Frankfurt School
FS-UNEP Collaborating Centre
for Climate & Sustainable Energy Finance

FEASIBILITY ASSESSMENT

SHORT-LIVED CLIMATE POLLUTANTS (SLCP) FINANCE INNOVATION FACILTY (FIF)

FOR THE CCAC FINANCING OF SLCP MITIGATION INITIATIVE

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GLOSSARY

Black Carbon (BC)	BC is the second most important climate pollutant after CO2 in terms of its climate impacts. BC is that component of fine particulate matter (PM < 2.5 µm) that is carbon absorbing sunlight and contributing to GWP. It is formed through incomplete combustion of fossil fuels, biofuel, and biomass.
EIRR	Economic Internal Rate of Return; the IRR calculated considering the defined project costs and revenues, as well as estimates of Environmental / social benefits
Equity FIRR	Equity FIRR refers to the IRR that makes the NPV of the net operating, investing and financing cash flow equal to zero; this is the return on equity because it is essentially the cash flow after debt service, which belongs to the equity holders.
FIF	Finance Innovation Facility - a combination of Technical Assistance and Credit Line provided to Partner Financial Institutions (PFI) that provide financing to ultimate borrowers
FIRR	Financial Internal Rate of Return; the IRR calculated considering the defined project costs and revenues. Environmental / social benefits are not included
GHG	Green House Gas contributing to global warming potential
Internal Rate of Return (IRR)	IRR is the discount rate that makes certain cash flow's NPV equals zero; generally speaking, the project with IRR higher than the discount rate should be accepted and the project with higher IRR is more desirable than the one with lower IRR.
Net Present Value (NPV)	NPV is the present value of future cash flows discounted at a certain discount rate; as a rule of thumb, projects with positive NPVs should be accepted and when comparing different projects, the one with higher NPV would be preferred given all others equal.
Particulate matter (PM)	PM with a diameter of 2.5 micrometres or less (i.e. PM2.5) is among the most harmful vehicle pollutants with a range of associated health impacts including cardiovascular and respiratory diseases, lung cancer, and infant mortality.
Payback Period (PP)	The PP is the period of time needed for the return to pay back the sum of the initial capital investment; the shorter the period is, the faster the project is to pay back the initial investment.
Project FIRR	Project FIRR refers to the IRR that makes the NPV of the net operating and investing cash flow equal to zero (which means before financing structure is applied); this is the return on project without taking financing decisions into consideration.
Global Warming Potential (GWP)	According to Intergovernmental Panel on Climate Change (IPCC), Global Warming Potential (GWP) refers to an index based upon radiative properties of well-mixed greenhouse gases, measuring the radiative forcing of a unit mass of a given well-mixed greenhouse gas in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide.

ABBREVIATIONS

BC	Black Carbon
BDT	Bangladeshi Taka
BTK	Bull's Trench Kiln
CCAC	The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFCs	Chlorofluorocarbons
CFIF	Climate Finance Innovation Facility
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
DDK	Down-Draught Kiln
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EELA	Energy Efficiency in Artisanal Brick and Plaster Kilns in Latin America
EU	European Union
FCBTK	Fixed Chimney Bull Trench Kilns
FCK	Fixed Chimney Kiln
FIF	Finance Innovation Facility
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GEF	Global Environment Fund
GHG	Green House Gas
GWP	Global Warming Potential
HCFCs	Hydro Chlorofluorocarbons
HFCs	Hydro Fluorocarbons
HHK	Hybrid Hoffman Kiln
HVD	Heavy-duty Vehicle
ICCT	The International Council on Clean Transportation
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
ISO	International Organization for Standardization
LNG	Liquefied Natural Gas
LPG	Liquid Petroleum Gas
LVD	Light-duty Vehicle
MCBTK	Movable Chimney Bulls Trench Kiln
MFI	Microfinance Institution
MLF	The Multilateral Fund
Mt/Y	Metric Tonne Per Year
MtCO2e	Million Metric Tons of CO2 Equivalent
NG	Natural Gas
NGO	Non-Governmental Organization
NGV	Natural Gas Vehicle
NPV	Net Present Value
O&M	Operational & Maintenance
OBA	Output-based Aid

ODS	Ozone Depleting Substances
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OICA	Organisation Internationale des Constructeurs d'Automobiles (International Organization of Motor Vehicle Manufacturers)
PIGs	Pipeline Inspection Gauges
PM	Particulate Matter
Ppm	Parts Per Million
PPP	Private Public Partnership
RBF	Results-based Financing
SDC	Swiss Agency for Development and Cooperation
SLCPs	Short-lived Climate Pollutants
SME	Small and Medium-sized Enterprise
SOE	State-owned Enterprises
TEAP	Technology and Economic Assessment Panel
The Alliance	The Global Alliance for Clean Cookstoves
USD	United States Dollar
VER	Voluntary Emission Reduction
VSBK	Vertical Shaft Brick Kiln
WACC	Weighted Average Cost of Capital

EXECUTIVE SUMMARY

Background: Feasibility assessment of a SLCP Finance Innovation Facility

The scientific and political communities are increasingly recognising the need to address Climate Change by not only substantially reducing carbon dioxide (CO2) emissions, but also through near-term actions to reduce the climate pollutants that remain in the atmosphere for much shorter periods of time, the short lived climate pollutants (SLCPs). With atmospheric lifetimes in the order of a few days to a few decades, (the) *SLCPs include methane, black carbon (BC) and certain hydro fluorocarbons (HFCs),* with BC being the fraction of fine dust/PM2.5 and (mostly) fine soot carbon particulates. SLCPs are responsible for 30-40% of global warming to date[1]. In addition to limiting the Climate Change impacts already underway, SLCP reductions would lead to reduce substantial local air pollution reductions and produce other co-benefits, such as reduced impact on health. The U.N. Environment Programme (UNEP) recently estimated that aggressive efforts to reduce SLCPs would avoid 2.4 million premature deaths by 2030 and reduce warming between now and 2050 by a half a degree[2].

The Climate and Clean Air Coalition (CCAC) has a mandate to address SLCPs by raising awareness, enhancing and developing new national and regional actions, promoting best practices, and improving scientific understanding of short-lived climate pollutant impacts and mitigation strategies. In its effort to promote global action on SLCPs, the CCAC established the CCAC Finance Initiative, which is a cross-cutting initiative aimed to stimulate the financing of SLCP mitigation projects at pace and scale by leveraging expertise, building knowledge and capacity, and engaging stakeholders around its sectorial initiatives.

There are many technologies and project types with demonstrable SLCP mitigating potential that are in theory commercially viable. However, even for these cases private financing is not flowing at the required scale, leaving the considerable SLCP-mitigation potential unexploited. This study, which was commissioned by the CCAC Finance Initiative, tries to assess the feasibility and potential impact of a SLCP Finance Innovation Facility (SLCP FIF).

The purpose of a SLCP FIF would be to provide private financial actors with technical assistance (TA) and associated grant funding for the development of financial products and services aimed at reducing SLCP emissions. In this way a FIF would increase financial flows into SLCP mitigation by removing the financing barriers to commercial finance. The CCAC's 5-Year Strategic Plan underscores the importance of leveraging private financial flows for scaling-up SLCP mitigation. This study additionally aims to investigate the readiness of commercial financing in SLCP mitigation for materialising CCAC's goal of leveraging finance at scale during the next 5 years. The study's focus is on the SLCP mitigation sectors identified by the CCAC, namely initiatives in brick kiln, diesel vehicle, cook stove, HFCs (in refrigeration & air-conditioning), waste, oil & gas and agriculture (livestock manure management).

A SLCP FIF approach of giving TA could be largely effective if: 1) it can remove financing barriers affecting partner financial institutions (FIs), helping them to mobilise funding in SLCP mitigation sectors; 2) it can remove market entry barriers (i.e. excluding regulatory barriers) which prevent FIs investing in SLCP mitigation sectors; and 3) if it can create business potential in SCLP sectors for the private sector. An SLCP FIF approach will not work where mitigation interventions require strong policy and regulatory support to increase private sector investment. The TA support within the FIs alone would not be enough to address the regularly barriers and other measures would be needed.

[1] http://www.c2es.org/science-impacts/short-lived-climate-pollutants

[2] CCAC (2014), Time to Act: To Reduce Short-Lived Climate Pollutants

Key finding by sector

The ***brick*** sector possesses significant BC reduction potential by adopting modern environmentally friendly production processes. About 1,500 billion bricks are annually produced globally. Of these, about 90% bricks are produced in Asia led by China (over 60%). The rest are produced in Latin America and in other parts of the world. The study shows that all modern technologies yield positive NPVs due to efficiency and productivity gains. Yet because the private sector is informal in nature and often does not meet the required social and environmental standards, it is not attractive to FIs. Therefore, access to finance by commercial financiers has been limited due to the lack of accountancy and credibility of the informal brick sector. Moreover, there is also a lack of motivation in the brick sector to adopt modern efficient technologies because fuel costs are cheap and existing regulation is weakly enforced.

In the ***transport*** sector, soot-free vehicles such as public buses, trucks and freight possess huge potential for improving the air quality in many regions. However, availability of low-sulphur fuel, which is required to ensure optimum emission reduction from soot-free vehicles, is a key bottleneck in developing countries. Refinery upgrades require huge investment, which are only within the financial capacity of a very few national level commercial banks. On the contrary, commercial banks can extend credits to the vehicle operators/owners for adopting soot-free diesel vehicles in countries where vehicle emission control programme exists. Commercial banks interest in financing in soot-free fleets will depend on the fleet operator's business model and their ownership structure (e.g. public/private). Unlike the developed countries, only few developing countries have established vehicle standards (Euro IV, V, and VI), fuel standards (10 to 50 ppm sulphur contents) and the necessary infrastructure, which are required to implement vehicle emission control programmes.

The ***cookstove sector*** is responsible for significant BC emission through the incomplete combustion of low-grade fuels and fuel wood. The cookstove sector also has large potential to reduce BC through the adoption of clean cooking practises. Some 3 billion people in the world lack access to clean and efficient cooking facilities. Not all energy efficient stoves can be smoke-free or less polluted. Clean cookstoves not only reduce fuel consumption, but also improves indoor air quality by ensuring a less-smoke/smoke free atmosphere in the kitchen, which in turn reduces the chances for developing respiratory diseases, in particular among women and children. However, cleaner cookstoves vary considerably in their ability to increase energy efficiency and even more in their ability to reduce BC emission and subsequent adverse health and environmental risks. The ISO (*International Organisation for Standardisation*) and Clean Cookstove Alliance are trying to promote certain clean cookstove standards (ISO tier standards), which offer a smoke-free or less polluted cooking environment. Customer willingness to adopt and their ability to pay for cleaner cooking options is a key issue here (i.e. choice between basic 'efficient' stove and 'clean' cookstove). Yet, there is lack of adoption of 'clean' cook stove compared to wide-spread use of regular 'efficient stoves'. The clean cookstove options (e.g. stove with cleaner fuel such as LPG, biogas; electric and solar cooker; forced-draft improved biomass stove) appear to be more expensive than basic efficient cookstoves. As such, the pricing disparity needs to be addressed by giving additional incentives to the end-users.

HFCs are any of several organic compounds composed of hydrogen, fluorine, and carbons are a collection and are primarily used in refrigeration. HFCs were introduced under the Montreal Protocol, as replacement of first and second generation chlorinated gases, such as chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs), which were responsible for the depletion of the ozone layer. Whilst HFCs have an ozone depleting potential of practically zero, they are potent greenhouse gases (GHGs).

To mitigate the contribution of HFC to near-term global warming, HFC-free or HFCs with low global warming potential (GWP) cooling technologies can and should be promoted. Mainly refrigeration and air-conditioning have large potential for using HFC-free and low-GWP HFCs refrigerants.

The Montreal Protocol has been funding the replacement of CFCs and HCFCs through its Multilateral Fund (MLF). The introduction of HFC-free or low GWP- HFC cooling options would therefore help the market to leapfrog to the most advanced environmentally friendly cooling solutions. The study reveals that with an investment of USD 1-3 billion, some 700 projects can be upgraded into alternative low-GWP cooling technologies. Although certain low-GWP/HFC-free refrigerant equipped cooling systems are commercially available, worldwide these technologies are still in demonstration phase in developing countries. To scale up this transition process would require an agreement on a HFC phase-out policy; this is currently under discussion among the parties of the Montreal Protocol. Depending on the countries' development stage, there are proposals for stepwise phase out of HFCs for developed countries, and a similar but delayed plan for developing countries with details still being under discussion.

The ***waste***, ***oil & gas*** and ***agriculture*** sectors possess large potential for significant reductions in both methane and BC. In the waste sector, methane and BC mitigation technologies for landfills and solid waste management are relatively mature but the sector is dominated by the public utilities and lacks a proper private-public partnership framework for creating a space for private sector participation in potential waste management projects. This is particularly the case in developing countries. The private sector shows non-willingness to contract with local government to provide waste management services due to their concern over the government's credibility in meeting their payment obligations and the absence of proper policies that allows safe collection, disposal and use of waste.

In oil & gas sector, the operators are mainly state-owned, and methane reductions are possible by the prevention of pipeline leakage and the recovery of methane from coal mining. These measures can provide improved gas recoverability, leading to additional revenues for the operator. However, in places where the operator is only responsible for delivery service and not held accountable for leakage, there is no financial incentive for the operator to reduce pipeline leakage. As a result, cost-effective opportunities for methane recovery vary by country and depend upon on the concentration of emission source, the condition of the infrastructure and the local price of natural gas, etc.

Coalmine methane projects are not cost-effective within standard power market rates. In the agricultural sector, large-scale manure management projects require high capital expenditure and the energy market tariff rate in the developing countries is not sufficient enough to cover project costs. Doubly challenging, there is also a lack of financial incentives for farmers and producers to implement mitigation practices through manure management, and rice management practices, which usually incur additional costs. For instance, the facilities required for the composting of rice straw and efficient irrigation and drainage systems for managing flooding and draining demand a considerable capital expenditure with little to no short-term payback to farmers. In the agriculture sector, country-level policies that price the negative impact from methane emission and grant programmes that support first phase research in laboratory studies would be a first step towards the mitigation of methane. In general, in terms of bankable projects, waste, oil & gas, agriculture sectors appear to be less appealing for the commercial banks at the moment.

In general, barriers for private sector investment across the SLCP mitigation sectors are not only financial, they are also largely due to other socio-economic, policy and regulatory factors. Low return on investment and maturity of the SLCP mitigation technologies also affects the bankability of SLCP mitigation focused interventions for the private sector. These largely sectorial and regulatory issues cannot be resolved by the implementation of a SLCP FIF alone, as a FIF would focus only on addressing the barriers within commercial FIs. To address the full range of barriers, coordinated action by a broader range of stakeholders is required.

In addition to sectorial and regulatory barriers, awareness of sectors with SLCP mitigation potential is low. This means that banks often lack the ability to assess the potential of SLCP financing due to information gaps and the lack of credit exposure in the SLCP sectors. The study identifies potential collaboration strategies to demonstrate to commercial financiers the SLCP financing potential for certain sectors, such as, awareness raising about the different market and technology, an investigation about potential business models and financing mechanisms, a study of supply and demand scenarios, and linkages with potential funding sources, etc. In the short term, these collaboration strategies will likely yield little to no leverage ratios for mobilising private finance unless strong regulatory and market enabling environments are established for the SLCP financing sectors which are ready for immediate upscaling. In the medium to long run this is expected to create an opportunity to design a full-fledged TA facility for implementing the bank's own SLCP finance programme, and as such the TA facility will be able to leverage private finance effectively.

Key implementation strategies by the Finance Initiative

To address both financial and non-financial barriers across the SLCP sectors, the following staged approach can be taken by the Finance Initiative:

***Firstly, by addressing the barriers to the mobilisation of SLCP finance that occur outside the FIs*:** Many of the challenges identified for achieving commercial finance at scale occur outside of FIs are regulatory or sectorial in nature. To successfully address these barriers it is necessary that the CCAC sector initiatives play a role. By providing financial advisory and TA services the Finance Initiative can enable CCAC sector initiatives to consider and embed a financial dimension (potentials, challenges, and needs associated with the availability of finance, especially private finance, for SLCP-mitigation investment) into the design of core sector strategies and projects.

Secondly, by addressing the barriers to mobilisation of finance that occur within FIs by designing pilot demonstration cases or developing pilot financing programmes about SLCP technologies: To achieve this, the Finance Initiative may work with small group of FIs that have been identified as having expressed interest in exploring SLCP financing potential in their region. The Finance Initiative proposes that collaboration strategies are established with promising FIs by offering TA support for identifying potential SLCP financing areas. For FIs operating under strong regulatory and market enabling environment for SLCP financing, pilot financing programmes can be further developed and brought to scale.

***Thirdly, at the early stage of scaling-up SLCP mitigation projects development organisations / donors should be engaged for channelling concessionary funding and designing innovative finance mechanisms for certain SLCP sectors*:** Commercial financiers alone cannot scale up SLCP financing programmes. This is because there will be demand for concessional funding to attract private investors to less commercially viable SLCP mitigation projects such as waste, agriculture etc. Moreover, multilateral development banks/donors shall consider integrating SLCP financing into their lending strategy. To make SLCP mitigation technologies competitive with contemporary solutions, innovative finance mechanisms such as results-based finance need to be applied where payments can be made for measured the health and environmental benefits of SLCP mitigation. Recently a new accounting methodology has been developed by the Gold Standard Foundation that focuses on measuring emissions reductions of BC and could be used for introducing results-based finance in the sectors mitigating BC. Similarly, the World Bank has introduced a pilot auction facility for methane reduction projects, a pay-for-performance instrument that uses auctions to maximise the use of limited public resources for climate change mitigation and leveraging private sector financing. The adoption of performance measurement tools at the programme level will be vital to direct financial flows to SLCP mitigation technologies.

1. INTRODUCTION

Banks are traditionally risk-averse and often associate environmentally friendly, low-carbon infrastructure projects with new, unproven and risky technologies. This is especially the case in developing countries because financing for projects is scarce and risk perceptions depends partly on familiarity and experience, the strong tendency is therefore to favour the status quo of financing conventional SLCP-intensive business activities.

Adding to the challenge is the fact that these climate markets often require new and specialised financial instruments. The costs associated with developing those instruments, as well as the initial transactions, can be prohibitive. Although they may be interested, most financial actors still prefer to wait on the sidelines instead of acting as first-movers. This wait-and-see attitude is compounded by an overall lack of information, experience and tools needed to quantify, mitigate and hedge project and product risks. It is however not uncommon to find a local champion in a FI that is willing to shepherd an environmentally friendly proposal through the bank's financial approvals process. These champions typically faces the challenge of convincing management that the project or financial product will provide returns that are commensurate with the risks - both real and perceived - of the new technology. Building a strong internal case that a particular initiative is a good financing opportunity often requires bringing in outside expertise. This might be, for example, technical specialists to verify that methane flows from a proposed landfill gas recovery project are technically sound; or market researchers to assess the demand for a brick kiln finance programme.

According to previous research undertaken on the economics of SLCP-mitigation efforts, there are many technologies and project-types with demonstrable SLCP mitigating potential that already are commercially viable and that, therefore, are in principle 'bankable' with private finance today. However, even in these cases, private financing is not flowing at the required scale and as such the considerable SLCP-mitigation potential is unexploited. In order to further understand this phenomenon, the Finance Initiative commissioned a study to assess the feasibility and potential *impact of a SLCP Finance Innovation Facility (SLCP FIF). The purpose of a SLCP FIF would be to 'unlock' at scale, sustainable and on-going flows of commercial finance for SLCP mitigation by providing private financial actors with targeted and punctual ('one-off') support in the form of TA or a small grant to support the development, and marketing, of financial products aimed at reducing SLCP emissions.*

Bank's loan capital is usually limited. In these situations unknown technologies or projects are often overlooked in favour of more conventional and widely understood alternatives. Knowledge gaps and information asymmetries, coupled with traditionally risk adverse FIs are important factors that need to be overcome before credit facilities can be developed and finance disseminated at scale to SLCP sectors.

By providing a one-off grant and TA a FIF support framework would provide the wide range of activities that are necessary to bring a financial product to market, including feasibility studies, technical product design, procedural development, training, supply chain development, loan product design, loan product marketing and pilot projects. The FIF engages with the bank partner throughout the financial product development phase, and helps to remove technical and market entry barriers so that they are able to engage in SLCP investment products.

The work seeks to build on work previously carried our between UNEP and the Frankfurt School UNEP Collaboration centre in developing and deploying a Climate finance innovation facility (CFIF) for low carbon infrastructure projects. The CFIF yielded exceptional results: In its four years of operation from 2010-2014, the CFIF supported 15 banks and MFIs, some with multiple loan products in their portfolio and it was active 10 countries across South and South East Asia. The CFIF provided support in the development of different types of loan products including: microfinance, project finance, commercial lending, carbon finance and vendor finance. The net impact of the CFIF interventions were: increased capacity for 9000 entrepreneurs, access to clean energy provided to 300,000 households and 200 SMEs, leading to an average reduction of 100k tCO_2 per year through clean technologies.

The CCAC has identified near-term SLCP mitigation actions across seven sectors (known as 'CCAC sector initiatives') that can ensure rapid delivery of scaled-up climate and clean air benefits by reducing the key SLCPs, including BC, HFCs and methane. Under these CCAC sector initiatives, CCAC partners have taken various global initiatives to raise awareness on SLCP impacts, promote best SLCP mitigation practices with transfer of technology and knowledge, and advocate for enabling policy and regulatory frameworks (*for identified SLCP control measures across the CCAC sector initiatives see next table 1 on the next page).*

The feasibility assessment focuses on investigating the SLCP mitigation technologies offering the highest mitigation potential of the sectors identified by the CCAC sector initiatives. The report assesses the barriers to expediently mobilise private financial flows towards SLCP mitigating technologies in a number of key sector and markets; analyse the financial profiles of the key technologies. With this, *the report aims to ascertain the appetite of commercial banks for SLCP technologies and the subsequent demand for a SLCP FIF*.

