test-response characteristics) will result in different solutions than in Europe and Japan, who have already phased out HCFCs. In Europe, this has been achieved with HFC-134a, HFC-152a and CO_2 (sometimes with a co-blowing agent or blended with an additives) while in Japan there has been significant use of hydrocarbons. Recently introduced so-called F-Gas regulations in Europe may change the scenario in that region as this regulation introduces limits on allowed GWPs.

Following is the current commercial/technical status on potential replacement for HCFCs:

Table-4: Status of HCFC replacements in XPS Boardstock

SUBSTANCE	COMMENTS
HFC-134a	Considered expensive; high GWP
HFC-152a	Moderately flammable and considered expensive
(Iso)butane	Highly flammable; high investment
CO_2	As gas only capable to replace 30% of the blowing agent. As liquid, high in investment and not fully mature
HFO-1234ze	Non-flammable, ideal boiling point, but still experimental

It will be important to assess for all technologies their climate impact. Using GWP and MW data as provided by the FTOC (2006), following indicative GWP changes are to be expected for the replacement of HCFC-141b in PU foam applications:

Table-5: Indicative GWP Changes when Replacing HCFC-142b/-22

SUBSTANCE	GWP	MOLECULAR WEIGHT	INCREMENTAL GWP	COMMENTS
HCFC-142b/-22 (75/25)	2,185	97	Baseline	
HCFC-22	1,810	87	-562	Non flammable
HFC-134a	1,430	102	-681	Non flammable
HFC-152a	124	66	-2,101	Moderately flammable
(Iso)butane	4	58	-2,183	Flammable
CO_2 (LCD)	1	44	-2,185	Non Flammable
HFO-1234ze	6	114	-2,178	Non flammable

Green = favorable GWP effect; red = favorable comparable GWP effect but higher that the EU F gas limit (150)

Based on these data, it appears that HCs, CO_2 (LCD) and HFO-1234ze have by far the lowest climate impact based on GWP.

HFC-152a may also be an acceptable alternative from a climate change perspective.

While HFC-134a reduces the comparable global warming effect, it will be disallowed in the future in the EU and its use is therefore discouraged. An HCFC substitution program for XPS boardstock may therefore include HFC-152a, Hydrocarbons, Carbon Dioxide and HFO-1234ze

5.2 PROPERTIES OF HFO-1234ze

General

HFO-1234ze is a hydrofluoroolefin developed by Honeywell as a fourth generation blowing agent to replace HFCs in non-A5 countries. Comparative properties are as follows:

Table-6: Comparative properties of blowing agents

Property	HCFC-142b	HCFC-22	HCFC-142b/-22 (75/25)[1]	Isobutane	HFC-152a	HFC-134a	HFO-1234ze
Molecular Weight	100	86	**97**	58	66	102	**114**
Boiling Point (^{0}C)	-9	-41	**-25**[2]	-12	-27	-26	**-19**
TLV or OEL (ppm)	1000	1000	**1000**	800	1000	1000	**1000**[3]
LEL/UEL(vol% in air)	6-18	None	**8-24**	1.8-8.4	3.8-21.8	None	**None**[5]
ə(mW/m^{0}K@ 10^{0}C)	8.4	9.9	**8.7**	16 (20^{0}C)	14 (25^{0}C)	12.4	**13**[4]
ODP	0.066	0.05	**0.063**	0	0	0	**0**
GWP	2270	1810	**2185**	4	124	1430	**6**

[1]linear weighted averages. [2]there may be a boiling point range [3]recommended [4]not known at what temperature
[5]however, at 30^{0}C LEL/UEL values of 7.0/9.5 exist

The two gases that will be compared in these trials are shown in bold. Apart from the molecular weight, the comparison appears favorable for HFO-1234ze. However, it should be kept in mind that the original baseline, CFC-12, has a molecular weight of 121!

Atmospheric Chemistry

In general, hydrofluoroolefinsð being unsaturated hydrofluorocarbonsð will have shorter atmospheric life times than saturated hydrofluorocarbons. This is evident from their much lower GWPs. However, the issue of decomposition products may be brought up. The University of Copenhagen conducted a study on the atmospheric chemistry of HFO-1234ze[1]. While trifluoroacetic acid (HFA) is mentioned as a major final breakdown product, this is a natural component of the background oceanic environment and any environmental burden associated with trans CF_3CH =CHF oxidation will be of negligible environmental significance. The study concludes ***ñthat the products of the atmospheric oxidation of trans-CF_3CH=CHF will have negligible environmental impact.ò***

The USEPA came to the same conclusion when evaluating HFO-1234ze under the Significant New Alternatives Policy (SNAP) program[2]. EPAôs decision states that:

Hydrofluoroolefin (HFO)ï 1234ze is acceptable as a substitute for CFCs and HCFCs in:

- ***Rigid Polyurethane Appliance Foam.***
- ***Rigid Polyurethane Spray, Commercial Refrigeration, and Sandwich Panels.***
- ***Polystyrene Extruded Boardstock & Billet.***

Toxicity

The toxicity of HFO-1234ze has been relatively extensively researched. Following table summarizes current informationð which shows low toxicity levels:

[1] M.S. Javadi et all, Atmospheric chemistry of trans-CF_3CH=CHF: products and mechanisms of hydroxyl radical and chlorine atom initiated oxidation
[2] Federal register / Vol. 74, No 188 / Wednesday, September 30, 2009 / rules and regulations, pg 50129 ev

Table-7: HFO-1234ze Toxicology Assessment

Test		Results
Cardiac Sensitization		No Effect to 120,000 ppm
Genetic Testing:	Mouse micronucleus Ames assay	Not Active at 100,000 Not Active at 50,000 ppm
Acute Inhalation		LC50>400,000 ppm
Chromosome Aberration Test:	Inhalation: 2 week Inhalation 4 week	Test Complete Test Complete
Unscheduled DNA Synthesis	rat; 4 week @15,000	Not Active
Bone Marrow Micronucleus Formation	rat; 4 week@ 15,000	Not Active
Carcinogenicity Screen Test		Complete
Metabolism Study		Underway
Inhalation	13 week	Test Complete
Developmental Toxicity Pilot Test		Complete

In conclusion, the outcome of toxicity and atmospheric studies confirm that HFO-1234fa is a non-ODP/insignificant GWP substance with low toxicity and valid for XPS applicationsð as is already the case in one component PU foams.

6. PROJECT COSTS

Following are the summarized cost expectations:

Table-8: project Budget

#	ACTIVITY	COSTS (US$)		
		INDIVIDUAL	SUB-TOTAL	TOTAL
	PHASE-I ï CONDUCTION OF TRIALS AND TESTING			
1	Preparative work Project Preparation (incl. second phase) Technology Transfer, Training	 40,000 30,000	70,000	165,000
2	Trials Purchase of materials (see **Annex-1**) Testing Retrofit	 40,000 10,000 20,000	70,000	
3	Validation	10,000	10,000	
4	Contingencies/Rounding (~10%)	15,000	15,000	

The costs for phase-1 of this project are relatively limited compared to most other pilot projects because cooperation with the manufacturer of HFO-1234fa, Honeywell, makes it possible to have most tests performed in existing facilities, avoiding in this way expensive equipment purchases and the trials can be performed on existing production equipment with only minor retrofits. No costs for phase-II have been calculated at this point. While it is assumed that existing production equipment can be used with fewð if anyð changes, phase-I will have to confirm this.

UNDP requests a grant for the first phase of this project amounting to

US$ 165,000.

7. IMLEMENTATION/MONITORING

Table-9: Implementation Schedule

TASKS	2009				2010			
	1Q	**2Q**	**3Q**	**4Q**	**1Q**	**2Q**	**3Q**	**4Q**
Project Start-up								
MF Project Approval			X					
Receipt of Funds			X					
Grant Signature				X				
Procurement arrangement				X				
Phase I								
-Arrival of chemicals					X			
-Trials					X			
-Testing					X			
-Analysis/Reporting/preparation phase II					X			

Table-10: MILESTONES FOR PROJECT MONITORING

TASK	MONTH*
(a) Project document submitted to beneficiaries	2
(b) Project document signatures	3
(c) Procurement	4, 5
(e) Chemicals delivered	5
(f) Trial Runs	6
(g) Testing/analysis/reporting	7
(h) Project closure/start Phase II	12

* As measured from project approval

7. ANNEXES

Annex 1: Budget Details

ANNEX-1

BUDGET DETAILS

Assumptions:

- Chemical prices: Crystalline Polystyrene US$ 2.50/kg
  Talcum US$ 1.00/kg
  HFO 1234ze US$ 20.00/kg (US$ 12.00 +freight & logistics)

- Output: 200 kg/hr total
  180 kg/hr PS
  20 kg/hr gas

- Trial duration: 6 hours total per thickness

Trial costs:

Trials	Duration [hours]	PS Crystal [kg]	Cost [US$]	Talcum [kg]	Cost [US$]	HFO-1234ze [kg]	Cost [US$]	Total Cost
20 mm	6	1,080	2,700	11	11	150	3,000	5,711
25 mm	6	1,350	3,375	14	14	187.5	7,500	7,139
40 mm	6	2.160	5,400	22	22	300	6,000	11,422
50 mm	6	2,700	6,750	28	28	375	7,500	14,278
Calibration	n/a	n/a	n/a	n/a	n/a	50	1,000	1,000
Total	**24**	**7,290**	**18,225**	**75**	**75**	**1,012.5**	**21,250**	**39,550**

*** Say US$ 40,000**

Total Budget:

#	ACTIVITY	COSTS (US$)		
		INDIVIDUAL	SUB-TOTAL	TOTAL
PHASE-I ï CONDUCTION OF TRIALS AND TESTING				
1	Preparative work Project Preparation (incl. second phase) Technology Transfer, Training	40,000 30,000	70,000	**165,000**
2	Trials Purchase of materials (see **Annex-1**) Testing Retrofit	40,000 10,000 20,000	70,000	
3	Validation	10,000	10,000	
4	Contingencies/Rounding (~10%)	15,000	15,000	