Table 1: Overview on CCAC sector initiatives and potential SLCP control measures

CCAC sector initiative	SLCP control measures	Key SLCPs
Cookstove	Replace traditional biomass cook stoves with modern fuel cook stoves	BC
	Replace traditional cooking and heating with clean-burning biomass stoves	
	Replace wood stoves and burners with pellet stoves	
	Replace lump coal with coal briquettes for cooking and heating	
Brick kiln	Replace traditional brick kilns with improved kilns	BC
Diesel	Diesel particulate filters for road and off-road vehicles	BC
	Eliminate high-emitting diesel vehicles	
Agriculture	Ban open-field burning of agriculture waste	BC, methane
	Intermittent aeration of continuously flooded rice paddies	
	Improve manure management and animal feed	
Oil & Gas	Pre-mine degasification and recovery and oxidation of methane from ventilation air from coal mines	BC, methane
	Recovery and utilization of gas and fugitive emissions	
	Reduce leakage from long-distance gas transmission pipelines	
Waste	Separation and treatment of biodegradable municipal waste and landfill gas collection	BC, methane
	Upgrade waste water treatment with gas recovery and overflow control	
HFCs	Replacement of high climate impact HFCs with low impact alternatives	High GWP[3] HFCs

Source: CCAC (2014)

[3] GWP: Global Warming Potential

2. METHODOLOGY

The feasibility assessment is based on extensive desk research for the sectors of brick kiln, diesel vehicle, cook stove, HFCs free/low-GWP HFCs refrigeration & air-conditioning, agriculture (livestock manure management), oil and gas (utility scale) and waste. Systematic research was carried out to investigate:

i. SLCP mitigation technologies across the sectors and their commercial applications, especially in the emerging economics;

ii. the financial viability of SLCP mitigation technologies based on simple net-present value (NPV) analyses and/or review of financial data;

iii. the market potential of SLCP mitigation technologies;

iv. existing policy, financial incentives and programmes in countries favouring SLCP mitigation;

v. funding sources and potential financing options in SLCP mitigation sectors; and

vi. the financial and non-financial barriers in SLCP mitigation sectors preventing financial flows by the commercial banks.

With these sector-base investigations, the feasibility assessment attempts to ascertain *the demand of TA facility through establishing a SLCP FIF for the commercial banks.* During this process, a number of local FIs, banks, MFIs and project developers were contacted to understand their awareness and appetite for rolling-out financing programmes targeting SLCP mitigation sectors.

In addition, representatives from various CCAC sector initiatives were consulted to find out: i) on-going actions of the sector initiatives where private financing dimension can be added, ii) barriers that prevent uptake of SLCP mitigation actions, iii) the most promising regions and countries for establishing a SLCP FIF. The information gathered enabled the Finance Initiative to focus its assessment on certain regions and countries where action plans have been enacted by other CCAC sector initiatives to promote SLCP mitigation programmes.

3. SLCP SECTOR FEASIBILITY ASSESSMENT

3.1 BRICK KILN

SUMMARY

- About 1,500 billion bricks are annually produced all over the world. Of these about 90% bricks are produced in Asia and 60% of it by China, while the rest are produced in Latin America and other parts of the world.
- Most of the countries holding a large share in the global brick production market still have a portion of their businesses that rely on out-dated energy inefficient brick kiln technologies such as the Bull's Trench Kiln (BTK) or the Fixed Chimney Kiln (FCK).
- Apart from increased energy efficiency in modern brick manufacturing technologies, reductions in significant fine particulate pollution could be achieved by improving firing methods inside the brick kilns.
- In terms of reducing emissions, the Tunnel Kiln technology is found to be the most efficient, followed by Hybrid Hoffmann Kiln (HHK), Vertical Shaft Brick Kiln (VSBK) and improved Zig Zag Kiln.
- In terms of brick production capacity and brick quality, Tunnel Kiln and HHK have large production scale with high quality bricks, while improved Zig Zag Kiln and VSBK feature smaller production and lower quality in these aspects.
- All technologies analysed yield positive NPVs. Improved Zig Zag Kilns require low upfront investment, have low yearly operation & maintenance (O&M) costs and the shortest payback period. HHK and Tunnel Kiln on the contrary are very capital intensive and feature longer payback periods.
- The brick industry is dominated by SMEs and most of the countries do not view brick kiln as being in the formal sector.
- Major challenges for commercial finance are: Commercial banks' high perceived and real credit risk, insufficient credit record of the brick operators, a lack of environmental compliance in the brick sector, and brick operator's limited capacity to operate modern brick factory
- The cheap price of fuel, absence of policy incentives and weak regulation and enforcement further slow down this technological transformational process in the informal brick sector.

3.1.1 BASIC SECTOR INFORMATION

The brick making industry is an area where significant emission reductions can be made with regard to SLCPs, in particular with BC. Yet in many countries bricks are being produced in the traditional way of burning fuels, in particular coal, in inefficient kilns. The incomplete fuel combustion of these traditional kilns leads to environmental and health risks and air pollution causes lung diseases for millions of people who work or live near the kilns.

About 1,500 billion bricks are annually produced all over the world. Of these, about 90% bricks are produced in Asia led by China (over 60%); rest are produced in Latin America and in other parts of the world. Besides China, countries such as India, Pakistan, Vietnam, Bangladesh and Nepal produce significant amounts of bricks by using mainly traditional technologies that are largely energy inefficient. The traditional and old brick production technologies contribute to GHG and BC emissions with a significant impact on human health and climate change.

Apart from increased energy efficiency in modern brick manufacturing technologies significant fine particulate pollution reductions could be achieved by improving firing methods inside the kilns. The ADB study shows that more efficient technologies can result in reductions of PM from 35% to 95% and CO2 emissions from 24% to 50%, depending on the process, scale and fuel used (ADB 2012c). However, the brick sector is yet to achieve the required scale in transforming the sector into a modern environmentally friendly brick industry. With the help of regulatory enforcements, policy incentives, funding and capacity building supports the stakeholders has taken new strategies to help transform the brick sector into an energy efficient and environmentally friendly industry.

3.1.2 SLCP MITIGATION OPTIONS

The most widespread technologies used by the sector, such as the Bull's Trench Kiln (BTK) or the slightly better Fixed Chimney Kiln (FCK), are highly polluting and energy inefficient. The BTK technology uses two 30 feet tall chimneys for pollutants dispersion and can be dated back to the 19th century. FCK is an improvement on the BTK technology, using taller chimneys (120-130 feet) to disperse the flue gas and its pollutants faster (World Bank, 2011). The BTK and FCK both feature very high pollution levels and high coal consumption rates. To reduce pollution from the brick kiln industries, the most widely available technologies to replace traditional brick kilns include improved "Zig Zag Kiln", "Vertical Shaft Brick Kiln (VSBK)", "Hybrid Hoffmann Kiln (HHK)", and "Tunnel Kiln". Table 2 lists different brick kiln technologies and their performance indicators:

Table 2: Indicators for different brick kiln technologies

Types of kiln	BTK (Bulls Trench)	FCK (Fixed Chimney)	Improved Zig Zag	VSBK (Vertical Shaft)	HHK (Hybrid Hoffman)	Tunnel kiln
Pollution level	Very high	High	Medium	Medium low	Low	Low
Fine particulate pollution emissions (mg/m per 100,000 bricks)	>1000	>1000	500-800	78-187	20.3	<50
CO2 emissions (tonnes per million bricks)	631	582	440	291	315	291
Coal consumption (tonnes per million bricks)	260	240	180-200	100-120	120-130	100-120
Brick production (per year)	2 millions	3 millions	3 millions	4 million	15 million	30 million
Brick price*	~USD 0.06	~USD 0.07	~USD 0.07	~USD 0.07	~USD 0.08	~USD 0.09

Source: Adapted from ADB (2012c)
* Brick price refers to the price of brick in Bangladesh market; projects' lifetime is assumed as 10 years for all technologies.

The Tunnel Kiln and HHK are the technologies that produce bricks with the highest quality (which is reflected in the brick price) with the lowest environmental impact. VSBK is comparable with HHK and tunnel kiln in terms of CO2 emission level but it has relatively small production capacity, and the quality of the bricks produced from VSBK technology may not be as good as other two technologies (GKS, 2012). Improved Zig Zag Kilns are more energy efficient than the conventional technologies (i.e. less coal consumption) but behind the Tunnel Kiln, HHK, VSBKs in terms of emission reduction potentials. VSBK has about 30% higher brick production output per year than FCK; HHK and Tunnel Kiln feature significantly higher production capacities with 5 times and 10 times the production capacity of FCK.

There are significant fine particulate pollution and CO2 emission reductions from VSBK, HHK and Tunnel Kiln technologies in comparison to FCK technology. Improved Zig Zag Kiln in comparison has lower emission reduction potentials. But with 35% fine particulate pollution reduction, 24% CO2 emission reduction and 21% coal consumption reduction, it is still a valid energy efficient technology in the brick kiln sector. The emission reduction potentials in comparison to FCK technology are summarised in the Table 3:

Table 3: Emission reductions for different brick kiln technologies

% Emission reduction in comparison to FCK	Improved Zig Zag	VSBK	HHK	Tunnel kiln
Fine particulate emissions (mg/m per 100,000 bricks)	>35%	87%	98%	95%
CO2 emissions (tonnes per million bricks)	24%	50%	46%	50%
Coal consumption (tonnes per million bricks)	21%	54%	48%	54%

Source: Own calculation based on table 2; the average is taken wherever there is a range, e.g. 500-800; wherever it is >1000, the number 1001 is taken; wherever it is <50, the number 49 is taken for estimation reasons. FCK is used as the standard technology for comparison.

3.1.3 MARKET ENVIRONMENT

About 86% of world's brick production is concentrated in Asia and 14% in the rest of the world. Out-dated firing technologies are still used in the brick production process. Table 4 lists major brick production countries worldwide:

Table 4: World brick production

Country	Production share (%)	Production capacity (Billion bricks per year)
China	66.7%	1,000
India	13.3%	200
Pakistan	3.0%	45
Vietnam	1.7%	25
Bangladesh	1.1%	17
Nepal	0.4%	6
Rest of Asia	0.5%	7
Total Asia	86.7%	1,300
USA	0.5%	8
UK	0.4%	4
Australia	0.1%	2
Outside Asia and countries mentioned above*	12.4%	186
Total outside Asia	13.3%	200
Total World Production	100.00%	1,500

Source: Baum (2012)[4]; *mostly Latin America, for details see table 5.

Brick industry in Asia

The top ranked South Asian countries in brick production (including India, Pakistan, Bangladesh and Nepal) on average produce 270-300 billion bricks per year with traditional firing technologies including BTK that are highly polluting. The operation is seasonal due to rainy seasons and it is highly dependent on migratory labour. In comparison, China and Vietnam utilise more advanced firing technologies such as, Tunnel Kiln, HHK and VSBK. There kilns are operational all year round and the enterprises rely more on local labour. In general, the brick industry is mixed with unorganised and organised units, which include both the private and public sectors, where unorganised or informal units mainly dominate the sector. The country-specific major brick industry market is described below:

CHINA

China's brick industry went through major structural changes since 1980s when about 90% of the state-owned brick enterprises stepped out of the stage and were replaced by private or joint stock enterprises. In 1996, the National Development and Reform Commission (NDRC) issued the China Energy Technology Policy, which required the phasing out, or technology upgrade, of high-energy-consuming kiln technologies

[4] Other sources used in the table include Mexico & India: GKSPL Estimate, Pakistan: Estimate based on CIWCE report Lahore, Bangladesh & China: ESMAP & World Bank Report, Vietnam: Ministry of Construction Vietnam, accessible online at http://www.hablakilns.com/industry.htm

(SDPC, 1996). Following a series of similar policies that aim to reduce pollution and enhance energy efficiency in the brick sector, some of the highly polluting brick enterprises closed down, reducing the number of remaining enterprises to 70,000 from about 120,000. Furthermore, in 2013, the Ministry of Environmental Protection issued National Standards for fired perforated bricks/blocks, that has set emission standards for the brick and tile industry. The decree came into effect on January 01st 2014 (MEP, 2013).

The Chinese market is composed of: medium-sized enterprises, with an annual production of 30-50 million bricks and account for nearly 30% of the market; small to medium-sized enterprises with an annual production of 10-30 million brick production make up 21% of the market, and; small enterprises with an annual production of less than 10 million bricks that account for roughly 15% of the market. Besides, large enterprises with an annual brick production of 50 million or above have 4% market share, the types of enterprises contributing to the remaining market is unknown (Sun, 2013). In particular the small enterprises still use out-dated firing technologies that are highly inefficient and produce high levels of particulate pollution (CRAES, 2009).

INDIA

India is the second largest producer of bricks in the world. The sector is fragmented with small enterprises using mainly traditional technologies such as BTK. Brick kilns are estimated to consume roughly 25 million tonnes of coal per year, thus making it one of the highest industrial consumers of coal in the country. A rapid increase in the brick production has given rise to environmental and health concerns in India. In 1990, the Central Pollution Control Board/ Ministry of Environment (MoE) and Forest issued air emission regulation for brick kilns aimed at improving the brick sector by introducing environmentally friendly technologies. The regulation required a shift of about 30,000 Bull's Trench Kiln (BTK) to Fixed Chimney Bull's Trench Kilns (FCBTK)[5].

Besides the Government initiative on FCBTK, till now Zig Zag Kiln, VSBK, Down-Draught Kilns (DDK)[6] are the main firing technologies that have been adopted in India through various programmes, which still require large-scale adoption. Driven by India's population and economy growth, it is projected that the building construction will require increasing volumes of building materials, growing at about 6.6% per year (GKS, 2012).

PAKISTAN

Pakistan's brick-making industry contributes in the region of 1.5% of its Gross Domestic Product (GDP). However, the brick production industry in Pakistan remains highly unregulated. The most widely used means of production contains a heavy hand moulding process that leads to an increase of wastage of around 27% compared to average wastage in the mechanised process which is about 2-5%. In addition, the quality of the bricks from manual process is not as consistent (Ahmad, 2009).

The most widespread technologies in Pakistan are FCBTKs. Recently new technologies such as HHK, modified FCBTK, VSBK and Tunnel Kiln have been introduced. However, they weren't widely adopted as a result of technological and operational difficulties, as well as an unwillingness of operators to adapt to the new technologies (Ahmad, 2009).

VIETNAM

Vietnam has a long history of brick manufacture and produces 1.67% of the world's annual supply. It is estimated that there are 600 brick enterprises in Vietnam that are operating over 10,000 traditional kilns and are heavily polluting the environment. The government plays a proactive role in the sector, including issuing supportive policies and participating in brick production activities through state-owned enterprises

[5] FCBTK technology is a slightly improved version of BTK; by converting FCBTK to Zig Zag firing technology can result in 20% saving in coal consumption and CO2 emission as well as 75% reduction in suspended particulate matter and black carbon (Lalchandani & Maithel, 2013).

[6] DDK technology is a slightly improved version of Clamp Kiln. The CO2 and black carbon emissions from DDK are 282 g/kg and 0.29 g/kg; these are twice as high as the emissions of FCBTK technology (UNEP, 2014b; UNEP, 2014c).

(SOE) (SDC, 2008). To address the environmental problems, in 2001, the Prime Minister's decree called for the phasing out of traditional firing kilns in urban areas by 2005 and all over the country by 2010. As a response, some 300 VSBKs were constructed in a short period of time. Other advanced environmentally friendly options such as tunnel kiln technology could not be rolled out, due to the large investment need. Moreover, the rapid replacement of traditional kilns with tunnel kilns is associated with considerable social costs, as the latter displaces manual labour to a large extent. As a result, VSBK appears to be the most accessible solution in Vietnam (SDC, 2010).

BANGLADESH

Bangladesh's brick sector has about 5000 kilns and contributes about 1% to the country's GDP. The brick is the main construction material for buildings in the country. The most dominant kiln is the energy inefficient FCK. The country's major brick production facilities are located around the capital Dhaka, which are major contributors of the deteriorating air pollution problem in the city. In addition, brick sector is largely contributing to deforestation, loss of farmlands and natural habitats through the extraction of fertile topsoil for brick making.

To improve the environmental condition of the country, in 2007, the government issued a notification that environmental clearance certificates would not be renewed if the technology used were not shifted to alternative and improved technologies by 2010. Furthermore, in 2010, the Government of Bangladesh issued a notification banning FCK operation from 2013. Due to the regulation, more environmentally friendly and more energy efficient technologies such as VSBK and HHK are being introduced but still remain at pilot stage (World Bank, 2011)

NEPAL

Nepal has more than 700 brick kilns, out of which around 38% are considered to be in the informal sector. The brick sector contributes about 1.41% to Nepal's GDP. The prevalent technologies in Nepal include Clamp Kiln[7], Movable Chimney Bulls Trench Kiln (MCBTK)[8], straight-line FCBTK, Zig Zag FCBTK and VSBK. MCBTK has 57% of the market share, followed by FCBTK with a share of 33%, Clamp Kiln with a share of 6.7%; VSBK with a share of 3.6% and HHK with a share of 0.3% (MinErgy Nepal, 2012). The Government of Nepal banned MCBTK technology for the Kathmandu Valley in 2003 and has enforced the ban on this technology throughout the country by 2012. The alternative technology options presently available in the country include FCBTK, VSBK and Tunnel Kilns (MinErgy Nepal, 2012).

BRICK INDUSTRY IN LATIN AMERICA

In addition to Asia, Latin America has a considerable number of brick making facilities. It is estimated that there are approximately 17,000 brick making facilities in Mexico, 6,898 in Brazil, 2,453 in Colombia, and 2,222 in Peru. Mexico's brick production relies 90% on manual labour and lacks the technology to modernise brick fabrication. Incomplete combustion and mixture of fuel types used in the kiln lead to a considerate amount of pollutants from the brick making process. This also means high levels of fuel consumption (Avitia & Covarrubias, 2012). According to CCAC (2012), Brazil and Colombia have semi-automated technologies and more efficient kilns, while Peru and Bolivia have a mixture of improved technologies and manual production technologies.

[7] Clamp Kiln technology does not have permanent kiln structure but only a pile of green bricks with combustible materials interspersed within. The technology phased out in developed countries after 18th century but is still prevalent in developing countries (UNEP, 2014a).

[8] MCBTK is a type of BTK technology. Compared with fixed chimney BTK, MCBTK has about 20%-30% less production capacity per year and 10% to 20% more energy consumption in terms of MJ/kg of fired product (PSCST, 1993).

Table 5: Brick production in Latin American countries

Country	Average country annual production (thousands of bricks)
Mexico	up to 7,500
Brazil	5,380
Colombia	up to 11,040
Peru	100 - 1,115
Bolivia	84 - 1,783
Argentina	144
Ecuador	45 – 208
Honduras	35 – 242
Nicaragua	29 – 311

Source: CCAC (2012)

3.1.4 COMMERCIAL VIABILITY

The financial analysis in this section is based on the data from Asian Development Bank's project "Financing Brick Kiln Efficiency Improvement Project" in Bangladesh. The financial analysis is limited by its single country context, however due to the concentration of the bricks industry in Asian countries, this is not a fundamental problem. The assumptions for brick production capacities and brick prices are as follows:

For improved Zig Zag Kiln, VSBK, HHK and Tunnel Kiln, the yearly production capacities are 3 million, 4 million, 15 million and 30 million bricks and the brick prices are USD 0.07, USD 0.07, USD 0.08 and USD 0.09 respectively. According to ADB (2012a), material, labour and other costs are based on kilns with medium-sized producing capacity. The FCK technology is used as reference to compare different technologies. Since the initial investment for FCK is low, the kiln owners usually finance it with 100% equity. FCK has low initial investment (USD 60,000 - 70,000 per unit) and low operating costs. The project Financial Internal Rate of Return (FIRR) and equity FIRR for FCK are both 23.7% (ADB, 2012a).

Table 6: Assumptions used for financial analysis

Cost of debt	**11%**
Cost of equity	15%
Debt share	70%
Equity share	30%
Weighted average cost of capital (WACC)	9,3%

Source: ADB (2012b)

Note: Tax shield effect is taken into consideration when calculating WACC

Table 7: Results of the financial analysis

Financial Analysis	Improved Zig Zag Kiln	VSBK	HHK	Tunnel Kiln
Capital investment (in USD)	90,104	226,438	1,682,987	3,550,796
O&M per year (in USD)	160,037	189,475	492,289	865,850
Revenue per year (in USD)	214,223	285,631	1,263,158	2,722,766
Capital investment per brick (in USD)	0.03	0.06	0.11	0.12
Payback Period (in Year)	3,7	6,1	5,6	5,4
Project FIRR	34,0%	33,6%	37,5%	35,1%
Equity FIRR	27,5%	18,2%	20,6%	21,3%
Net Present Value (NPV) (in USD)	101,458	119,983	1,083,320	2,847,173

Source: Own analysis

Note: Numbers are subtracted from ADB (2012a)'s cash flow model, NPV is own calculation based on the existing model; capital investment per brick is own calculation based on data in Table 2 and Table 7.

The loan tenure for all technologies is assumed to be 5 years; the facilities are assumed to have 10-year lifespan (ADB, 2012b). Table 7 shows a summary of the results of the financial analysis on improved Zig-Zag Kiln, VSBK, HHK and Tunnel Kilns.

The HHK and Tunnel Kilns are the most capital-intensive technologies, which require more than USD 1 million in capital investment and substantial O & M costs every year. Nevertheless, they also have extensive brick production capacity, and are able to generate more than USD 1 million revenues annually. To make it more comparable, capital investment per brick is calculated and it shows that HHK and VSBK are relatively "expensive" technologies in this aspect with USD 0.11 and 0.12 per brick while Improved Zig Zag Kiln and VSBK are much cheaper with USD 0.03 and 0.06 per brick respectively.

Looking at the payback period, the improved Zig Zag Kiln has the shortest period, followed by Tunnel Kiln, HHK and VSBK. All the four technologies have a similar project FIRR, while the improved Zig Zag Kiln stands out with an equity FIRR of 27.5%. Comparatively, VSBK has the lowest equity FIRR of 18.2%. Improved Zig Zag Kiln and VSBK have a similar revenue structure and similar NPV, but the improved Zig Zag Kiln appears to be more attractive because the initial capital investment is about 40% of that of VSBK and equity FIRR is about 9% higher than that of VSBK. Table 8 combines the NPV with performance indicators of different alternative brick kiln options for an investor:

Table 8: Comparison of brick kiln technologies

	Improved Zig Zag Kiln	VSBK	HHK	Tunnel Kiln
Capital intensity	+	++	+++	++++
Production capacity	+	+	+++	++++
Initial capital investment per brick	+	+	++	++
Energy efficiency	+	+++	+++	+++
Brick price	+	+	++	++
NPV	+	+	++	+++

Source: Own analysis
Note: the number of "+" indicates the intensity of the variable, e.g. more "+" means bigger capital investment requirement, better energy efficiency, better brick quality and larger NPVs; FCK is used as a reference case.

In summary, the most easily accessible technology is the Zig Zag Kiln, because it has a relatively low initial investment requirement and the shortest payback period. In addition, the equity FIRR is high and NPV is positive. HHK and Tunnel Kilns are more suitable for large-scale production; the bottleneck is the huge initial capital investment and O&M cost (especially for Tunnel Kiln) that are needed for such investment as well as a rather long payback period. VSBK has a moderate initial investment requirement but it features the lowest equity FIRR and the longest payback period. Additionally there are issues of product quality and there have been reports of poor brick quality with certain clays (GKS, 2012). However, the selection of technology for a certain market will depend upon technology availability, brick demand, experience and the financial capacity of the investor willing to adopt energy efficient brick kiln production process.

3.1.5 FINANCING AND MAJOR PROGRAMMES

The Financial market for brick kilns is still early stage, particularly in Asia. Banks generally *do not consider the brick sector as a formal industry and are not ready to extend credit to the brick enterprises. Though recently, various multi donor based funds have been created to channel funding to the local brick enterprises*. This is expected to increase financing to the brick sector. The major country-specific brick kiln financing programmes are described below:

- **China:** Market transformation of 'Energy Efficient Bricks and Rural Buildings Project' supported by Global Environment Fund (GEF) and the Ministry of Agriculture. This project lasted from 2008 until 2014, with a budget of USD 52 million. The project aimed at removing barriers to market transformation in rural areas through information dissemination, creation of policy and regulatory framework, development of financial support schemes and demonstration of technologies by developing technical guidelines for both rural energy efficient bricks and building applications. During the project tenor, the "National Standards of Fired Perforated Bricks/Blocks (GB13544-2011)" was formally promulgated on April 1, 2012. Later, nine pilot energy efficient brick factories started producing bricks following the project standards. Concerning financial support in the brick production, an assessment on the financing capabilities of pilot brick makers and financial institutes has been completed. (UNDP, 2014).

- **India:** Energy efficiency Improvements in the brick industry supported by United Nations Development Programme (UNDP) and GEF. The project started in 2009 and is expected to be completed by 2016, with a total budget of USD 2.69 million. In partnership with the Ministry of Environment and Forests, Government of India, the project aimed to make the clusters of Indian brick making industries more resource efficient (UNDP, 2009). Financing appears to be a key bottleneck for India. As GKS (2012) points out, the majority of brick kiln producers in India does either not have, or has only limited access to bank credits, while the capital investment needs for semi-mechanization brick making ranges from USD 0.16-3.19 million, which is not easily financeable through 100% equity. So far, the project has reached out to 930 brick entrepreneurs and relevant public/private stakeholders for promoting production of resource efficient bricks in Karnataka, Punjab and the neighbouring regions of India. By providing market development support, the project supported production of resource efficient brick production in nine traditional brick producing units.
- **Pakistan: A** VSBK trial project funded by the Swiss Development Corporation (SDC) aimed to introduce an environmentally friendly technique to Pakistan. In the pilot phase, two VSBKs were constructed in Pakistan. However, the project did not expand, partly due to weak legislation in the brick sector and partly because of the government's inability to extend financial and technical support to the brick owners (Shahid, 2011).
- **Vietnam:** Vietnam's Sustainable Brickmaking Project (VSBP) lasted between 2002-2010, with the aim to help small brick makers in Nam Dinh Province to move to environmentally friendly and commercially viable production technologies. The region has a sizable brick industry with more than 600 kilns. With support from Swiss Agency for Development and Cooperation (SDC), the project provided technical supports for introducing brick industry best production practises in Vietnam. The project provided technical, business and regulatory supports for expanding VSBKs and supported institutional improvements for adopting 14 low-cost tunnel kilns in the Nam Dinh Province (SDC, 2010).

  The low Carbon Transition in Energy Efficiency (LCEE) programme in Vietnam was supported by Danish Ministry of Climate Energy and Buildings. The implementation period for the project was 2013-2015. The total budget was about USD 10 million. The objective was to improve energy efficiency in Vietnam's SMEs, including the brick sector. The project supported the development of a financing mechanism by providing loan guarantee of up to 50% of investment costs and a rebate scheme for achieved energy efficiency measures in the SMEs including brick sector. The ultimate goal was to implement 150-200 energy efficiency investment projects in the brick and ceramic sectors and at least three demonstration projects in the food processing industry (MFAD, 2013). It has not been possible to find a status update from the available materials.
- **Bangladesh:** ADB has supported The Financing Brick Kiln Efficiency Improvement Project by proving a USD 50 million credit facility to Bangladesh bank. The aim was to help Bangladesh to build energy efficient brick kilns by removing financing barriers of the local lenders. The project was supposed to be implemented from 2012 to 2015 (ADB, 2012b). According to ADB, the project implementation has been slow and current demand for upgrading the traditional brick kilns to a more energy efficient technologies has been low due the changing market conditions. The slow implementation progress is mainly due to government's inability to enforce the phasing-out of traditional kilns, weak implementation capacity, and performance of the local implementing agency[9].
- **Nepal:** The Nepal Energy Efficiency Programme (NEEP), supported by GIZ, is being implemented to promote and realise industrial energy efficiency in Nepal**.** The project started in 2009 and is planned to last for 8 years. The project aims to improve energy efficiency in Nepal, which includes Nepal's brick making industry (GoN, 2014). According to MinErgy Nepal (2012), VSBK is not preferred by entrepreneurs in Nepal because of its high initial investment and lower returns compared with FCBTK; this is the same situation for HHK, which is being introduced over 40 years but could not achieve large scale. In addition, the FIs in Nepal do not provide commercial loans with competitive interest rate because the brick kiln sector is not viewed as an formal industry.

[9] Source: http://www.adb.org/projects/45273-001/main#project-pds

- **Latin America:** One large-scale on-going project that is operating in Latin American countries to improve energy efficiency in brick kiln industry is the 'Energy Efficiency in Artisanal Brick and Plaster Kilns in Latin America to Mitigate Climate Change (EELA)'. The project is being funded by SDC (Red ladrilleras, 2013). The project locations include Argentina, Bolivia, Brazil, Colombia, Ecuador, Mexico and Peru. The project focuses on fostering technology know-hows and promotes different technologies with different investment requirements, which range from installing fans in brick kilns, switching fuels, and converting traditional kilns to more efficient kilns with ventilation systems. The project is expected to reduce emissions from the operating kilns by 50%. The benefits are calculated to be approximately USD 10 million increase in the net income of the kiln owners and an emission reduction of 0.8 million tonnes CO2/year (Swisscontact, 2015).

3.1.6 BARRIERS[10]

The study has identified the key barriers for investment in improved brick kiln technologies to include regulatory, financing technology, knowledge and capacity gaps. A description of each is detailed below:

- **Regulatory barriers:** Fiscal incentives, supporting regulations and effective emission standards are usually lacking. For example, brick sector policies do not distinguish between energy intensive and energy efficient technologies in many countries and policies promoting investment in energy efficient technologies are often not in place. Even if policies are in place, they are often not implemented or enforced e.g. Government of Bangladesh banned fixed chimney kiln operation from 2013 but there is little activity occurred to enforce the regulation (ADB, 2012d).
- **Financing barriers:** FIs often lack the experiences and willingness to lend to brick owners, e.g. the FIs in Asia and Latin America do not consider brick kiln as a formal industry and are not ready to extend credit to the brick enterprises. Moreover, improved technology such as VSBK and HHK usually requires high upfront investment compared to conventional technologies, making them less attractive for brick owners to invest in.
- **Technology barriers:** The complexity in operating the improved kiln technologies such as VSBK, HHK, discourages brick entrepreneurs from adopting new technologies; this is one of the most important barriers to implementation.
- **Knowledge gaps:** Brick owners lack the awareness and knowledge in the new technologies / alternative options and the economic benefits such technologies would bring to the brick owners if it were implemented.
- **Capacity gaps:** Brick enterprises lack the technical and management capacity to initiate changes to more energy efficient technologies within themselves.

[10] Source: Own Analysis based on World Bank (2011)

3.1.7 WAY-FORWARD FOR SLCP FIF

In order to scale up the on-going technology transformations that are presently taking place, the brick sector requires a holistic approach that involves policy makers, financiers and the brick owners. The brick sector may not be as advanced yet to obtain the full benefit of a TA facility targeted for the finance industry, as would be provided by a SLCP FIF.

The informal nature of the sector is the key impediment preventing the finance from commercial institutions that is needed for upgrading their traditional kilns into environmentally friendly technologies mitigating BC. Though donor funding is being increasingly made available for the sector, due to bank’s perceived and real credit risks in the sector, commercial financing programmes are still not being implemented at the desired scale. Moreover, the dominant small & medium sized informal business units do not have proper track record to manage any advanced technology. This is often coupled with their unwillingness to adopt a new production process, even though it reduces production and energy costs. The cheap price of fuel, absence of policy incentives and weak enforcement of regulation are key impediments in the technological transformational process in the informal sector. This would render any TA intervention that focused only on the issuing FIs, such as that provided through a SLCP FIF, largely ineffective. As the barrier to financing is not a shortage of the financing skills necessary to appraise the sector and set up and market a new loan facility, but the credit risk the sector represents to the bank itself.

To encourage private finance to flow into the sector, the finance initiative can work together with a select number of banks/FIs operating in the countries such as Bangladesh, Nepal, India, few Latin American countries where existing policies are supportive for implementing brick kiln finance programme. The finance initiative can provide advisory support for bank’s credit-risk enhancement; investigate potential funding sources and innovative finance mechanisms such as guarantees, results-based finance mechanism by measuring health and environmental benefits, so as to help finance industry reduce the real and perceived credit risks in the brick kiln sector. The finance initiative, with help of brick kiln technology expert, may come forward to bridge the information gap between financiers and brick kiln owners by advocating both on selection of proper kiln technology; it’s potential financial benefits; and suggesting capacity enhancements required at the local level to be able to manage environmentally friendly kiln production process. In tandem, the finance initiative can bring policy makers, financiers and brick kiln owners on-board to address the barriers of the sector through consultations, dialogues and policy supports.

3.2 DIESEL

SUMMARY

- The transport sector accounts for 19% of the world's BC emissions and contributes to 3.2 million premature deaths per year from exposure to pollutants.
- While heavy-duty diesel vehicles (HDVs) such as urban buses, trucks, and freights in most countries constitute only a small share of the total vehicle fleet they generate more than two-thirds of atmospheric PM.
- From a technological point of view, the most common measure for the reduction of BC emissions is retrofitting of diesel vehicle with a diesel particulate filter (DPF); procuring soot-free engines and switching from diesel to a cleaner fuel.
- Emission control measures such retrofitting with DPF, is an incremental capital cost for the vehicle owner. The additional investments may not always be justifiable from a commercial point of view. However, fuel-efficient soot-free engines with DPF features will bring fuel reduction benefits alongside environmental and health benefits.
- Both vehicle standards and low-sulphur fuel standards are absolutely necessary in the transport sector in order to adopt advanced emission reduction processes that can reduce BC from the vehicles. Emission standards for PM2.5 set limits that require particulate filters on diesel vehicles and are effective at reducing BC. To enable optimal use of the particulate filter, the sulphur content of the diesel fuel must be lower than 50 ppm.
- The global vehicle market has grown on average by 3.5% for the last 10 years. In terms of sales, 85% of the total vehicle sales are mainly concentrated in 10 countries, namely China, the US, Japan, Brazil, India, Russia, Canada, South Korea, Australia, Mexico and the EU region.
- Natural gas vehicle (NGV) is still niche. More than 70% of all NGVs and almost half of all fuelling stations are found in only five non-OECD countries. Contributing factors are lower fuel tax on natural gas, subsidy policies for CNG conversion and purchase of new CNG vehicles.
- In the US, the EU and Japan, vehicle emission regulations have accelerated the commercialisation of advanced emission control technologies. The emission control regulatory measures of the US and EU provide a pathway for other countries to follow to improve the environmental performance of their vehicles.
- Globally, vehicle financing is done three ways, financing through: 1) an Original Equipment Manufacturer (OEM) known as 'captive'; 2) a commercial bank; or, 3) an independent finance company.
- The car loan market is saturated in mature markets due to high competition among different financing groups. Leasing presents immense opportunity in emerging countries. Demand of additional banking products like insurance, maintenance and fleet services is also growing in emerging markets.
- Availability of low-sulphur fuel is a key bottleneck for the implementation of emission control programmes in the emerging countries. Further, the investment required for refinery upgrades is considerable and beyond the financial capacity of the local commercial banks.
- It is very unlikely that vehicle emission control programme can be alone driven by commercial banks. Compliance and enforcement measures are also fundamental to a successful emission control programme. Moreover, there is lack of adoption for soot-free engines in many developing countries due to the absence of required vehicle and fuel standards and prohibitive additional capital costs. To be effective a vehicle emission control programme requires involvement from the government transport authority, vehicle manufacturers, fleet operators and financiers.
- Some emerging economies have already established emission control programmes at the city level, which can be scaled up to the national level. By making ultra-low-sulphur fuels available, cities in Brazil, India, China, and Mexico have potential for introducing soot-free diesel engines over the next five years.

- A key barrier to achieving commercial finance in the sector is a lack of awareness concerning less polluting vehicles within the finance industry. This is more acute in emerging countries.
- Commercial banks' interest in financing environmentally friendly fleet programmes is dependent on the fleet operator's business model and their ownership structure (e.g. public/private). In many countries, fiscal policies have been proven to be an effective tool to complement mandatory regulatory requirements of the emission control programmes.
- There is however potential for commercial finance in the low-carbon transport sector by offering various vehicle financing loan products leveraged on the available government financial incentives.

3.2.1 BASIC SECTOR INFORMATION

According to CCAC, the transport sector accounts for 19% of the world's BC emission, contributing to 3.2 million deaths per year[11] from exposure to pollutants. Most of the harmful emissions from diesel vehicles come in the form of PM, 75% of which is typically BC. Reducing PM emissions from the transport sector can provide improved air quality and health benefits, and address near-term global warming.

Vehicles are largely categorised by two types: *light-duty vehicles like cars and vans (LDVs) and heavy-duty vehicles like trucks and buses (HDVs)[12].* While HDVs such as urban buses, trucks, freights in most countries constitute only a small share of the total vehicle fleet, they contribute more than two-thirds of exhaust PM. Cities are mainly affected by the air pollution originated from vehicles. Introducing low-sulphur fuels along with equivalent vehicle emission standards would reduce BC emissions by 7.1 million tonnes by 2050, and annual emissions of PM2.5 by over 85%, resulting in 100,000 fewer yearly premature deaths in 2020, and 470,000 in 2050[13]. There are technologies available and in use, especially in the developed countries such the US and the EU that can control BC emissions from the vehicles effectively. By implementing stricter limits on emissions and vehicle standards; introducing low sulphur fuels; incentivising vehicle upgrading programmes, developed countries provide a pathway for other countries to follow so as to improve the environmental performance of their vehicles. Yet, only few developing countries have the appropriate emission limits, vehicle standards and fuel infrastructure in place to setup vehicle emission control programmes immediately.

Encouragingly, many emerging countries have taken steps to implement a low-carbon pathway in the transport sector by adapting regulations on fuel and vehicle standards, targeting replacement/ upgrading programmes, especially for the urban buses and freights. For example, the CCAC 'Soot-Free Urban Bus Fleets' project works towards soot-free engine technologies in 20 major cities across Latin America, Africa and Asia. Successful vehicle control programmes would prevent 3,700 premature deaths and up to 6.6 MMT CO2e by 2030 in the region consisting of 234 million population (Ray,M., 2015). Yet there are significant challenges relating to technology transfer, low-sulphur fuel infrastructure, financing and the implementation of policy measures supporting the transition to a low-carbon transport sector in the emerging countries.

3.2.2 SLCP MITIGATION OPTIONS

From the technology point of view, the most common BC emission reduction measures in the transport sector are achieved by:

– Retrofitting of diesel vehicle [e.g. installation of diesel particulate filter (DPF), diesel oxidation catalyst (DOC)]

– Using soot-free engines

– Switching from diesel to a cleaner fuel (e.g. CNG, LNG)

[11] http://www.ccacoalition.org/en/initiatives/diesel
[12] LDVs in the EU are defined as vehicles having a maximum mass not exceeding 3.5 metric tons and vice versa for HDVs.
[13] http://www.ccacoalition.org/en/resources/diesel-factsheet

A *DOC* is a flow-through device that oxidises carbon monoxide (CO), gaseous hydrocarbons (HCs), and liquid hydrocarbon particles (unburned fuel and oil). DOCs can reduce overall PM mass by 20%-50%. However, a *DPF* is more effective than DOCs in controlling the large number of fine and ultra-fine particles in diesel exhaust, and can lead to reductions of PM of between 85% and 95% (Kleeman, M., Schauer, J., and Cass, G., 2000).

Soot-free engines are defined as any fuel and vehicle combination that meets emission levels for PM set by Euro VI or US 2010 vehicle standards. This can include compressed natural gas or electric-powered buses, alongside other fuel/engine types, including conventional diesel engines (Ray,M., 2015).

In addition, fuel desulphurization or the use of low-sulphur diesel fuel (i.e. through upgrading refineries) contributes significantly to the reduction of BC emission from the vehicles. These technologies are being targeted for both in-fleet and new vehicles. On the programme level, various strategies are presently being taken to reduce BC emissions, such as scrappage, replacement and the retrofitting of older vehicles.

Scrappage programmes are designed to eliminate high-emitting vehicles from the fleet. These typically target older vehicles meeting less stringent emissions standards and operating with degraded pollution control equipment. Usually, these programmes are set up in a way that the owner of a scrapped vehicle must simultaneously purchase a new vehicle complying with more stringent emissions standards and control techniques.

Retrofit programmes (e.g. installation of DPFs, DOCs) are more suitable for vehicles that have some useful life and for which scrappage is not cost-effective. *Retrofitting DPFs on old vehicles is not done at the local level, as from the cost and energy efficiency point of view it does not make economic sense for the user*. DOCs are widely used to comply with Euro 3/III- 4/IV standards and DPFs are used with Euro 5/V-6/VI standards vehicles.

Replacement programmes, for example, feature changing a vehicle's diesel engine with a newer model with stricter emissions control standards, or one that uses cleaner fuel (e.g. Compressed Natural Gas – CNG - engines). Other compliance and maintenance programmes, such as mandatory periodic inspections, vehicle certifications, also play a key role to limit the BC emissions throughout the useful life of the vehicles.

Before implementing any vehicle emission control programme in a particular country, *the vehicle emission standards as well as the fuel standards of that country* need to be assessed**.** If fuel and emission policies are not paired together, countries will not be able to reduce BC emissions significantly. *Therefore, the promulgation of emissions standards together with the availability of low-sulphur fuel is absolutely necessary***.** The most stringent emission standards for LDVs currently in effect are, US Tier 2[14], Japan's New Post Long-Term Standards and Europe's Euro 6, whereas for HDVs, US 2010, Japan's New Post Long-Term Standards and Euro VI are the most stringent. *Emission standards for* $PM_{2.5}$ *(i.e. U.S. 2007/2010 and European Euro 4/IV, Euro 5/V and 6/VI standards) set limits that require particulate filters on diesel vehicles and are effective at reducing BC***.** For instance, Euro 6/VI standards reduce the exhaust emissions of PM by 97% over unregulated levels (ICCT, 2014a).

Fuel standards set limits on the sulphur content of diesel. *To enable the optimal use of the particulate filter, sulphur content of the diesel fuel must be low (≤ 50 ppm)* as reductions in BC become significant at sulphur content of 50 ppm (parts per million) and lower (≤15 ppm or ultra-low-sulphur fuel is recommended for getting optimum performance of the particulate filter) (ICCT, 2014a). .

For Euro 3/III or lower standard vehicles, an alternative path would be to adapt for fuel switching technologies, i.e. a conversion from diesel to CNG. For instance, CNG buses have significantly lower PM and BC emissions than the Euro II/III diesel buses and its BC emission is comparable with Euro VI levels i.e., 10 times lower levels than Euro II standards (World Bank, 2014).

[14] In addition to US Tier 2, US Tier 3 is the most stringent emission limits of any national level LDV regulation in the world to come into effect in 2017-2025 in US.

3.2.3 MARKET ENVIRONMENT

Cleaner vehicle markets are very much driven by the local policies and regulations. Table 9 summarises the *vehicle emissions equivalent to Euro 4/IV or up (i.e. standards that limit PM) and fuel standards (at least 50 ppm or lower)* that are currently adopted for all sales and registrations in selected regions (2014):

Table 9: Emission and fuel standards in selected countries/regions

Country	Emission standards: LVD current	LVD adopted [a]	HVD current	HVD adopted	Fuel standards (Diesel) Sulphur content in ppm: current	adopted
China	China 4	China 5 [b]	China IV	-	350 (50, 10) [c]	10
US	Tier 2	Tier 3	US 2010	-	15	
EU	Euro 6	-	Euro VI	-	10	
Japan	PNLT	-	PNLTES	-	10	
Brazil	L-6	-	P-7	-	500 (10)	
India	Bharat III	Bharat 4 [d]	Bharat III	-	350 (50)	
Russia	Euro 4	Euro 5	Euro IV	Euro V	350	10
Canada	Tier 2	-	US 2010	-	15	
South Korea	Euro 6	-	Euro V	Euro VI	10	
Australia	Core 'Euro 5'	Euro 6	Euro V/US 07	-	10	
Mexico	Tier 1/Euro 3	-	US 04/ Euro IV	-	500 (15)	
Turkey	Euro 4	-	Euro V	-	10	
Chile	Euro 5	-	Euro IV		15	

Euro equivalent (based on limit values)

Euro 3/III	Euro 4/IV	Euro 5/V	Euro 6/VI	Post Euro 6/VI

Source: ICCT (2014a)

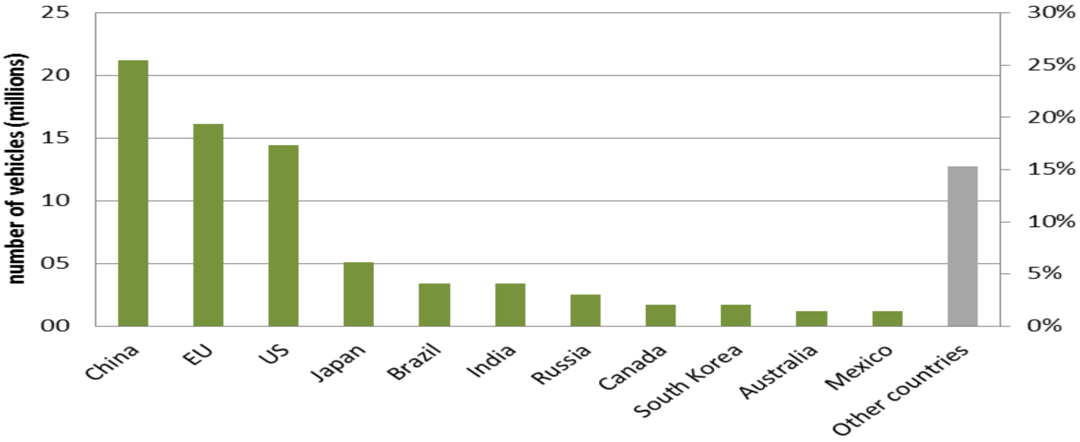
[a] Regulations that are yet to be implemented indicated as 'Adopted'
[b] China 5 has been implemented in Beijing and Shanghai and Guangzhou province
[c] Values in parentheses indicate higher quality fuel is available sub-nationally, but not required nationwide.
[d] As of April 2014, Bharat IV standards were in effect in 33 cities including the national capital region[15]; however, a nationwide implementation date has yet to be formally adopted. In 2014, the Auto Fuel Policy Committee published recommendations for a nationwide roadmap to Bharat VI standards for vehicles and fuels; however, as of August 2014, these recommendations have yet to be officially notified as a government proposal.

In the US, EU and Japan, vehicle emission regulations have accelerated the commercialization of advanced emission control technologies, while the markets offers various incentives for these technologies to become cost-effective. For instance, the most recent Tier 3 LDV regulations in the US yields a benefit of USD 4.5 to USD 13 for every dollar spent on cleaner vehicles and fuel (ICCT, 2014a). The regulatory approaches developed in the US and EU provides a pathway that other countries can follow to improve the environmental performance of their vehicles. The technologies for clean vehicles and fuels necessary to meet the latest regulations are commercially available in the US, EU, and Japan, and can be transferred to other countries that adopt such regulations.

In terms of sales, the total vehicle market is mainly concentrated around 10 countries and the EU region (2013). Together, they represent 85% of total global vehicle sales (2013) (ICCT, 2014a). These markets include China, US, Japan, Brazil, India, Russia, Canada, South Korea, Australia, Mexico and the EU region. LDV markets in US, Canada, EU, Japan, South Korea, and Australia follow the highest emission standards (i.e. equivalent to Euro 6). In 2013, 43% of global new LDV sales (i.e. mainly passenger cars) were subject to Euro 6 standards, and this share could increase to over 80% if such standards are adopted in China, Brazil, India, Russia, and Mexico-the markets that currently follow Euro 4 and Euro 5 standards. Eight countries, namely the US, Canada, China, Japan, Brazil, India, South Korea, Mexico and the EU have adopted policies requiring vehicle manufacturers to improve the energy efficiency of new LDVs.

[15] Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Agra etc.

Figure 1: Total vehicle sales in 2013 worldwide

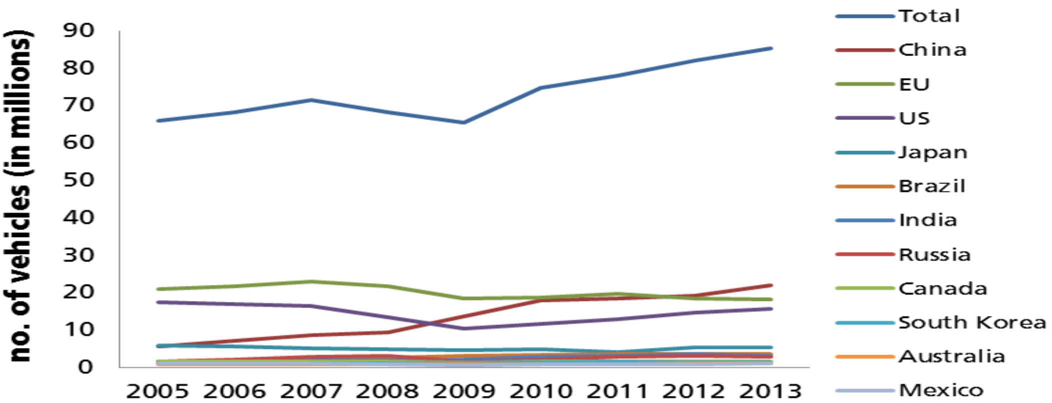


Source: ICCT (2014a), based on OICA (2014)

Figure 1 shows sales of vehicles (LDVs and HDVs) by region in 2013. *The five markets US, Canada, EU, Japan, and South Korea have implemented or adopted the highest emission standards (i.e. equivalent to Euro VI) for HDVs***.** In 2013, 46% of the global vehicle sales (i.e. HDVs and LVDs) were made from these five markets. *That implies, there can be immense scopes for BC emission reductions from the HVDs globally, if the markets, especially the major ones like China, India, Brazil, Russia Australia, opt for the highest fuel and emission standards***.** According to Ray,M., 2015, cities in Brazil, India, China, and Mexico have potential to introduce soot-free diesel engines over the next five years by making ultra-low-sulphur fuels available in these countries.

The Global vehicle market has grown at an average of 3.5% for the last 10 years. China (+18.2%), Brazil (+10.3%), India (+10.7%) and Russia (+6.3%) maintain the highest growths in the vehicle markets. Figure 2 shows historical growth of vehicle markets in some emerging and main vehicle markets:

Figure 2: Annual sales of new vehicles



Source: ICCT (2014a), based on OICA (2014)

According to OICA, the growth of vehicle market in countries like Thailand (Euro III and 4), Indonesia (Euro 2/II), Turkey (Euro 4 and V), Argentina (4/IV), South Africa (Euro 4 and III), and Malaysia (Euro 2/II) are also noticeable, each of which had over half a million new vehicle sales in 2013. Nearly half of new vehicle sales include world-class emission controls (Euro 6/VI), indicating that the need for strong controls on vehicle emissions in emerging and developing economies is increasing as vehicle sales continue to grow (OICA, 2014).

According to IEA, *the share of the natural gas vehicle (NGV) market* in the total sales will rise from current 1% to 5% by 2035 (IEA, 2010). CNG conversion technologies continue to improve; the market for this technology remains a niche, as the current the global share of natural gas in road transportation is still quite limited. *More than 70% of all NGVs and almost half of all fuelling stations are found in only five non-OECD countries: Argentina, Brazil, India, Iran and Pakistan.* Lower fuel tax on natural gas, subsidy policies for CNG conversion and purchase of new CNG vehicles are in place in these countries. According to

IEA's projection for the next 15 years, NGV market is expected to remain strongest in Asia-Pacific and Latin America, while in Europe and North America, the NGV market share is expected to remain limited as now (IEA, 2010).

3.2.4 COMMERCIAL VIABILITY

Any emission control measure is an incremental capital cost on a vehicle. The additional investments may not be always justifiable commercially, in particular if environmental benefits are neglected. Investing in a clean diesel vehicle may not bring any notable fuel reduction benefits, but only environmental benefits like BC reduction. In the same way, retrofitting a diesel vehicle with DPFs will bring positive environmental benefits, which a vehicle owner may not account for. Table 10 shows the costs for HDVs and various emission control technologies.

Table 10: Capital cost for a HDV

Vehicle type	Purchase price (USD)
Baseline diesel[16]	150,000 - 180,000
Clean diesel[17]	158,000 - 188,000
DPF retrofit[18]	5,000 - 8,000
CNG[19]/LNG	172,500 - 207,000
CNG-conversion	15,000 - 30,000
Green freight retrofit[20]	10,000 - 12,000

Source: Default Costs for Bus/Truck Technology Intervention, World Bank (2014)

Since these emission-control initiatives are greatly influenced by policy and local/regional pricing systems for diesel, commercial aspects cannot be generalised on a global level, but should be analysed at the national or local level. The fiscal policies and legal framework conditions are key drivers in the vehicle market to adopt emission reduction measures. When applied emission control measures also lead to fuel cost savings, such measures are even more likely to penetrate the market. For example, the CNG or LNG vehicles can penetrate into the market faster if a differential but favourable fuel price[21] between natural gas and diesel exists in that market. In New Delhi, differential price is about 0.38 USD/litre between diesel and CNG[22]. If we consider the capital cost of CNG bus to be 20% higher than the baseline diesel bus, switching to CNG-with similar/the same engine efficiency of the CNG and diesel bus would bring favourable financial benefits under the assumptions shown in Table 11.

Table 11: Financial analysis of a CNG bus in New Delhi

Distance travelled by Bus	90,000 km/year
Engine efficiency	5.3 km/litre
Fuel consumption	16,981 litres/year
Incremental cost of capital	30,000 USD
Lifetime	10 years
Annual fuel savings	6,406 USD
Payback period	4.7 years
NPV @ 10% discount rate	9,364 USD
IRR	16.9%

Source: Own analysis. The assumptions used in the analysis are derived from IMACS (2013)

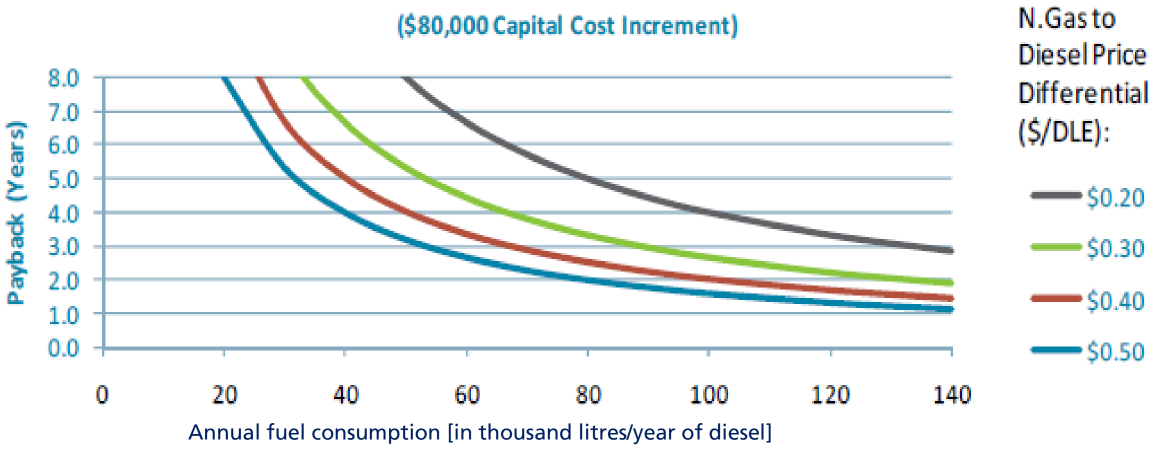
It has to be noted that for a fuel switching intervention, its financial viability would vary largely according to two key factors; capital cost increment (i.e. capital cost of CNG bus is assumed to be 20% higher than the baseline diesel bus and yearly mileage covered by the vehicle (i.e. fuel savings benefits at a given

[16] typical 1998-2001 diesel engine operated on standard diesel fuel
[17] diesel engine compliant with 2007 EPA emission standards (i.e. with DPF)
[18] baseline diesel retrofit with a diesel particulate filter
[19] natural gas engine compliant with 2007 or 2010 EPA emission standards and CNG fuel system
[20] combination of fuel efficiency improvement technologies and diesel particulate filters
[21] End-use fuel prices differ from country to country and particularly, from region to region, as well as a result of different regional pricing systems due to different level of subsidies and/or taxations.
[22] Average diesel price 55.76 INR/litre and CNG 38.15/kg in New Delhi in 2014. Exchange rate 0.016 INR/USD Source: http://www.mypetrolprice.com

differential fuel price between diesel and CNG). Similar analysis from the "Marbek report" (Marbek, 2010) shows that, line haul, transit bus, LDV and marine segments offer attractive returns in the range of 20% (at a discount rate of 10%), provided the existence of a CNG to diesel differential in the market.

Figure 3 shows the financial sensitivity of a line hauler, i.e. how the payback period of a CNG-run line haul varies with annual fuel consumption levels and natural gas to diesel differential price. The payback period for investments in fuel switch for a CNG-run line haul decreases from 4 years to 1 year, when annual mileage or diesel consumption increases from 40,000 thousand litres to 140,000 litres; the payback period increases from 4 years to 7 years when different price between natural gas to diesel reduces from USD 50 cents to USD 30 cents (Marbek, 2010).

Figure 3: Graph: Difference in payback period for investments in fuel switch for a CNG-run line haul as function of annual fuel consumption and gas-to-diesel price ratio



Source: Marbek (2010)

Similarly, improved vehicle efficiency standards[23] for LDVs have proven to be a cost-effective in the US, EU, and China; recent regulations of these countries have resulted in fuel savings that pay off the incremental vehicle costs within 1-5 years (ICCT, 2014a). Payback periods vary by regulatory design, vehicle type, and region-specific activity patterns.

3.2.5 FINANCING AND MAJOR PROGRAMMES

Globally, vehicle financing is done through one of the three ways: financing through, 1) an Original Equipment Manufacturer (OEM) known as 'captive', 2) a commercial bank or 3) an independent finance company. There are two main products used, lease finance and consumer finance, but the market operates through a different business model for each route whilst competing for the same customers.

Table 12: Financing products and services of different vehicle finance groups

Finance group	Financing products and services
OEM captive-- Financing units wholly owned and operated by automotive companies (e.g. Volkswagen Bank GmbH, Mercedes-Benz Bank)	Vehicle finance and leasing for private and corporate customers and dealers ▪ Vehicle finance and leasing packages ▪ Service and insurance products ▪ Fleet management ▪ Inventory financing for dealers ▪ Direct banking (with full banking license), issuance of credit cards
Commercial bank- Standard commercial bank (e.g. HSBC, Bank of China, Deutsche Bank)	Common banking business- dedicated business units for vehicle financing ▪ New car financing ▪ Used car financing ▪ Direct banking, issuance of credit cards

[23] Efficiency standards refer to fuel economy, fuel consumption, or CO2 standards.

Independent finance company, Independent consumer finance or specialised vehicle leasing company (e.g. ADAC, ACF Car Finance)	Consumer financing and leasing ▪ Vehicle finance and leasing ▪ Service and insurance products ▪ Fleet management ▪ Dealer financing

Source: KPMG International (2012)

In mature markets the establishment of the finance and leasing business started in the 1930s, while in emerging markets the business is still fairly nascent, starting only a couple of years ago. Commercial banks are dominating the emerging markets, whereas OEMs or captives are popular in the mature markets. OEMs go beyond the traditional automotive value chain and tap into the banking business to access low cost funding and reach out more customers. Besides offering basic finance and leasing products, OEMs have been increasingly expanding their value chain by offering service products (maintenance/repair, wheel service, insurance, warranty, fuel/service cards) and fleet management (vehicle management, service management, transport management, reporting tools etc.) solutions to their portfolios.

In Germany, OEMs dominate the market for passenger cars (69%), while the truck market is shared equally between OEMs and banks. *In the emerging markets, the picture is quite different. For example, in China over 80% of car loans are provided by domestic banks. Major banks in China that provide car financing include: CITIC Industrial Bank, Industrial and Commercial Bank of China (ICBC), Bank of China and Agricultural Bank of China.* Similarly in India, the financial sector dominates the vehicle financing market by offering vehicle loans. Between 60% and 80% of new cars are purchased through loans. Leasing services are rarely found in India due to users' preference to own a vehicle (KPMG International, 2012).

The choice of financial product (lease or consumer finance) depends on the customer profile (commercial vehicle user or private car user), who consider the total cost of ownership as the primary criteria in the purchase decision. For instance, in Germany 42% of truck users choose vehicle loans, 45% truck users choose leasing and about 15% truck user choose cash purchase (KPMG International, 2012).

In the middle-income markets, the car loan market is saturated due to high competition between different financing groups and constantly increasing popularity in emerging markets. Leasing is an almost untapped business with immense opportunities in the emerging countries like India and China. Demand for additional banking products like insurance, maintenance and fleet services are also growing in emerging markets.

In countries with vehicle emission control programmes, mandatory regulation is often supplemented by fiscal incentives, tax benefits offered by the state to encourage vehicle owners to opt for high standard vehicles. A number of in country fleet programmes in the developing countries are described below:

- **Brazil** implemented the "Inovar-Auto" programme in 2013, a fiscal instrument that offer 30% reduction in vehicle sales tax, in order to incentivise passenger car makers and light commercial vehicles to improve new fleet efficiency at least by 12% between 2013 and 2017 (ICCT, February 2013).
- **China** offers various fiscal incentives ("market-pull" measures) to complement mandatory vehicle efficiency standards. China provides RMB 3,000 (US D 490) energy-saving car subsidy, a direct deduction from the vehicle sales price, for the early implementation of China 5 (Euro 5) standards[24] in the light-duty vehicle category. To qualify for the subsidy, the Corporate Average Fuel Consumption (CAFC)[25] limit values must stay within 6.9 L/100 km, a further 2% to 14% fuel savings in different weight classes from the current levels. Though subsidy is determined by the fuel consumption criteria (i.e. not by emission reduction criteria), early adoption to China 5 standards vehicles would naturally bring PM reduction benefits (ICCT, November 2013).
- **India's** "NGV development programme" has been quite successful. Over the last decade the programme has been introduced in around 30 cities. More than 1 million NGVs ply on the roads today in India, including buses, three wheelers, taxis and small commercial vehicles. The 30 cities are mostly located in two states: Maharashtra and Gujarat. Among them Delhi, Mumbai, Pune, Vadodara, Surat

[24] Implementation period of China 5/Euro 5 standards for light-duty vehicles starts from 2018.
[25] The Corporate Average Fuel Consumption (CAFC) is a metric that describes the average fuel consumption of all cars produced by a manufacturer in China.

have the most developed NGV markets in terms of number of fleets and refuelling stations. Initially, NGV development was driven by public policy as well as a price differential between petrol and CNG that drove commercial interest from the owners of the fleets. Individual state government, like Delhi, offer various fiscal incentives to help stimulate growth of NGVs that include lower the interest rates of loans for the purchase of CNG vehicles, VAT subsidies to replace old diesel vehicles by CNG and exemption from sales tax and taxation on diesel fuel in order to fund clean transportation subsidies (IEA, 2010).

– Mexico's Transport and Treasury Ministry launched the Programmea de Modernización del Autotransporte de Carga y Pasaje (Programme to Modernise Federal Road Transportation) in 2003 with the objective of renewing the federal freight and bus fleets. Currently, truck owners with vehicles over ten years in age can exchange their old vehicle for a down payment or reduced costs for the purchase of a new, or semi-new (less than 5 years old), vehicle. The owner receives 15% of the cost of the replacement vehicle, or one-time bonus (USD 6,200- USD 12,400), depending on the vehicle categories. By January 2012, the programme had resulted in the scrappage of 20,974 old vehicles. These old vehicles are mainly operated by small, family businesses, which represent 29% of the federal freight and bus fleets and 83% of all transport businesses. The programme has been complemented with National Financing through NAFIN, the Mexican development bank, through which vehicle owners have the option to pay for the replacement vehicle in 1-5 years, have guaranties of credit worth 1.5 times the price of the replacement vehicle and get preferential interest rates. However, the replacement programme has been slow to pick up due difficulties in achieving access to credit especially in the smaller family operated businesses, low incentives to scrap and replace the fleets due to non-mandatory emission norms. The main accomplishment of this programme is many new replacement vehicles now comply with Euro IV emission standards. According to the estimation by the National Institute of Ecology and Climate Change, between 2004 and 2010 the old fleet replacements have resulted in a reduction of 7,543 tons of PM2.5 (ICCT, March 2015).

– **Chile** started the *Cambia tu Camión'* (Swap Your Truck) programme in 2009, targeting the renewal of trucks that have been in service for more than 25 years. The programme was aimed at micro and small business owners with revenues below a minimum threshold of USD 25,000 per year. The programme provided a buy-down grant or subsidy for the scrappage of old vehicles or replacement with a new vehicle (Euro III equivalent). The subsidy amount of between USD 8,000-USD 24,000 was dependent on the gross vehicle weight (GVW)[26]. The subsidy represented 1.2-2.0 times the resale value of the old truck, and about one third of the price of the new one. To qualify for the subsidy, the vehicle owner had to provide proof of a pre-approved loan from a FI for the remainder of the replacement vehicle price. Although the programme led to the removal of only around 5% of the pre-1984 trucks in the country it however made significant improvements in the reduction of PM and CO2, leading directly to the reduction of PM emissions by 84% and more than 100,000 tonnes of CO2 (ICCT, March 2015).

Multi-city and country programmes of the CCAC

Leveraging public policy supports, the project aims to engage vehicle manufacturers, bus operators, and seek their commitments to procure soot free engines, matched with respective country's fuel standards within next 3 years. Successful transitions toward soot-free bus fleets in 20 megacities will prevent 3,700 premature deaths and up to 6.6 MMT CO2e by 2030 in the region of 234 million people (Ray, M., 2015). Few cities have already taken the/a procurement plan: Sao Paulo has a plan to introduce 15,000 buses from now until 2020; Santiago is starting a similar process with 6,000 buses; and Bogotá is going to introduce 1,800 buses by 2016. New investments in Bus Rapid Transit are underway in Addis Ababa, Buenos Aires, Daar es Salaam, Johannesburg, and many other cities (Ray, M., 2015). Similarly, The International Council on Clean Transportation (ICCT) with UNEP, the C40 Cities Climate Leadership Group and the Centro Mario Molina-Chile are undertaking a two year project beginning in 2015 to secure commitments from city officials to procure soot-free urban buses with the aim of accelerating a shift toward soot-free urban bus fleets around the world. This project will undertake activities that encourage shifts to soot-free engines in

[26] Subsidy amount according to the GVW: 3.86 ton < GVW< 9 ton: USD 8,000; 9 ton < GVW < 17 ton: USD 16,000, and GVW> 17 ton: USD 24,000 (ICCT, March 2015)

cities with a population of three million or larger. This reflects at least 115 cities globally, who will be called upon in regional public meetings, online and other coordinated outreach with member nations of the CCAC to shift all new bus purchases to engines that achieve the lowest technically feasible BC emissions matched by current fuel quality, and to make a public commitment to shift all new bus purchases to soot-free engines by a target date selected by the city (Ray, M., 2015).

The CCAC has been providing policy and capacity building supports to the East Africa Community (EAC) - Kenya, Tanzania, Uganda, and Burundi. These countries have moved forward to adopt regional low-sulphur fuel policies (50 ppm for diesel) in the HDV sectors[27]. With help of CCAC, further capacity building efforts are on-going in these countries to implement low-sulphur fuel policies having an ultimate goal of supporting their future emission control programmes.

3.2.6 BARRIERS[28]

- **Policy barriers:** Developing countries face a number of challenges to implement diesel emission control policies. Unlike the OECD countries, most developing countries are yet to adopt vehicle efficiency standards or on the pathway to adopt the highest vehicle standards. The availability of low-sulphur fuel at the regional/local level is also an impediment in developing countries. By way of example, it took 4-6 years for US, EU, Japan to achieve the refinery upgrades needed to create the capacity to supply low sulphur 50 ppm fuel nationwide or continent-wide.
- **Higher upfront costs and financing barriers:** Upgrading to higher vehicle standards require higher upfront costs, and to some extent higher maintenance costs. On top of that, a lack of adequate fiscal incentives, financing options and non-mandatory regulations, also impede market development. Even though vehicle financing in the form of lease finance and consumer finance is a quite established loan product globally, yet, FIs lack the experiences and know-how concerning financing to new energy efficient vehicles or, retrofit with advanced control emission or engine calibration techniques.
- **Infrastructure barriers:** Investment in refineries is essential to produce low sulphur diesel at the national level[29]. A lack of refuelling infrastructure also holds back the greater use of CNG in vehicles. There are about 17,000 fuelling stations for NGVs worldwide. Over half of these are located in just five countries: Argentina, Brazil, India, Iran and Pakistan. NGVs have been underutilised in the HDVs; so far NGV market mainly grew for the LVDs (i.e. cars, taxis, three-wheelers) and transit buses. The reasons for this vary from insufficient willingness to change the status quo, minor price differentials between diesel and natural gas, low availability of NGV models and, as previously explained, the lack of refuelling infrastructure.
- **Technology and knowledge barriers:** Unlike the OECD nations, the advanced emission control technologies remain niche in the developing countries. The countries that have adopted, or are on the pathway to adopt vehicle and fuel standards, also have little experience in advanced/technology-based emission control techniques. The private and public stakeholders therefore need to build their institutional capacities in order to implement higher vehicle and fuel standards, improve after sales service, develop supply chain and strengthen their vehicle inspection and compliance programmes. Practices in OECD nations in particular provide lessons for developing countries to address these problems through transfer of knowledge and technologies at the local level.

[27] http://www.unep.org/Transport/PCFV/regions/EA_lowsulphur.asp

[28] Source: Own analysis based on World Bank (2014), IEA (2010)

[29] Refinery upgrade costs for fuel desulfurization is about USD 0.01-0.02 per litre per 100 ppm sulphur reduction (World Bank, 2014).

3.2.7 WAY-FORWARD FOR SLCP FIF

As far as vehicle financing is concerned, financial market already exists in both the developed and emerging economy countries. There is however a lack of awareness within finance industry, especially in the emerging countries, about less polluting vehicles (e.g. Euro VI/6), a market that can be opened up by offering vehicle financing loan products that could make up of a blend of existing vehicle financing loan for less polluting vehicles. However, *it is very unlikely that an emission control programme can be implemented by the commercial banks alone. Regulatory interventions, both vehicle standards and low-sulphur fuel standards (at least Euro IV/4 vehicle standards, and 50 ppm or lower sulphur content fuel standards)* are absolutely necessary to stimulate the transport sector to adopt the advanced emission reduction processes that can reduce BC from fleets. The availability of low-sulphur fuel is a key bottleneck for implementing emission control programmes by introducing soot-free engines in the developing countries. Furthermore, the investment required for refinery upgrades can be quite large and may require funding from multilateral development banks/donors, as these types of large scale financing are within the capacity of the very few local commercial banks. With steady growth in diesel vehicle globally, it is important to share the experiences, lessons, and approaches for reducing diesel emissions from the countries that have already implemented world class emission standards to the countries that have adopted or are on the pathway to adopting better emission standards. The developing countries can benefit from the expertise of environmental agencies such as United States Environmental Protection Agency and EMBARQ, who provide regulatory and capacity building supports to the transport sector regulators.

Some emerging economies like India (in selected cities), China (in selected cities), Brazil, Mexico and Chile have already established emission control programmes at the city level that can be scaled up at the national levels. Though these countries have adopted better or world-class low-sulphur fuel standards and fiscal policies, its implementation plan needs to be supported by making technologies, such as soot-free engines (Euro VI/US 2010 vehicle standards), available to the local market. The finance initiative may also support the global vehicle emission control programs such as CCAC's soot-free urban bus fleets project that targeted urban bus fleets of the 20 major cities across Latin America, Africa and Asia for transition to soot-free engines. The finance initiative can support these countries in designing cost-effective emission reduction programmes (e.g. scrappage/replacement programme), tailored to the need of the local markets. This will require involvement from local government, transport authority, vehicle manufacturers, fleet operators and financiers. In these countries, commercial banks' interest in financing environmentally friendly fleet programmes may depend on the fleet operator's business model and their ownership structure (e.g. public/private). The finance initiative could also address the issue of the financing gap for higher vehicle standards by investigating potential financial instruments and financial incentives available in these countries.

In many countries, fiscal policies have been proven to be an effective tool to complement mandatory regulatory requirements of the emission control programmes. The finance initiative can also help commercial banks leverage local fiscal policies to address the financing needs of the low-carbon transport sector.

Besides the countries mentioned above, environmentally friendly vehicle markets are being developed in other emerging economics, especially in Asia-Pacific, Latin America, Central Asia and Africa. *Thailand, Indonesia, Malaysia, South Africa and Argentina are few examples of the countries that need to strengthen their transport policies, vehicle and/or fuel standards, and advanced emission control technologies, yet, the existing fuel and emission policies of these countries are inadequate for the implementation of a vehicle emission control programme immediately*[30].

[30] Own analysis based on ICCT 2014a and ICCT 2014b

3.3 COOKSTOVES

SUMMARY

- Globally, around three billion people lack access to clean and efficient cooking options. As a result an estimated 4.3 million premature deaths annually are due exposure from smoke from open fires and traditional cookstoves.
- Clean cookstoves can be broadly divided into three main categories: electric cookstoves, cookstoves based on clean fuels (biogas, ethanol, solar cooker, LPG), and efficient biomass cookstoves with cleaner combustion techniques (e.g. forced draft improved biomass stove).
- There is significant market opportunity for clean and efficient cookstove technologies. The Alliance for Clean Cookstoves is trying to facilitate the adoption of clean and efficient cookstove solutions in 100 million households by 2020.
- Typically the financial payback period of improved cookstoves is short. The payback period for an efficient biomass cookstove is between 1 to 5 months and for a domestic biogas plant for cooking is just a few years. However, the payback period may vary largely depending on local factors, such as available fuel and cookstove subsidies.
- Cookstove demand is influenced by many factors, including reduced fuel consumption, reduced cooking time, affordable price and product design. Customers' willingness to adopt or ability to pay for cleaner cooking options is vital in disseminating clean cookstoves.
- Globally, grants are the most common funding source for the cookstove market. Due to the advancement in public-private partnerships in the cookstove market other innovative financing mechanisms are increasingly being applied. There is also the potential to introduce results-based financing in the clean cookstove sector by providing payments against measured climate and health benefits.
- Demand for clean and efficient cookstoves is depressed by high upfront cost and limited availability of financing. Micro-finance or instalment payment facilities can be extended by local MFIs/banks for relatively more expensive or larger capacity clean cookstoves used commercially.
- Access to capital in the manufacturing and distribution level is vital for scaling up distribution of clean cookstoves. Many local manufacturers have been increasingly producing cookstoves commercially, but distribution of these stoves at an affordable cost remains a challenge. Designers and manufacturers lack adequate capital for research & development (R&D) to design and develop clean cookstoves as required at the local level.
- End-users are largely unaware about the health, environmental and financial benefits of clean cookstoves. Manufacturers are unfamiliar with the standards and testing protocols for evaluating BC emission reductions potential of the clean cookstoves. For optimum BC reductions from clean cookstoves, ISO 'tier' standards need to be promoted at the local level and the fuel supply chain needs to be strengthened.
- The availability and low price of traditional/ basic biomass cookstoves can threaten the sustainability of clean cookstove adoption. Subsides on fuels such as kerosene, as well as on basic cookstoves can have a strong effect on the demand of clean cookstoves.
- To encourage private financing to flow into the clean cookstove sector, it is necessary to increase the demand of clean cookstoves at the end-user level by creating awareness about health, environmental and financial benefits. It is also necessary to provide technical support for design, marketing and testing of clean cookstoves at the manufacturing and distribution level.
- To increase affordability at the end-user level and increase supply capacity, innovative financing mechanisms need to be created that engage on both the demand and supply sides.

3.3.1 BASIC SECTOR INFORMATION

Globally, domestic cookstoves are a major source of BC emissions, one of the major SLCPs. Nearly three billion people or 500 million households around the world burn wood, charcoal and animal dung in open fires or in inefficient stoves for daily cooking. The inefficient cooking and heat are responsible for significant GHG emissions, whilst the demand for fuel wood puts the global forest resources under tremendous pressure. In addition, prolonged exposure to BC in the form of smoke from indoor cooking can also causes respiratory diseases, threatening the health rural people, particularly women and children who have the highest exposure. About 4.3 million premature deaths annually are attributed to exposure to smoke from open fires and traditional cookstoves.

Residential solid fuel burning accounts for 25% of global BC emissions. This is about 84% of which is from households in developing countries. In South Asia, inefficient cookstoves are responsible for more than half of total BC emissions[31].

With a vision to provide rural households with affordable and environmentally friendly cooking solutions, public and private institutions have been working in the improved cookstove sector for more than five decades. In the beginning, the improved cookstove dissemination programmes were mainly the responsibility of development organizations and NGOs with help of various development aids. With the advancement of the sector, private-public partnerships have taken place creating more opportunities for adapting business-oriented approaches in the cookstove sector. More recently, new technologies have emerged from the basic energy efficient stoves to modern fuel and even smoke-free/smokeless stoves, which have had considerable impact in the reduction of BC emission. With cookstove distribution programmes expanded in different parts of the world, a handful of project developers, cookstove manufacturers, distributors, and suppliers have become engaged in the businesses in different roles and capacities.

Beyond the business-as-usual ‘capital buy-down’ grants for cookstoves, various other modes of financing such as indirect subsidies, carbon finance, end-user finance and working capital, etc., are now available at end-user and entrepreneur level, which are expected to accelerate the growth of the sector. For instance, The *Global Alliance for Clean Cookstoves (the Alliance)* is working to bring private-public partnership in clean cookstove business and enable better business opportunities for the private players. With collaboration from more than 1,000 partners from the public, private and non-profit sectors, 46 national governments, 12 UN agencies, various NGOs and foundations across six continents the Alliance has set a goal to support the adoption of clean and efficient cookstoves and fuels in *100 million households by 2020. Yet there are challenges in the widespread dissemination, adoption and scale-up of cookstoves* across all income groups of people living in the rural areas.

3.3.2 SLCP MITIGATION OPTIONS

According to the World Bank (2013), the term ‘traditional stove’ refers to a rudimentary baseline stove (either traditional three-stone open fire’, or constructed by artisans or household members) that is energy inefficient with poor combustion features. ‘Clean cookstove’ refers to a stove that, with the benefits of laboratory research, performs better in fuel efficiency, emissions, durability and safety than open fires or rudimentary traditional cookstoves. Depending on the fuel availability, the traditional stove users normally use low-grade fuels such as agricultural residues, firewood, dung, etc., often which can be collected free of cost.

Clean cookstoves can be broadly divided into three main categories (Differ 2012a)**:** *i) electric cookstoves, ii) cookstoves based on clean fuels, such as, biogas, ethanol, solar cooker, LPG, and iii) more efficient biomass cookstoves with improved combustion features.* Clean cookstove reduces both fuel consumption and improve indoor air quality, by reducing emissions, which in turn reduces the incidence of respiratory diseases, especially for women and children.

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[31] Global Alliance for Clean Cook Stoves: http://cleancookstoves.org/impact-areas/environment/

Due to the high purchase costs and limited rural availability electric cookstove might be less relevant in the developing world. The cookstoves based on clean fuels are also offering a large improvement in performance compared to traditional stoves or cooking on an open fire. However, these technologies are less available in rural areas and more popular in the urban areas due to their higher affordability. Biomass[32] cookstoves, with improved combustion technology are the most widely used technology in the rural areas in terms of both availability and price. Processing biomass into compact, evenly sized pieces, such as pellets or briquettes can improve the burning efficiency of the cookstove. Table 13 shows a non-exhaustive comparison of efficiency, price, durability of different technology types.

Table 13: Overview on key parameters of different cook stove technologies

Cookstove	Electric stove	Clean fuel stove	Efficient biomass stove	Traditional stove (3-stone fire)
Thermal efficiency	>50%	40-50%	25-40%	5-10%
Price (USD)	40-100	20-100+	10-100	0-3
Durability (years)	2-3	2-3	2-10	0
Customers	Mostly Urban	Mostly Urban	Rural/Urban	Rural

Source: Own analysis. Data were analysed from the Clean cooking catalogue of the Alliance at http://catalog.cleancookstoves.org/stoves?search=r and Differ (2012a)

According to Differ (2012a), price and durability of efficient biomass stove varies considerably according to the design, performance and the materials used. Average retail price of a biogas stove, made of metal and plastics and manufactured in the factory, is about USD 30, which is relatively high. The durability of these manufactured stoves ranges from 2 to 5 years. On the other hand, production cost of locally produced biomass stove that are made of locally available materials such as ceramics, clay and bricks, is usually lower than the factory manufactured stove. The price of these biomass stoves varies depending on the design. The lifespan of locally produced cookstoves with permanent fitted chimneys varies between one to 10 years. In India the price of an improved cookstoves with a thermal efficiency of 25%-31% range from INR 750 to INR 2000 (USD 12 to USD 33), depending on the design (GIZ GmbH, 2014).

Not all efficient stoves are smoke-free or less polluting. Some stoves are quite effective at reducing BC emissions. The forced draft biomass stove can be mentioned here specifically, as this stove has the potential to reduce BCs significantly. One limitation of promoting this technology is that it requires electricity or battery backup for forced air circulation inside the stove which may not be available in all rural areas. Based on the data obtained from The Energy and Resources Institute (TERI), India, the key features of a forced draft biomass stove are shown in Table 14.

Table: 14 Key parameters of forced draft biomass cook stove

Model	Thermal efficiency	Reduction in PM	Reduction in CO	Reduction in BC
Forced draft	30-40%	42-55%	31-48%	49-85%

Source: TERI (2012)

To standardise clean cooking options with significant health and environmental benefits, the Alliance has developed a set of definitions for “clean” and “efficient” stoves. These definitions are aligned with the ‘Interim Tiered Performance Guidelines’ of the International Organization for Standardization (ISO)[33]. This guideline is yet to be finalised, but the interim guidelines provide a common and easy-to-understand terminology for governments, donors, investors, and consumers to make decisions on the various technology options. Table 15 shows the ISO ratings for cookstoves on four indicators: efficiency, indoor emissions, total emissions and safety. Emission and efficiency ratings are associated with the water-boiling test. The

[32] Biomass refers to all organic matter derived from living or recently living organisms, plant and animal-based. Wood is the most common form of biomass used for cooking. Other forms of biomass are sometimes not as convenient to burn, such as sawdust, charcoal dust, grass, urban waste wood, and agricultural residues.

[33] The ISO, namely the ISO Technical Committee 285, is the key body that develops and approves clean cooking standards In the ISO technical committee, Kenya’s Bureau of Standards (KEBS) and the US’ American National Standards Institute (ANSI) serve as co-secretariats of the committee, comprised of other participating national committees and approved external liaisons, and a representative from the Alliance as the Committee’s Chairperson.

cookstove performance indicators are rated on a scale of five tiers, with 0: the lowest to 4: the highest performing.

Table 15: ISO tiers of performance parameters for cookstove

Tiers (level) of perfor-mance	Emissions CO		Emissions PM2.5		Indoor emissions		Efficiency/fuel use		Safety
	High Power CO g/MJd	Low power CO g/min/L	High Power PM mg/ MJd	Low power PM mg/ min/L	CO g/min	PM2.5 mg/min	High power thermal efficien-cy %	Low power Specific consumpt-ion MJ/min/L	Scale 0-100
Tier 0	>16	> 0.2	> 979	>8	>0.97	>40	<15	>0.05	<45
Tier 1	≤ 16	≤ 0.2	≤ 979	≤ 8	≤ 0.97	≤ 40	≥15	≤ 0.05	≥45
Tier 2	≤ 11	≤ 0.13	≤ 386	≤ 4	≤ 0.62	≤ 17	≥25	≤ 0.04	≥75
Tier 3	≤ 9	≤ 0.1	≤ 168	≤ 2	≤ 0.49	≤ 8	≥35	≤ 0.03	≥88
Tier 4	≤ 8	≤ 0.09	≤ 41	≤ 1	≤ 0.42	≤ 2	≥45	≤ 0.02	≥95

Note: (g/MJd= grams per mega joule delivered to pot; g/MJd= milligrams per mega joule delivered to pot; high power refers to operation of a stove at maximum (or nearly maximum) rate of energy use; low power refers to operation of a stove at minimum (or nearly minimum) rate of energy use. Tier boundaries are defined by quantitative values determined by laboratory testing. Tier 0 is not equivalent to the performance of a traditional stove, as some improved stoves can have tier 0 performance.

Source: Alliance, accessible online at http://cleancookstoves.org/about/news/01-01-1990-iwa-tiers-of-performance.html

Stoves and fuels that meet tier 2 or higher for efficiency are considered as 'efficient'; stoves/fuels that meet tier 3 for indoor emissions or higher are considered 'clean', as it relates to potential health impacts; and stoves/fuels that meet tier 3 for overall emissions or higher are considered clean, as it relates to environmental impacts.

According to the ISO, the tier indicators give the flexibility for governments and organizations to achieve desired performance of the cookstoves. For example, a stove might be tier 2 for efficiency, tier 3 for indoor emissions, tier 2 for total emissions, and tier 4 for safety. By following these criteria, the 'clean' cookstoves meeting at least tier 3 performances can be promoted, so as to reduce indoor pollutants. Besides electric and clean fuel cookstoves, advanced biomass stoves such as forced draft biomass stoves could in principal meet these performance criteria; however any particular cookstove model would require testing at field and/or laboratory level.

3.3.3 MARKET ENVIRONMENT

Nearly three billion people lack access to clean and efficient cooking options, of which nearly two billion are based in Asia, 657 million in Africa, and 85 million in Latin America. These people still depend on biomass as their main source of energy, burning mostly charcoal or wood for cooking. However, in spite of the vast market size, these potential customers are located at the "bottom of the pyramid", making them relatively unattractive for private companies (Differ, 2012a and Differ, 2012b).

In the past cook stoves were distributed as development aid by the development aid organizations, NGOs and charities. International aid organisations and NGOs have been active in the distribution of cookstoves since the 1970s, and millions of cookstoves were distributed for example, in Sub-Saharan Africa during the 1970s-1980s. However, the large numbers of cookstoves distributed during this 'first wave' of cookstove projects were the result of international and domestic aid programmes, with no intention to develop a commercial market for cookstoves (Differ, 2012b).

However, the cookstove industry is becoming increasingly market driven. Designers of cookstoves therefore take into account customer needs and preferences as needed to fit into the local conditions. Public-private partnerships are increasingly taking place in the cookstove sector. For instance, The Global Alliance for Clean Cookstoves (the Alliance) is working to bring private-public partnership in clean and efficient cookstove markets and enable better business opportunities for private enterprises. Still, the cookstove market is not fully commercialised at present (Differ, 2012a). Associated enterprises require soft loan or grant supports to scale up production of cookstoves. Many end-users require capital buy-down grant to enable them to purchase cookstoves at affordable price (see further details in financing and major programmes section). Although many local manufacturers have been increasingly producing cookstoves commercially, distribution of these stoves at an affordable cost remains a challenge

In spite of this there are a number of successful examples of commercial stove production and distribution, for example:

- 'Ugastove' a brand efficient cookstoves manufactured in Uganda manufactures and distributes in the region of 9,000 Ugastoves every month with additional payments received from carbon revenues (Nicholson and Beevers, 2013 and Rehema, 2013);
- The Kenya Ceremic Jico (KCJ) charcoal stove, developed by the Kenya Energy and Environment Organisation (KENGO) manufactures around 13,000 each month. While avoiding direct subsidies for KCJ stoves in Kenya, a number of organisations provide training, outreach services, publicity, and logistical support for the local commercial industry (Kammen, 2000).

According to Kameen (2000), support for stove programmes need not take the form of direct subsidies, partnerships between institutional groups, including NGOs and international organisations, involved in R&D, promotion, and training can also support commercial producers and sellers if co-operation are planned and developed. The Alliance strongly supports this market-based approach that aims to bring together public and private sectors by creating an enabling clean cookstove and fuel market.

The Global Alliance for Clean Cookstoves (the Alliance)[34]

The Alliance was launched in 2010 with the goal to drive the adoption of clean and/or efficient cookstoves in 100 million households by 2020. The Alliance has brought together more than 1,000 partners from the public, private and non-profit sectors to accelerate the market for clean cooking solutions. It works with 46 national governments, 12 UN agencies, hundreds of NGOs and scores of foundations across six continents.

To date, the Alliance has helped the adoption of more than 25 million clean and/or efficient cookstoves. The Alliance has been mobilising global investment in the clean cooking sector. Between 2010 and 2015, the Alliance has brought more than USD 400 million investment pledges for the widespread adoption of clean and efficient cookstoves and fuels. Ultimately by 2020, the Alliance aims to establish a thriving and sustainable global market for clean cookstoves and fuels by replicating successful market enabling activities across many impacted countries.

In 2012, about 8.2 million clean and efficient stoves were disseminated in 59 countries by the Alliance partners (Global Alliance for Clean Cookstoves, 2013a). The actual sales figure is considerably higher if dissemination activities by the Non-Alliance partners are also accounted for. Sales are mainly concentrated in 59 countries in Africa, Asia and Latin America. *Africa leads the market with 52% of total sales, followed by Asia (45%) and Latin America (2%).*

Between 2006 and 2012, stove distribution grew at an average rate of 74% annually. Cookstoves are now being manufactured in about 50 countries. *Africa as a regional manufacturer produces the largest number of stoves (4.8 million in 2012), 78% of which originated in Ethiopia and Kenya***.** Asia accounts for 4.3 million stoves. China is the world's single largest country in stove manufacturing, producing 77% of the stoves manufactured in Asia (4.3 million stoves in 2012 exporting 34% to some 23 countries across the globe (Global Alliance for Clean Cookstoves 2013a).

*70-80% of disseminated stoves are biomass/charcoal stoves; the remainder is composed of LPG, alcohol, and biogas***.** While the type of stoves and fuels produced and distributed vary by region, *rocket stoves are the most favoured technology among the end-users, about 4.2 million rocket stoves were manufactured in 2012, more than 50% of the total stoves manufactured***.** According to the Alliance, in 2012, 64% of the stoves were disseminated in the urban/peri-urban/slum areas, 32% in rural areas and 1%

[34] Source: www.cleancookstoves.org/

in humanitarian settings (e.g. UN humanitarian shelters). *Poor and low-income consumers in urban or peri-urban areas are the most commonly targeted end-users* followed by users within other income brackets in urban and rural areas (Global Alliance for Clean Cookstoves 2013a).

In terms of market penetration Africa and Asia leads the cookstove market, followed by Latin America. The Alliance has identified 87 countries with at least 25% of solid fuel use. The Alliance has prioritised 8 countries - *Bangladesh, China, Ghana, Guatemala, India, Kenya, Nigeria, and Uganda* - for widespread adoption of clean and efficient cookstoves by 2017. While prioritizing the countries, it has considered the market size, impact, market maturity, innovation, need, and partner commitment (Global Alliance for Clean Cookstoves 2014c*). Within these these eight countries alone, roughly 76% of the population relies on solid fuels for cooking, whilst 1.75 billion people are affected by household air pollution that causes the premature deaths of 2.25 million people each year.*

Besides the eight countries prioritised by the Alliance, other countries with significant market potential for clean and efficient cookstoves could be *Cambodia, Vietnam, Nepal, Indonesia, Philippines, Pakistan, Ethiopia, Tanzania, Rwanda, and Mozambique***.** These countries demonstrate good market potential in terms of the high proportion of cookstove users by population; about 50% of the population in each country depends on solid fuels, and the high incidence of respiratory health impacts; 500 million people are affected by household air pollution resulting in an approximate 500,000 deaths each year.[35]

3.3.4 COMMERCIAL VIABILITY

Customers' willingness to adopt or ability to pay for cleaner cooking options is vital in disseminating clean cookstoves. The increased socio-economic benefits such as *reduced fuel consumption, reduced cooking time, affordable price, design and comfort aspects,* determine the saleability of clean cookstove.

The section provides a financial and economic analysis of two types of stoves: efficient biomass stove and domestic biogas cooking system[36] (with construction of a biogas plant). These two stoves were selected considering two different clean cooking practices; the efficient biomass stove represents cleaner combustion process in cooking, while the domestic biogas based cooking system represents use of alternative/clean fuel in cooking.

Efficient biomass cookstove

In Uganda, a very commonly used wood-burning efficient stove is Ugastove. Typically the financial payback period of efficient biomass cookstove is between 1 to 5 months for households in the rural areas (Nicholson and Beevers, 2013); if environmental benefits and shadow costs i.e. opportunity costs of time invested for fuel collection are accounted[37], economic payback period will be even shorter. As an example the financial analysis of an efficient biomass stove 'Ugastove' is presented in Table 16.

Table 16: Financial analysis of an efficient biomass (wood burning) stove in Uganda[38]

Wood burning stove	Assumptions
Fuel	Fuel wood
Lifespan	3 years
Fuel reduction	60%
Retail price (without carbon revenue)	12 USD
Savings potential	
Annual fuel consumption/household (HH)	3,000 kg/year
Annual fuel wood savings/HH with Ugastove	1,200 kg/year
Price of fuel wood	USD 0.044/kg
Annual Savings	USD 53

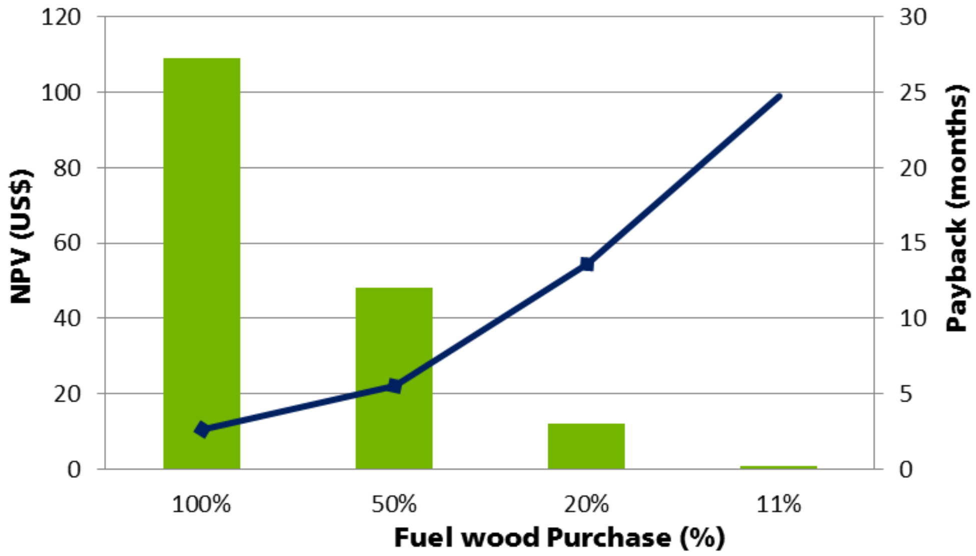
[35] Source: The Alliance, http://cleancookstoves.org/country-profiles/focus-countries/index.html
[36] Biogas, mainly composed of methane (60-70%) and carbon dioxide (30-40%), is a combustible gas produced by anaerobic fermentation of organic materials by the action of methanogenic bacteria.
[37] Collecting fuel can take up to 5 hours per day and women and girls spend another 3 hours per day preparing meals.
[38] http://catalog.cleancookstoves.org/#/stoves

Financial analysis	
NPV (at 15% discount rate)	USD 109
FIRR	437%
Payback	~2.7 months

Source: Own analysis. The assumptions used in the analysis are derived from Nicholson and Beevers, 2013

From the financial analysis, it can be seen that the efficient biomass stove gives very high IRR (due to high fuel wood savings potential over the 3 years lifetime of the cook stove) compared to the returns in private investments. However, the analysis above considered the fuel wood consumed by a household in every year is fully purchased. As in rural areas, fuel wood is often collected free of cost, neglecting the commercial value of the fuel wood would and thus resulting in negative NPV for the efficient biomass stove. The figure 4 and table 17 presents the sensitivity between NPV, payback period and percentage of fuel wood purchased by a household for an efficient biomass stove:

Figure 4: NPV and payback period with different fuel wood purchase ratios for the efficient biomass (wood burning) stove



Source: Own analysis based on assumptions used in Nicholson and Beevers, (2013)

The Figure 4 indicates that the NPV for the efficient biomass stove becomes zero if just 10% of the total fuel wood consumption is purchased and the rest is collected free of cost. The payback period also increases when avoided fuel cost is reduced from 100% to 11%.

Table 17: Sensitivity analysis of fuel costs savings, NPV and payback period with different fuel wood purchase ratios

Share of fuel wood purchase	100%	50%	20%	11%
Annual fuel wood savings (USD)	53	26	11	6
NPV at 15% discount rate (USD)	109	48	12	1
Payback (months)	2.7	5.5	13.6	24.8

Source: Own analysis.

Biogas based cooking system (with construction of a biogas plant)

In Nepal, biogas based cooking practices are common. The cost of a 4m3 biogas plant[39] with stove is about USD 436 and has a lifetime of 20 years. The table 18 presents the assumptions used for the financial analysis of a biogas stove with construction of a biogas plant.

Table 18: Financial / Economic analysis of a domestic biogas cooking system (with construction of a biogas plant) in Nepal

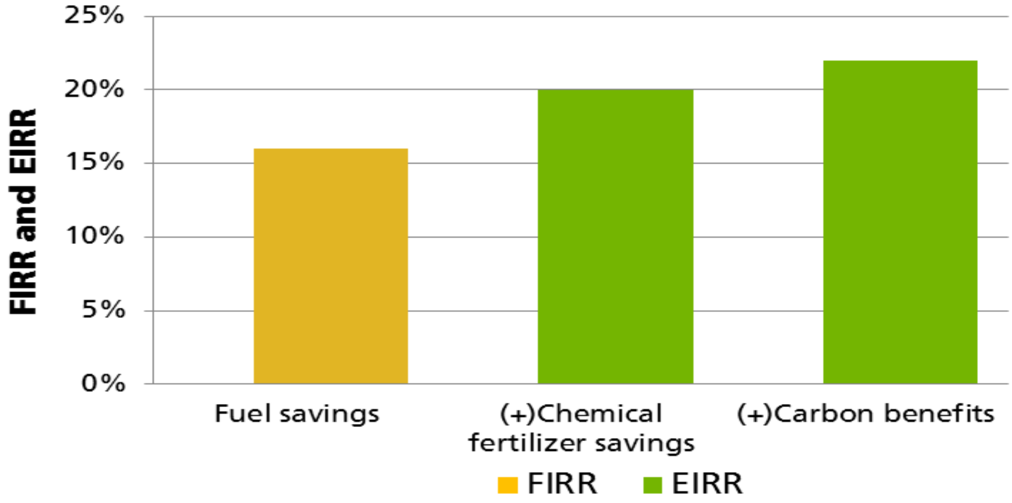
Biogas plant with stove	Assumptions	Unit cost	Total
Plant size	4 m^3	-	4 m^3
Construction cost	436 USD	-	436 USD
Lifetime	20 years	-	20 years
Savings potential			
Firewood savings/household (HH)	2.1 tons/year	21 USD/tons	44 USD/year
Kerosene savings/HH	24 litres/year	0.9 USD/litre	22 USD/year
Chemical fertilizer savings	75 kg/year	0.2 USD/kg	15 USD/year
GHG reduction	2.5 tons CO2e/year	5 USD/tons	13 USD/year
Financial NPV and IRR			
NPV (15% discount rate)	24 USD	Financial IRR	16%
Payback	3.67 years		
Economic NPV and IRR			
NPV (15% discount rate)	USD 134 to USD 205	Economic IRR	20% to 22%

Source: Own analysis based on assumptions used in Dhakal, N.H (2008)

In the financial analysis of a domestic biogas cooking system (with construction of a biogas plant), the IRR becomes 16% and payback period is about 3.67 years (20 year lifespan), if only avoided fuel costs are considered. For economic analysis, EIRR increases to 20% if chemical fertilizer savings are included, and to 22% if carbon benefits are additionally encountered. Fertilizer savings refer to the use of the solid biogas residues instead of chemical fertilizers.

[39] A small biogas plant uses the manure of 1-2 cows or other sources for bio-digestion. Such a digester is mainly a concrete dome (vessel) with a pipe on top allowing the biogas formed to escape and being collected.

Figure 5: FIRR and EIRR for a biogas based cooking system



Source: Own analysis based on assumptions used in Dhakal, N.H (2008)

From both cases, the NPV appears to be positive considering the full commercial value of the fuel. The payback period is few months for an efficient biomass cookstove (under 100% fuel purchase scenario) and few years for a biogas based cooking system.

3.3.5 FINANCING AND MAJOR PROGRAMMES

According to the Alliance, globally the most common available funding sources in cookstove businesses are *grants* in the form of government grants, foundation grants, individual donations, and multilateral grants. Other funding sources are equity investments and sales revenue in the cookstove businesses by private sectors. International government grants are the primary source of funding for domestic government programmes, while stove and fuel sale revenues are the primary source of funding for the partners working directly in distribution (Global Alliance for Clean Cookstoves 2013a).

Recent developments in public-private partnerships have opened up other innovative forms of funding such as indirect subsidies, and as carbon finance in the cookstove projects. *Indirect subsidies,* in the form of grants or loans, do not subsidise cookstove price. Indirect subsidies are used for R&D, marketing, financial product development, or to give credits to scale up production, distribution and sale. For example, the price of an efficient charcoal stove is about USD 26 in Uganda (locally known as Ugastove, a price that is not affordable to reach at the critical mass (''bottom of the pyramid'') in large scale. Direct/indirect subsidies are used from external sources (e.g. carbon revenues) to bring down the stove purchase cost at affordable level. Besides the stove cost, stove programmes require very high transaction cost for dissemination, i.e. the programmatic cost per stove is prohibitively high. Non-stove costs in a programme can be as high as 35% of the actual cost of the stove (Ecofys 2006). The programmatic costs involve annual administrative cost, marketing cost, quality control costs, field tests, transport costs, which can vary quite widely depending on technology/fuel and region. The direct/indirect subsidies help the programme developers recover their programmatic costs and increase product sales for the very low-income target group. *The carbon finance mechanism* has to a large extent stimulated clean cookstove distribution. An efficient cookstove can on average save between 1-3 tonnes of carbon dioxide (CO2) equivalent emissions per year and some cleaner cooking solutions save considerably more. Carbon financing provides the stove programmes with additional financing from the proceeds of the offset sales. Projects distributing improved cookstoves are typically able to fetch a carbon reduction premium such as certified emission reduction (CER) price in the compliance carbon market or voluntary emission Reduction (VER) price in the voluntary market. In 2012, almost 50% of the total stoves distributed (8.2 millions) had support from carbon finance, up from 15% in 2011. A total of 16.9 million carbon offsets were sold from cookstove projects in 2012, up from 4.2 MtCO2e (million metric tons of CO2 equivalent) in 2011. These emissions reductions valued at USD167 million. Geographically, the majority of carbon offsets were from Africa-based projects, valued at USD 110.8 million. *However, in recent years, the CER price continued to fall sharply. In 2008 the average CER price was 15 USD/ton*

CO2e, which had dropped to 2 USD/ ton by 2012. The price volatility, in combination with today's low CER price and negative price forecasts has somewhat limited the CDM's ability to stimulate the development of a commercial clean cookstove market at the moment. In the carbon offsetting market the trend is now shifting towards VERs, as voluntary buyers are willing to pay a premium on CER prices. As a result the VER market remained fairly constant at around USD 4/ton over the years (2008-2012), and for the cookstove programmes the VER price is approximately USD 5- 8/tons CO2e (2013) (Global Alliance for Clean Cookstoves 2013a).

Similar to carbon finance mitigating GHGs, there is an increasing recognition among the expert groups to introduce results-based finance in the clean cookstove sector. To scale up distribution of clean cookstoves mitigating SLCPs, the Black Carbon Finance Study Group Report, the World Bank recommends introducing a *results-based financing mechanism* in which payments can be made against measurable climate and health outcomes. The World Bank also observes that some of the existing global clean cooking funds, such as Spark fund, Deutsche Bank's working capital loan fund etc., have the potential to integrate BC abatements so as to stimulate the clean cookstove market. (BCFSG, 2015).

In terms of end-user financing, stoves are purchased by the end-users mainly on cash-sale basis due to the available subsidies and carbon finance that make the stove affordable even for the low-income groups. For domestic use, the price range of most common efficient wood/charcoal stoves are between USD 10 and USD 30, which makes it financially unattractive for the micro-lenders to extend micro loans to the individuals due to higher transactional costs. According to the Alliance, 99% of stoves distributed within the sector as a whole were purchased by end users on cash basis (Global Alliance for Clean Cookstoves, 2013a. *However, limited demand of micro-finance in cookstove can be seen for more high-end products, such as biogas cookstove, LPG cookstove or larger capacity efficient cookstoves used in commercial places (e.g. hotels, restaurants, guest houses etc.). This gives an opportunity for the local MFIs to extend micro-finance or instalment payment facilities to the end-users.* According to estimation by the World Bank, USD 4.7 billion is needed globally to ensure universal access to clean cooking energy through 2030 (Global Alliance for Clean Cookstoves, 2015). To achieve the global goal of reaching 100 million households by the Alliance, *the sector will need USD 1 billion in grants and investments* **(**Global Alliance for Clean Cookstoves, October 2012). Few donor-funded cookstove programmes are listed below:

- The Alliance is using grants and other forms of soft and patient capital to prepare a pipeline of new opportunities for investors. *Spark fund, pilot innovation fund, women's empowerment fund* are examples of such grant based facilitates initiated by the Alliance that aim to provide capacity building supports to the cookstove entrepreneurs and help them adopt commercialising approaches into their cookstove businesses. More than USD 50 million of private capital has flowed in to the sector to support the growth of enterprises along the cookstoves and fuels value chain. In fact, the Alliance is currently leveraging a dollar of investment funding for every dollar of grant funding. Compared to the estimated USD 1 billion needed this indicates the huge gap still to be covered, possibly with the help of additional FIF credit lines (Global Alliance for Clean Cookstoves 2013a). *The spark fund,* established in 2012, provides grants from minimum USD 50,000 to maximum USD 500,000 to support early stage investment. The goal of this fund is to help enterprises reach commercial viability and scale by funding business capacity development and growth. The fund aims to invest USD 2 million in grant capital annually in enterprises with scalable approaches that have the potential to transform the sector through their success- Global Village Energy Partnership (GVEP) in Kenya, Impact Carbon in Uganda, Gyapa Enterprises in Ghana are few enterprises that has got access to the spark fund. *The pilot innovation fund (PIF)* provides seed money up to USD 150,000 to scale and kick-start innovative approaches to strengthen supply and enhance demand along the cookstove sector's value chain. Sustainable Green Fuel Enterprise in Cambodia, UpEnergy in Uganda, Solar Sister in Nigeria, Greenway Grameen Infra in India, Potential Energy in Sudan are few of the enterprises that have been receiving funding supports under the PIF. The *women's empowerment fund* has issued grants to six organizations that are implementing gender and empowerment interventions within their clean cooking business models. The Alliance's *capacity building facility* is designed to fund cookstove enterprises that are ready to scale and obtain long-term capital. These grants for capacity building are coupled with growth financing from investors. The Alliance's *Carbon Finance Platform* provides guidelines, tools, templates, reports, case studies and other tools to assist stakeholders with varying levels of carbon expertise (Global Alliance for Clean Cookstoves, 2013b)

- **Working Capital Fund of Deutsche Bank:** Many traditional sources of capital, such as bank loans or lines of credit, are out of reach for smaller entrepreneurs who lack sufficient collateral or financial history for a loan. Even if these enterprises are able to secure a commercial loan, interest rates are often prohibitively high. To help solve this problem, *Deutsche Bank's Global Social Investment Group is establishing the USD 4 million Clean Cooking Working Capital Fund* to deploy working capital loans and loan guarantees to enterprises that are unable to access more traditional forms of debt financing. The fund will offer flexible financing at reduced interest rates (Global Alliance for Clean Cookstoves 2014b).

- **Improved cookstove programme of SNV, the Netherlands Development Organization:** SNV is one of the founding partners of the Global Alliance for Clean Cookstoves. At the 2014 Clean Cookstove Summit in New York, SNV made the commitment to facilitate the dissemination of one million cookstoves, including biomass as well as biogas stoves, benefiting about five million people in Africa, Asia and Latin America. The total expenditure for this period is estimated around USD 107 million, excluding the investments by the households. SNV facilitates large-scale adoption of clean and efficient cookstoves by building a competitive value chain consisting of manufacturers, retailers, distributors, and end-users.

  In the cookstove sector, SNV has been active in Nepal, Laos, the Democratic Republic of the Congo, Cambodia and Tanzania through its various programme initiatives. Notably, in Nepal, SNV started a five year improved cookstove project (2012-2017), aiming to reach 150,000 households by working with private sector led distributor retailer groups. At the end of 2014, a new cookstove design with a prefabricated metallic combustion chamber had been developed.

  In direct cooperation with local and international manufacturers, SNV offers training and advisory services, conduct research, test new designs, and adapt innovative cookstove technologies to cater to local needs. Since supporting domestic biogas activities in Nepal in 1989, SNV realised the installation of over 600,000 biogas plants by the end of 2014, benefiting an estimated three million people and reducing CO2 emissions by over one million tonnes per year (SNV, 2015).

- **Improved cookstove programme of GIZ (The Deutsche Gesellschaft für Internationale Zusammenarbeit):** GIZ has been supporting the distribution of efficient and clean stoves in Africa, Asia and Latin America for 30 years. GIZ develops and implements clean and efficient cookstove solutions for households, institutions and small businesses. GIZ's core business is capacity development with the aim to develop local and regional markets for modern stoves. GIZ has developed several successful scaling up schemes, promoted technologies ranging from locally produced cooking stoves for wood, charcoal, biogas to industrially manufactured stoves. Since 2005, GIZ has been supporting national partners and has led to sustainable access to more than three million fuel-efficient stoves through various initiatives such as ''Energising Development'' or "EnDev" (GIZ, 2012).

  EnDev is a multi-donor funded programme led by GIZ to promote universal energy access in line with Sustainable Energy for All (SE4All) initiative. EnDev is currently being financed by the governments of the Netherlands, Germany, Norway, Australia, the United Kingdom and Switzerland. By mid-2014, the EnDev partnership comprised 26 activities in 24 different countries.

  The interventions are designed to be appropriate to the country requirements. Project interventions include developing markets for energy products and services; this includes targeted awareness campaigns, assisting entrepreneurs with energy-related businesses as well as transferring knowledge regarding technology and business skills, technical assistance and capacity building. Where necessary, EnDev provides financial support to energy-related businesses to kick-start markets or buy down capital investments.

  The EnDev programme is active in 18 countries[40] in Asia, Africa and Latin America, with a focus on Sub-Saharan Africa (EnDev funding by region: Africa 58%, Asia 21%, Latin America 21%). Starting from

[40] List of countries under EnDev improved cookstove programmes: Bangladesh, Benin, Bolivia, Burkina Faso, Burundi, Ethiopia, Honduras, Kenya, Liberia, Madagascar, Malawi, Mozambique, Nepal, Nicaragua, Peru, Senegal, Tanzania, Uganda

phase I in 2005 up to June 2014 in phase II, the EnDev programme has facilitated access to improved cooking technologies, such as improved firewood and charcoal stoves or biogas plant, to about 10.01 million people (EnDev/GIZ 2015). EnDev is committed to a high cost efficiency in its activities with the benchmark that a least 5,000 persons, 10 social institutions and 20 enterprises will gain sustainable access to modern energy technologies or services per EUR 100,000 programme budget. For improved cookstove programme, EnDev's objective is that per EUR 100,000 committed, at least 600 households will be using improved cookstoves sustainably (minimum half of these households shall be using at least tier 2 stoves defined by the Alliance) and reduce the health burden caused by smoke and soot in kitchens and cooking sites for at least 1,500 people for every EUR 100,000 spent (EnDev/GIZ 2015)

3.3.6 BARRIERS[41]

In the following lists the most commonly known barriers are listed which the industry perceives as major hurdles to fully commercialise the clean cookstove market:

- **Customer unawareness in adopting clean cookstoves:** The targeted customers are often unaware of the health, environmental and financial benefits of clean cookstoves. Moreover, even if they are aware of these benefits, the willingness to pay for such benefits remains relatively low due to their low disposable income.
- **Lack of access to capital at manufacturing and distribution level:** Businesses are unable to connect with investors. Distributors and retailers lack working capital and struggle to identify economically viable models for distributing stoves and delivering after-sales services to remote rural customers. Likewise, designers and manufacturers lack adequate capital for R&D to design and develop clean cookstoves as required at the local level.
- **High upfront cost & limited available financing at the end-user level:** High upfront cost of stoves and limited availability of financing reduce demand for clean cookstoves at the end-user level. Consumer loan products and alternate payment options are not widely available to enable financing at the end-user level. Also, the current CER price and the high volatility of carbon market add concern to the carbon project developers to consider carbon revenues as a long-term, reliable source of financing.
- **Lack of market knowledge:** There is limited market data available for most of the targeted customer segments in various developing countries. Large regional differences in cooking practices, cultural differences, fuel access and availability, implies a need for highly customised stoves to ensure long-term adoption. The lacking market data, uncertain market demand and incomplete information makes it difficult for the investors to make long-term investment decisions. Particularly for clean cookstoves mitigating SLCPs, the investors are unfamiliar with the standards and testing protocols, so as to evaluate BC emission reductions potential of the clean cookstoves.
- **Lack of scale, limited distribution & sales:** Low profit margins on cookstoves increase the need to sell a larger amount of stoves to cover overhead expenses. Low margins reduce liquidity and distributors' ability to carry high stock volumes. On top of that, lack of infrastructure and high transportation cost can make it uneconomic to deliver cookstoves to the targeted communities. To achieve scale, mass manufacturing or assembly at the local level is necessary which is not always occurring in the most efficient manner. Manufactures are not aware of and able to leverage existing last mile distribution channels.
- **Availability and subsidised price of fuels and clean cookstoves:** The availability and low price of traditional/basic biomass cookstoves can threaten the sustainability of clean cookstove adoption. The subsidised price on fuels, such as kerosene, as well as on basic biomass cookstove will strongly affect the commercial viability of clean cookstoves.

[41] Own analysis based on Global Alliance for Clean Cookstoves (October 2012), Differ (2012b), Global Alliance for Clean Cookstoves (2014c)

3.3.7 WAY-FORWARD FOR SLCP FIF

The market opportunity of cookstove technologies, irrespective of clean or efficient ones, is large. Globally about three billion people or 500 million households still need clean and efficient cooking solutions. However, the market is largely unaware about the benefits of clean cookstoves mitigating SLCPs. Clean cookstoves based on cleaner fuel or improved techniques (e.g. forced draft biomass improved stove) are yet to have a large market share compared to the conventional improved biomass cookstoves that are widely available in the rural areas.

The supply of cleaner fuel needs to be easily accessible at the local level to get the benefits clean cookstoves. Moreover, there can be challenges in market adaption of smoke-free/less polluted cookstoves reducing BC, given the fact that various types basic biomass cookstoves are being widely disseminated in the market, which are available at cheaper prices. It is also unlikely that the clean cookstove end-users be incentivised by the abatement of BC emissions. Though, recently a new accounting methodology has been developed by the Gold Standard Foundation that focuses on measuring emissions reductions of SLCPs[42] and could be used for introducing results-based finance in the clean cookstove sector, but this methodology will need some times to take effect at the field-level.

As a result of these factors, a full-fledged TA support facility may not be feasible at this stage. However, the finance initiative could engage with selected partner banks, MFIs and other stakeholders in order to thoroughly investigate the local markets where they are operating. In terms of selecting clean cooking options, ISO 'tier' cookstove standards need to be promoted at the local level to get the maximum benefits of SLCP reductions. By systematically investigating the most suitable alternative clean cooking technologies; the supply and demand side of the selected technologies; potential financial mechanisms; policy incentives, it will showcase market-enabling environments and benefits of the smoke free/less polluted clean cookstoves where selected FIs/MFIs would feel more comfortable to bring additional financing in the clean cookstove sector.

[42] http://www.ccacoalition.org/en/initiatives

3.4 HFCS

SUMMARY

- HFCs, the third generation of refrigerant gases, were introduced to replace first and second generation chlorinated gases such as chlorofluorocarbons (CFCs), and hydro chlorofluorocarbons (HCFCs), which are considered as ozone depleting substances (ODS) under the Montreal Protocol.
- Atmospheric observations show that the volume of HFCs in the atmosphere is increasing rapidly, by about 10-15% per year.
- Under the Montreal Protocol there are Article 5 ("A-5") signatory countries and Non-Article 5 ("Non A-5") countries, which have pledged to regulate the production and consumption of ozone depleting substances (ODS). A-5 countries are referred to as developing countries and Non A-5 countries as developed countries
- HFCs are mainly used as coolants in refrigeration and air-conditioning. In 2010, 55% of total HFCs were used in refrigeration and air-conditioning equipment in residential, commercial and industrial operations; and 24% for air-conditioning in vehicles.
- GWP HFC refrigerants with high GWP are considered to be those with GWP >1,000.
- There are certain low-GWP refrigerants (such as HC-600a, R-744, HC-290, R-717) that are already commercially available worldwide. Besides reducing near-term global warming, refrigerators/air conditioners equipped with low-GWP refrigerants are found to be more energy efficient, thus saving energy costs. In the commercial refrigeration sector, supermarkets for example, can achieve an improvement in energy efficiency of 15-30% by switching to low-GWP alternatives.
- In global commercial refrigeration up to 65% of new installations are equipped with low-GWP refrigerants, including CO2, ammonia, and hydrocarbons. While in the domestic refrigeration sector, low-GWP hydrocarbon technologies are expected to reach about 75% of global production by 2020. Global residential air-conditioning is estimated to grow significantly from 900 million units (2015) to 2,500 million units by 2050, with much of the growth in major emerging economies such as India, Brazil and Indonesia.
- The Multilateral Fund (MLF) of the Montreal Protocol remains the key funding source for private sector businesses across various countries seeking assistance in various environmentally friendly, energy efficient investment projects.
- The slow introduction of low-GWP alternatives in A-5 countries is likely to accelerate as each technology matures and costs decease.
- There is a lack of knowledge and expertise, particularly in A-5 countries, on the use and application of low-GWP refrigerants and low market awareness on their environmental and cost benefits. The safety issue stemming from the flammable nature and/or higher toxicity of low-GWP alternatives at high ambient temperatures could be of concern for A-5 countries, and this might require appropriate design/measures at the local level.
- The financial sector also lacks awareness on the financing of low-GWP alternative systems and potential financing mechanisms such as ESCO finance; consumer loan products to scale up financing in cooling technologies mitigating HFCs.
- Besides residential users, commercial, industrial and large corporate groups (e.g. Coca-Cola, Wal-Mart, Nestlé, supermarkets etc.) show the highest potential for upgrading/replacing existing cooling technologies to low-GWP/HFC-free alternative solutions.

3.4.1 BASIC SECTOR INFORMATION

HFCs, the third generation of refrigerant gases, were introduced to replace first and second generation chlorinated gases, such as chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs), considered as ozone depleting substances (ODS) under the Montreal Protocol[43]. HFCs pose no harm to the ozone layer because, unlike CFCs and HCFCs, they do not contain chlorine. However, HFCs are *Green House Gases* (GHG) with high Global Warming Potential (GWP), along with CFCs and HCFCs. CFCs and HCFCS are being phased out under the Montreal Protocol because of their destructive impact on the ozone layer. As HFCs are being used as replacements for CFCs and HCFCs, the use of HFCs are increasing. Atmospheric observations show that the volume of HFCs in the atmosphere is increasing rapidly, about 10-15% per year. If no measures are taken, it is estimated that HFCs will amount to 9-19% of total GHG emissions by 2050 (CCAC, April 2015). Fast mitigation of HFCs combined with mitigation of the other SLCPs — BC, methane, and tropospheric ozone — is said to avoid 0.6°C of future warming by 2050, and up to 1.5°C by the end of the century, with HFC mitigation contributing one-third of the avoided warming by the end of the century (IGSD, July 2015).

Under the Montreal Protocol, there are Article 5 ("A-5") countries and Non-Article 5 ("Non A-5") countries that are signatories of regulating the production and consumption of ozone depleting substances (ODS); developing countries are referred to as A-5 countries and Non A-5 countries denotes developed countries. As per the Montreal Protocol, A-5 countries are those developing country parties whose annual per capita consumption and production of ODS is less than 0.3 kg. Currently, 147 of the 197 Parties to the Montreal Protocol are referred to as A-5 countries[44].

For implementation of the Montreal Protocol, the Multilateral Fund (MLF) was established in a decision of the Second Meeting of the Parties to the Montreal Protocol in June 1990 and began operation in 1991 (UNEP, 2015). The MLF primarily assists A-5 countries with annual consumption and production of ODS <0.3 kg/capita[45] in various investment projects.

In terms of global consumption, HFCs are mainly used as refrigerants in refrigeration and air-conditioning. In 2010, 55% of total HFCs were used in refrigeration and air-conditioning equipment in residential, commercial and industrial operations and 24% for air-conditioning in vehicles. Encouragingly, low-GWP HFCs and non-HFC alternatives are now increasingly being applied globally in commercial applications. China, the U.S., and the EU, the top three global consumers of HFCs, have all announced new policies and regulations to control and reduce HFC emissions. Actions have been taken by many CCAC partner countries to avoid the growth of high-GWP HFCs by identifying policies and measures, developing nation-wide HFC inventories, demonstrating low-GWP/HFC-free alternative refrigeration/air-conditioning technologies, and their environmental and economic benefits. Yet there is a lack of knowledge, experience and awareness on the use and benefits of low-GWP HFC/alternatives in developing countries. This is translating into a lack of policy and financial incentives, which are preventing the scale-up of low-GWP HFC/alternative systems while contemporary systems are still in use in many countries.

[43] The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion. The Montreal Protocol entered into force on 1 January 1989. The Montreal Protocol has been ratified by 197 parties, which includes 196 states and the EU. Through the signing of the treaty, the signatory states recognise the depletion of the ozone layer caused by worldwide emissions of certain substances and its adverse effects on human health and the environment, commit to protect the ozone layer by taking precautionary measures to equitably control total global emissions of substances and accept a series of stepped limits on CFC use and production. Reference: https://en.wikipedia.org/wiki/Montreal_Protocol

[44] http://ozone.unep.org/new_site/en/parties_under_article5_para1.php

[45] The MLF is managed by an Executive Committee with an equal representation of seven industrialised and seven Article 5 countries. The work of the MLF on the ground in developing countries is carried out by four Implementing Agencies- UNEP (DTIE), UNDP, UNIDO and World Bank- which have contractual agreements with the Executive Committee (IGSD, July 2015)

3.4.2 SLCP MITIGATION OPTIONS

As far as the global consumption of HFCs is concerned, the major application is primarily refrigerants used in refrigeration and air-conditioning. In addition, HFCs are used in transport refrigeration, vehicle air-conditioning and as blowing agents in foams used for thermal insulation. This section focuses on the refrigeration (domestic/commercial/industrial) and air-conditioning market since their use is quite widespread in the commercial and residential sectors, and together they contribute more than half of the total HFCs globally.

High-GWP HFC refrigerants are those with GWP >1,000. Alternatives to existing high-GWP HFCs fall into two basic categories: non-fluorinated substances with low-GWP, and fluorinated substances with low- to mid-range GWP. Commercially available non-fluorinated or "natural refrigerants" primarily include ammonia with a GWP of near zero, hydrocarbons (e.g., propane and isobutene) with GWPs of less than four, and CO2 with a GWP of one.

Table 19: Indicative list of HFCs with high-GWP refrigerants & alternatives with low GWP

Application	Current Refrigerants	GWP	Alternative refrigerants	GWP
Refrigeration (Domestic)	HFC-134a	(1,300)	HC-600a (isobutene) HC-290 (propane) HFO-1234yf	(~3) (<5) (<1)
Refrigeration (Commercial & Industrial	HCFC-22 HFC-407C HFC-134a HFC-404a	(1,760) (1,774) (1,300) (3,943)	HC-600a (isobutene) R-744 (CO2) R-717 (ammonia) HFCs and HFC blends	(~3) (1) (0) (<1-1,600)
Air Conditioners (Room)	HFC-410a HCFC-22 HFC-407C	(1,923) (1,760) (1,774)	HC-290 (propane) HFC-32 HFCs & HFC blends	(<5) (677) (~350)
Air Conditioners (Commercial)	HFC-134a HCFC-22	(1,300) (1,760)	HFC-1233zd HFC-1234ze HFC &HFC blends HFC-1234yf	(<1) (<1) (400-500) (<1)

Source: IGSD (July 2015)

Alternative fluorinated substances primarily include low-GWP HFCs, also known as "HFOs", with a GWP100-yr of less than one (IGSD, July 2015). *The Montreal Protocol's Technology and Economic Assessment Panel (TEAP) uses the term "low-GWP' to refer to refrigerants with GWPs of 300 or lower while "moderate-GWP" refers to refrigerants with a GWP of 1,000 or lower (UNEP, 2014).*

According to the UNEP Technical Options Committee, the *domestic refrigeration* sub-sector is the major component and comprises appliances that are broadly used domestically, such as refrigerators, freezers and combined refrigerator/freezer products. A domestic refrigerator has an electrical input between 50-250 kW and contains less than 30-150g of refrigerants (dependent on the type of refrigerant). HFC-134a is one of the most commonly used high-GWP HFC refrigerants in the domestic sector, with a GWP of 1,300. Replacement of HFC-134a by HC-600a is expected to continue, driven by either local regulation on HFCs, by the requirement of suppliers or uses to reduce global warming impact.

Commercial refrigeration is characterised by storing and displaying food and beverages at different temperatures within commercial stores with a sales areas varying in size from approximately 10 to 20,000 square meters. Commercial refrigeration can be broadly classified into three different groups of systems: centralised systems (refrigerant is field charge- typically 20 kW- 1 MW with refrigerant charges ranging from 40 -3000 kg) installed in supermarkets, condensing units (refrigerant is field charged- typically 5-20 kW with a refrigerant charge varying from 1-5 kg) installed mainly in small shops and restaurants, and self-contained or stand-alone units such as ice-cream freezers, beverage vending machines, etc. (refrigerant is factory charged) (UNEP 2014). On a global basis, HFC-404A and HCFC-22 continue to represent a large refrigerant bank in commercial refrigeration and is used at all temperatures. Over the last decade, HCs (for low refrigerant charge systems) and CO2 (for supermarkets) have taken a significant market share as refrigerants, especially in Europe.

Industrial Refrigeration systems are characterised by heat extraction rates in the range of 0.1 to 10 MW, typically at evaporating temperatures from –50°C to +20°C and with refrigerant contents of many hundreds of kilograms. Industrial refrigeration systems are used for large applications such as food processing plants, cold stores and large industrial cooling processes. HCFC-22 is the most widespread refrigerant in the industrial system. The majority of large industries use R-717 as the alternative low-GWP refrigerant.

On a global basis, *air conditioners* for cooling and heating (including air-to-air heat pumps) ranging in size primarily from 2 to 35 kW (although in some cases up to over 750 kW) comprise a significant segment of the air-conditioning market. Nearly all air conditioners and heat pumps manufactured prior to the year 2000 used HCFC-22. HCFC-22 remains the dominant refrigerant in use along with HFC blend R-410A, R-407C and HFC-134a. HC-290 and HFC-32 are being used as alternative low-GWP refrigerants in split systems, window and portable air conditioners (UNEP, 2014).

3.4.3 MARKET ENVIRONMENT

Following the agreements under the Montreal Protocol, CFC production has been phased out over the last decade in Non A-5 countries, and the CFC phase-out in the A-5 countries, scheduled for 2010, has been completed. For HCFCs, a freeze in production was agreed in 2013 based on the average 2009-2010 consumption/production levels, and from 2015 there is a step down every five years, aiming to phase them out completely by 2030 for non A-5 countries (phase-out by 2020, allowing a servicing period until 2030), and 2040 for A-5 countries (phase-out by 2030, allowing a servicing period until 2040). Already HCFCs have been largely phased out in Non A-5 countries and now attention is increasing in A-5 countries for phasing-out within the stipulated timeframe. In both Non A-5 and A-5 countries, HFCs have so far been important substitutes for CFCs and HCFCs. The CFC/HCFC phase-out was mostly driven by their ozone depletion potential; the GWP of alternative HFCs now gets more attention implying greater consideration for the use of low-GWP HFCs/refrigerants when replacing HCFCs. The provision of necessary incentives to A-5 countries remains for the transition from HCFCs to non-HCFC refrigerants, which will include both HFCs and non-fluorocarbon alternatives (UNEP 2010 and UNEP 2014).

The Montreal Protocol does not regulate the consumption of HFCs. However, negotiations are ongoing among signatory countries for an amendment to phase out the production and consumption of HFCs, which was discussed at the 27th Meeting of the Parties to the Montreal Protocol in Dubai in November 2015 (EIA 2015). Several parties have submitted proposals for the phase out plan of HFCs for both A-5 and non A-5 countries. Five proposals have been submitted by a total of 95 Parties to the Montreal Protocol to phase out the upstream production and consumption of HFCs for both A-5 and non A-5 countries[46]. For instance, the EU proposes that the phase out schedule for A-5 Parties should be defined by 2020, when detailed data on production and consumption of HFCs have become available. It is anticipated that the market will have further developed acceptable and available low-GWP alternatives by that time, which will allow Parties to define a realistic and ambitious phase out schedule (UNEP Ozone Secretariat, June 2015). India has also submitted its own proposal for A-5 and non A-5 countries to phase out high-GWP HFCs under the Montreal Protocol, reversing several years of opposition (IGSD, July 2015).

China, the U.S., and the EU, the top three global consumers of HFCs, have all announced new policies and regulations to control and reduce HFC emissions. In May 2014, the State Council of China announced that they would strengthen their management of HFC emissions and accelerate the destruction and replacement of HFCs as part of their action plan to implement the energy conservation and emission reduction targets in the 12th five-year plan. The CCAC is also targeting HFCs as part of its global effort to scale-up action to reduce SLCPs. Many CCAC state partners already have existing HFC policies (mainly developing countries), and six are developing national-level inventories of HFCs and identifying policies and measures to avoid the growth of high-GWP HFCs (Bangladesh, Chile, Colombia, Ghana, Indonesia, and Nigeria). These inventories record the current and projected future use of HFCs, as well as opportunities to avoid growth in high-GWP HFCs through policies and other measures (IGSD, July 2015). Regulations for mandatory end-of-life refrigerant handling management have existed in many developed countries for several years and are being introduced in A-5 countries (UNEP, 2014). Through the assistance of the Multilateral Fund (MLF) of the Montreal Protocol, Nigeria has established a hydrocarbon (HC) production facility for the production of high-grade HC refrigerants to be used as alternatives to HFC refrigerants (CCAC, April 2015).

[46] The 95 Parties include a coalition of island States let by the Federated States of Micronesia and the Philippines, the Africa Group of 55 Parties, the U.S., Canada and Mexico, the EU-28, and India.

In terms of HFC-free/low-GWP HFC products, refrigeration and air-conditioning possess good market potential. As far as HFC consumption is concerned, refrigeration and air-conditioning are the subsectors with the largest CO2-equivalent emissions, representing over 50% (refrigeration and air-conditioning sector including unitary air-conditioning) of the total annual refrigerant emissions. The table 20 provides an analysis of the sector wise consumption of HFCs taking 2010 as a reference:

Table 20: Consumption of HFCs by sectors (2010)

Sector	Consumption
Residential, commercial and industrial air-conditioning & refrigeration	47%
Mobile air-conditioning (i.e. for vehicles)	24%
Unitary air-conditioning	8%
Foam agents	11%
Others (Aerosol, fire extinguishing and solvents)	10%

Source: CCAC (April 2015)

According to the UNEP Technical Options Committee, about 2,000-2,300 million units of domestic refrigerators exist in the market. The operational lifetime of these products is quite broad ranging from 9 to 19 years. Approximately 170 million domestic refrigerators and freezers are produced annually. The vast majority are used for food storage in residential houses, with a significant minority used in offices for domestic purposes and small businesses for commercial purposes. The low-GWP HC-600a (GWP~3) is the ideal refrigerant for domestic refrigeration products, giving roughly 5% higher efficiency than HFC-134a (GWP 1,300). Worldwide over 50 million appliances are produced annually with HC-600a; about 500 million domestic freezers that exist in the market today are based on HC-600a. (UNEP, 2014)

In commercial refrigeration, globally, up to 65% of new installations use low-GWP refrigerants, including CO2, ammonia, and hydrocarbons, while in the domestic refrigeration sector, low-GWP hydrocarbon technologies are expected to reach about 75% of global production by 2020. A number of global companies that are already making the transition away from HFCs report significant gains in energy efficiency. For example, the Coca-Cola Company and PepsiCo have reported energy efficiency gains of up to 47% in their new CO2 and hydrocarbon-based refrigeration equipment over baseline HFC-based models. Global supermarket chains Tesco and Unilever both report a 10% gain from new hydrocarbon-based commercial refrigeration equipment and freezer cabinets over HFC-models. Individual companies such as Wal-Mart, Nestlé, Sobeys, Supervalu, and Tesco are purchasing alternative refrigerant equipment, converting existing equipment, and improving efficiency while reducing leakage (IGSD, July 2015).

In the air-conditioning sector, thousands of hydrocarbon units have been sold and new production lines are coming online each year. The installed population of air conditioners has an average service life of 15 to 20 years (UNEP, 2014). Global Room AC stock is estimated to grow significantly from 900 million units (2015) to 2,500 million units by 2050 with much of the growth in major emerging economies such as India, Brazil and Indonesia (ETA, July 2015). The annual market of air conditioners is over 100 million units sold per year. Split air-conditioning systems using low-GWP HC-290 (GWP <5) are available in Europe and Australia, in production in India, and HCFC-22 (GWP 1,760) equipment production capacity is being converted to HC-290 (GWP<5) in China. The low-GWP refrigerant equipped air-conditioners are also more energy efficient than the existing ones currently available on the market. Another mid-moderate-GWP HFC-32 (GWP 677) is currently on the market for various types of air conditioners and has recently been applied in split units in several countries- China, Japan, India, Indonesia, and other countries have projects underway using moderate-GWP HFC-32 with high levels of operating efficiency. CO2 air-conditioning prototypes are also available on the market (IGSD, July 2015).

The economic impact of refrigeration technology is quite significant: 300 million tonnes of goods are continuously refrigerated worldwide. While the yearly consumption of electricity may be huge, and where the investment in machinery and equipment may approach USD 100,000 million, the value of the products treated by refrigeration alone will be four times this amount (UNEP, 2014). According to Energy Technologies Area (ETA), efficiency improvement of air-conditioners along with refrigerant transition has significant peak electrical load reduction potential: by 2030, 676-1576 numbers of peak power plants of 500 MW each could be avoided through efficiency improvements in the air-conditioning (ETA, July 2015).

3.4.4 COMMERCIAL VIABILITY

HFCs, irrespective of GWP values (high, medium or low) have gained a large share of the replacement market. In many applications, HFCs, as blends of HFCs or as non-HFC alternatives have become commercially available as alternatives to HCFCs with larger global warming impacts (UNEP, 2014). According to the UNEP Technical Options Committee, low-GWP HFCs and non-HFC alternatives are now being increasingly applied globally. Ammonia (R-717) and hydrocarbons (e.g. HC-290, HC-600a, HC-1270 etc.) enjoy growth in sectors where they can be easily accommodated, and for certain applications, CO2 refrigerant-based equipment is being further developed and a large number of CO2 demonstration installations (e.g. R-744) have been extensively tested on the market. Work is being done by several committees to develop standards to permit the application of new refrigerants, and it is the intent of companies to reach worldwide accepted limits in those different standards (UNEP, 2014).

The advantage of refrigerators/air conditioners equipped with low-GWP refrigerant is firstly the use of low/zero GWP refrigerants, but they are also more energy efficient further reducing GHG emissions and reducing electricity costs for the users. According to the Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol, low-GWP hydrocarbon and ammonia systems are typically 10-30% more energy efficient than conventional high-GWP HFC systems. Fluorinated refrigerant producers also report high levels of energy efficiency through the use of their air-conditioning products, particularly in hot climates. In the commercial refrigeration sector, supermarkets are improving energy efficiency by 15-30% when they switch to low-GWP alternatives (IGSD, July 2015).

The table 21 presents two actual cases of commercial refrigeration with low-GWP HFCs or alternative refrigerants. The cases have been developed by CCAC to showcase low-GWP energy efficient technologies that have been adopted in the commercial refrigeration sector as alternatives to replace or avoid high-GWP HFCs (CCAC, UNEP 2014). The technologies presented in these cases are only examples of the many available options for zero- and low-GWP substances, taking into account all design criteria, such as system performance, environmental impact, and cost analysis.

Table 21: Cases of commercial refrigeration[47]

Cases	Old system	New system	Benefits
Commercial food refrigeration of Carrefour SA Express Kurtköy Food & Department Store, Turkey	▪ HFC refrigerant R-404A having a GWP of 3,922 ▪ Emissions due to refrigerant leaks	▪ Natural fluid CO2 is used as alternative refrigerant having a GWP of 1 ▪ The new system is mainly composed of CO2 compressor racks with total refrigeration capacity of ~67 kW	▪ The CO2 solution improves the energy efficiency of the refrigeration units by around 15% ▪ Annual energy bills 7% reduced ▪ Less costly refrigerant (CO2 costs are currently 90% less expensive than traditional refrigerants (USD2.2/kg versus USD24.2/kg for R-404A ▪ Refrigerant leaks 75% reduced through improved pipe fittings
Chain food and wine shop of Supermercado Verdemar – Nova Lima Store, Belo Horizonte, Brazil	▪ HCFC refrigerant based conventional system	▪ The approach is to use CO2 as one of the fluids in a cascade system along with HFC refrigerant (R-134a) having a GWP of 1,430 ▪ The Primary dual circuit system is based on R-134a ▪ The Secondary system is based on R-744 (CO2), developed with special high technology parts and components. ▪ A capital cost increase of 20%, considering rack assembling and other equipment	▪ The new solution improves the energy efficiency of the refrigeration units by 30%, compared with the previous HCFC conventional systems. ▪ The payback of this system is less than 30 months. ▪ The maintenance cost is reduced by 40%. ▪ Lower energy costs.

Source: CCAC, UNEP (2014)

[47] The accuracy of the content and figures is the responsibility of the company and these have not been verified by the CCAC or UNEP.

3.4.5 FINANCING AND MAJOR PROGRAMMES

The MLF has been playing a key role in achieving cost-effective emissions reductions. Since its establishment, the MLF has provided more than USD 3 billion in funding, mainly for investment projects and less than 4% of it has been spent for capacity building and training of the technicians, enforcement officers, etc. (UNEP Secretariat, 2015). In 2014 at the 26th Meeting of the Parties of the Montreal Protocol, the Parties agreed to a MLF replenishment of over USD 500 million for 2015–2017 (IGSD, July 2015). Funds are being used, for example, to finance the conversion of existing manufacturing processes, train personnel, pay royalties and patent rights on new technologies, and establish national ozone offices[48]. In addition to funding incremental costs (capital and operational costs) of the investment projects, MLF has also funded diverse types of TA and capacity building activities to support parties for meeting the Montreal Protocol's obligations. It is expected that once regulation for the HFC phase out is adopted in the Montreal Protocol, MLF would also provide funding for HFC alternative investments in the targeted countries (EIA, July 2015). The MLF has already approved 14 demonstration projects with a total value of approximately USD 17.9 million to promote the introduction of low-GWP/zero-ODP alternative technologies and an additional USD 10 million has been allocated for other demonstration projects for low-GWP alternative technologies.

According to the findings of the inter-sessional, informal meeting of the Montreal Protocol held on 12-13 June 2015, the cost of mitigating activities, conversion of refrigeration, stationary AC and mobile air-conditioning units to low-GWP alternatives, would lie in the range of USD 1.08- 3.24 billion. In the event of a possible HFC phase out, second and third conversions (e.g. HFC-32/HFC-410a/HFC-1314a to low-GWP alternatives) could potentially take place in more than 700 projects in the refrigeration, air-conditioning, aerosol and foam sectors, which converted from CFCs/HCFCs to HFCs in MLF projects (UNEP Ozone Secretariat, June 2015). According to another estimation of TEAP, approximately 241,038 tonnes of refrigerant require conversion in the manufacturing sector at an estimated total cost of USD 2-2.7 billion which, spread over six years, would mean an amount of USD 1,200 ± 170 million per triennium. Considering the GWP of the refrigerants concerned, this would result in costs per tonne of CO2 reduction ranging between USD 1-8, representing a cost-effective means of climate mitigation (EIA, July 2015).

The private sector is complementing these efforts through the establishment of a Global Cold Food Chain Council (GCFCC) and a Global Refrigerant Management Initiative. The GCFCC aims to reduce the use and emissions of high-GWP HFCs and enhance energy efficiency in the cold food chain while minimising food spoilage. The Global Refrigerant Management Initiative seeks to identify and explore opportunities to educate the industry's global supply chain on ways to improve the management of refrigerants to reduce leakages and service emissions, and to promote the recycling, recovery, reclaiming and end-of-life destruction of refrigerants (CCAC, April 2015). Other industry groups including the Air-Conditioning, Heating and Refrigeration Institute, the European Fluorocarbon Technical Committee, the company "Refrigerants, Naturally!", the Consumer Goods Forum, a global network of over 400 retailers, manufacturers, and service providers from over 70 countries have pledged that its members will begin phasing out HFCs by 2015 (IGSD, July 2015). The CCAC has supported the demonstration of emerging low-GWP HFC alternative technologies in Jordan, Chile and India, as well as a technology feasibility study in the Maldives. The aim of these demonstration projects is to test and validate the new technologies, with a view to enabling their wider adoption globally, and particularly in developing countries.

[48] https://en.wikipedia.org/wiki/Montreal_Protocol

End-user financing in India in HFC-free Refrigeration[49]

Godrej Appliances of India manufactures 100% CFC- HCFC- and HFC- free refrigerators. Depending on the design, capacity and energy consumption level, the price of these refrigerators ranges from Rs. 21,000 (USD 328) to 77,500 (USD 1,210). The 100% CFC- HCFC- and HFC- free refrigerators are claimed to be 15% more energy efficient meaning lower electricity bills for the customers. A non-bank FI Bajaj Finance Limited extends consumer financing to the customers for purchase of refrigerators as well as other home appliances on flexible loan terms and conditions. The customer is required to pay a down payment on the equipment price and the remaining amount is paid over an 8-24 month instalment period. The FI may charge nominal interest on the product price to the customer or the manufacturers may bear an annualised rate of interest which is based on risk gradation, cost of funds, margin and risk premium.

3.4.6 BARRIERS[50]

UNEP has identified a number of barriers to technology penetration for low-GWP refrigerants in A-5 countries that needs to be addressed, including the development of enforceable regulations and safety standards; sufficient supplies of refrigeration and air-conditioning equipment based on alternatives; sufficient infrastructure for refrigerant supply in certain regions; sufficient skills and training in safe handling flammable or toxic refrigerants.

- **Technical barriers:** There is a lack of knowledge and experience in all sectors with the use and application of the low-GWP HFC/alternative refrigerants. Handling some of these refrigerants is considered to be too complex for some engineers', technicians' and operators' current levels of knowledge and basic refrigeration training. This is due to limited experience, especially with HCs, CO2 and low-GWP HFCs, relating to safety matters (flammable and/or higher toxicity), design issues, general expertise, and knowledge of availability of parts and equipment. Furthermore, there is very little in terms of research or development activities within A-5 countries to build up (internal) confidence in working directly with the LGA refrigerants, specifically in larger and more complicated types of systems such as industrial refrigeration.
- **Supply and availability of systems & components:** This mainly applies to the inability to obtain systems / appliances, components, the refrigerant itself and service equipment, as and when required. In many A-5 counties there are few system suppliers and they rarely supply systems using low-GWP refrigerants. Similarly producers of equipment also rarely market such products in A-5 countries.
- **Commercial barriers:** Low GWP refrigerant systems are only available for a specific market sector (such as domestic refrigeration using HCs and large industrial refrigeration using R717). The (current) price of systems, components, service equipment and refrigerant is quite high. In order to produce systems using low-GWP refrigerants, there are greater costs involved for the manufacturer. At the same time, there is an absence of financial incentives for importers of systems and equipment or producers to adopt the alternatives as well as the potential increase in business risk associated with the unknown.
- **Market awareness:** There is a lack of awareness on the benefits of low-GWP refrigerant technology, or the problems (such as climate or "non-green" issues) associated with existing products. Consumers may consider that the initially higher upfront price does not justify the environmental benefits.
- **Information resources:** The information resources barrier refers to the availability of technical data, design guides, instructions for carrying out and using, servicing and maintenance equipment, etc., specific to low-GWP refrigerants, compounded by the absence of in-depth training. These barriers are considered to apply to stakeholders involved in the design, construction, servicing and operation of systems as well as national and international consultants. There is often little or no awareness/guidance of the existence of low-GWP refrigerants, and their application, especially the general absence of

[49] Sources: http://www.godrejappliances.com/GodrejAppliances/index.aspx; http://www.bajajfinserv.in/finance/default.aspx
[50] Source: Own analysis based on UNEP (2010)

technical know-how tends to be an issue with smaller enterprises/ small workshops that represent the larger portion of the sector.

- **Regulations and standards:** Standards and regulations normally assist enterprises in applying technology safely, and without such an infrastructure in place, stakeholders will not have the confidence to apply the technology. In A-5 countries, there are no regulations and/or standards that apply to the use of low-GWP refrigerants. Existing regulations and standards (such as HCFC phase-out regulations) in A-5 countries are less rigorous and not enforced stringently and therefore (may be considered as) less effective.
- **Psychological and sociological aspects:** Barriers may come in the form of negative recommendations and advice from peer groups, industry association representatives, consultants, etc., recommending against the use of certain low-GWP refrigerants, or reporting on "bad" experiences. Such fears are often compounded by natural resistance to change, such as, technicians preferring to work using their traditional methods and activities, and the anticipation that the additional cost will be significant. Other psychological and sociological barriers include stakeholders not considering global warming as a reality, that addressing it is not their or their businesses' responsibility, that the current use of HFCs is already "green" or "eco-", and that the concept of low-GWP refrigerants is too "distant" and an industrialised country issue.

According to the analysis of UNEP, it is possible that the majority of the barriers can be overcome by implementing a number of measures relating to the areas of awareness-raising within the industry, training, technical developments in the areas of system efficiency and safety, local market development, financial incentives for low-GWP refrigerant based systems, improvements and changes to regulatory infrastructure, addressing Montreal Protocol issues such as funding criteria and actions of implementing agencies (UNEP 2010).

3.4.7 WAY-FORWARD FOR SLCP FIF

From technology point of view, there are certain low-GWP refrigerants (such as HC-600a, R-744, HC-290, R-717) that are already commercially available worldwide, especially in the refrigeration and air-conditioning sectors. Low-GWP alternative technologies are still at demonstration phase in the developing countries meaning technologies are not widely available at the local level and yet the private sector is not familiar with potential business cases of low GWP alternative systems. However, they are beginning to be introduced in A-5 countries and this is likely to accelerate as each technology matures and costs decease. To get the benefits of a SLCP FIF targeting HFC mitigation, the technologies need to be made available at the local level; the business cases need to be showcased to the private sectors. The financial sector also lacks awareness on financing of Low-GWP alternative systems. The finance initiative may work together with local manufacturers/suppliers and FIs to create market awareness of low-GWP/HFC-free refrigerant systems by demonstrating the technology and its economic and environmental benefits at the targeted user groups. Many CCAC state partners- mainly developing countries-already have existing HFC policies, and six countries, Bangladesh, Chile, Colombia, Ghana, Indonesia, and Nigeria, are developing national-level inventories of HFCs and identifying policies and measures to avoid the growth of high-GWP HFCs. The CCAC has also supported demonstration of emerging low-GWP HFC alternative technologies in Jordan, Chile and India, as well as a technology feasibility study in the Maldives. These countries can be targeted for developing pilot projects, which will have replication potential across the region. The MLF provides funding opportunity to the manufacturers for leap-frogging to low GWP/HFC-free alternative options from existing systems. The finance initiative may work with both FIs and potential vendors for introducing potential financing mechanisms such as consumer loan product, ESCO financing in HFC-free/ low-GWP alternative refrigeration and air-conditioning sectors. Besides, domestic users, the finance initiative may help local commercial banks to target sectors such as such as food, beverage and cold storage and also commercial houses, factories, large corporate groups (e.g. Coca-Cola, Wal-Mart, Nestlé, supermarket etc.) which have high potential to seek financing for upgrading or replacing their refrigeration and air-conditioning systems to low-GWP/HFC-free alternatives.

3.5 OTHER SECTORS: WASTE, OIL& GAS AND AGRICULTURE

SUMMARY

- Waste, oil & gas utility, and agriculture, are responsible for high emissions of methane and BC from various types of sources.
- Landfills are the third largest source of methane emissions, accounting for approximately 11% of estimated global methane emissions. The municipal solid waste sector is also a significant source of BC through the open burning of waste. Waste management is considered as a public good in economics. Thus, a local government is usually the entity responsible for the provision of waste management services.
- In recent years, Public-Private Partnerships (PPP) have been introduced into many public sectors and mainly in developed countries to enhance competition, management flexibility and service quality. In these cases, the government plays a big role in contract enforcement and incentive mechanism design.
- It may still be too early for developing countries to develop comparable mechanisms, as the financial base and legal system (e.g. contract enforcement) in PPPs are still weak. On the other hand, methane mitigation technologies in the waste sector are relatively mature and there may be commercially viable cases.
- The private sector shows unwillingness to contract with local government to provide waste management services due to their concern over the government's credibility in meeting their payment obligations.
- The oil & gas sector is considered to be the second largest source of global methane emissions, accounting for approximately 20%. The oil & gas operators are mainly state-owned and are comprised of a few large enterprises.
- There are significant methane reductions available by preventing or reducing pipeline leakages and recovering methane from coal mines, both of which can provide operational benefits of improved gas recoverability which lead to additional revenues for the operator. However, in places where the operator is only responsible for delivery service and is not punished if there is leakage, then there will not be any financial incentive for them to reduce pipeline leakage.
- Cost-effective opportunities vary from country to country and depend upon the concentration of emission source, the condition of the infrastructure and the local price of natural gas, etc. Coalmine methane projects are not cost-effective with standard power market rates.
- The agriculture and land use contributes approximately 22% of all global GHG emissions, including roughly 40% of global BC emissions and approximately 40% of global methane emissions.
- Potential methane and BC emissions reductions could be achieved through livestock & manure management, banning open agricultural burning and improving rice cultivation practices.
- Weak public private partnership structures and the absence of robust local policy incentives are limiting the scalability and bankability of projects.
- Larger scale manure methane projects require high capital costs and the market energy tariff rate is not sufficient to cover the project costs. Additionally, there is lack of financial incentives among farmers and producers to implement mitigation practices through manure management and rice management practices as the farmers usually incur additional costs.
- In the agriculture sector, country-level policies that price the negative impact from methane emission and grant programmes that support first phase laboratory research are needed as a first step towards mitigating methane.

3.5.1 BASIC SECTOR INFORMATION

This section analyses few selected sectors- waste, oil & gas utility, and agriculture- that mainly emit methane and BC from various types of usage. Along with BC and HFCs, methane emissions also have environmental impacts and global warming potentials. Methane also indirectly has an influence on human health and crop productivity by affecting ozone and the ecosystem structure (CCAC, 2014). Annual BC emissions and other PM2.5 are about 6048 metric tonnes (UNEP & WMO 2011). Annual methane emissions are about 498 metric tonnes (UNEP & WMO 2011). GWP of BC is about 500 over 100 years while GWP of methane is approximately 21 over the same time frame (EPA, 2012; IPCC, 2007).

Landfills are the third largest source of methane emissions, accounting for approximately 11% of estimated global methane emissions[51]. The municipal solid waste sector is also a significant source of BC through open burning of waste. In general, waste is considered as a public good. In many countries, the financial base for waste management is weak as waste management is low–priority in the country's development budget allocation. This results in no systematic disposal of waste being developed, and the recovery of energy from the waste goes unexploited. Proper waste management benefits health, the environment, and the economy, as well as improves the quality of life of local communities, especially in urban areas.

The oil & gas sector is considered to be the second largest source of global methane emissions, accounting for approximately 20% (CCAC, December 2015). Significant methane reduction opportunities exist from the oil & gas sector that can provide operational benefits of improved gas recoverability, leading to additional revenues for the operator. In the oil and gas sector only utility scale investment was considered in the analysis. This is due to the fact that production stage energy efficiency investment in oil & gas sector is quite large which are only within the financial capacity of a very few national level commercial banks. The oil and gas operators are mainly state-owned and most countries are yet to have a comprehensive policy framework for methane emissions from the oil and gas sector, which limits the potential of cost-effective emission reduction projects.

The agriculture sector (including forestry) contributes approximately 22% of all global GHG emissions, including roughly 40% of global BC emissions and approximately 40% of global methane emissions[52]. Potential methane and BC emissions reductions could be achieved through livestock & manure management, banning open agricultural burning and improving rice cultivation practices. However, there is a lack of scale of bankable projects in this sector due to weak public private partnership structures and the absence of adequate policy incentives at the local level.

3.5.2 SLCP MITIGATION OPTIONS

Waste management: Solid waste management and wastewater treatment

Waste management can refer to solid waste management and to waste water management. In *solid waste management*, there are several different types of waste: i) hazardous waste which contains harmful chemicals that create harmful by-products when burnt or stored in a landfill; ii) biodegradable waste which contains organic substances that can be broken down, treated and recycled into useful products; iii) non-biodegradable waste which cannot be recycled like biodegradable waste. Waste could be combustible waste which has high heat value and can release heat energy when combusted or non-combustible waste which cannot be easily burnt (UNEP, 2003). The techniques for solid waste management include landfills, incineration, source reduction, composting and recycling. Land filling is considered as the most polluting form, but is still the most used waste disposal method worldwide. Incineration can facilitate to destroy part of the waste including bio-waste, and besides killing any microbes reduces the volume of any ashes to be landfilled. Source reduction reduces the production and generation of waste. Biological treatment, e.g. composting may either be classified as recycling or pre-treatment before land filling (Joana, 2010). Different technologies have different implications for the environment. Usually reuse, recycling and recovery of waste are considered more preferable than waste disposal (UNEP, 2003).

[51] http://www.ccacoalition.org/en/initiatives/waste
[52] http://www.ccacoalition.org/en/initiatives/agriculture

Biodegradable waste is transformed with the help of bacteria to methane and CO under anaerobe conditions as in landfills or wastewater ponds. This mix of methane and CO is referred to as landfill gas. This gas can be burnt to drive a motor or produce heat and electricity. While the separation of biodegradable waste requires regulation which is out of scope of the study, the recovery and utilization of landfill gas can be achieved through directing the collected gas to be used to drive motors or as light or heat sources using gas collection. The usage of the gas includes electricity production, direct use, or alternative vehicle fuel (IEA, 2009).

Wastewater treatment on the other hand refers the process that turns wastewater into an effluent that can be returned to the water system or be reused for other purposes. Wastewater service is typically provided by municipalities and there is limited access for private sector involvement (WB/UNEP, 2013). From this aspect, wastewater de-pollution control falls under governmental regulation and will not be discussed in detail.

Oil and gas (utility level)

The analysis of the short-lived pollutants mitigation of the oil & gas sector will focus on two technologies: preventing leakage from long-distance gas transmission pipelines and coal-bed methane arising from coalmines. The technology identification is summarised based on IEA (2009)[53].

- Pipeline leakage: the methods to reduce methane emissions in oil and gas including pipeline leakage are technology upgrades such as using low-bleed pneumatic devices or installing dry seals on centrifugal compressors[54]. In addition, improvements can be made through a leak detection programme. Several technologies can help detect methane leakages which are can be difficult to detect, e.g. in buried pipelines. There are also programmes such as direct inspection and maintenance programmes to detect and measure leakages. One of the commonly used technologies is so-called Intelligent PIGs (Pipeline Inspection Gauges), which use magnetic resonance technologies to detect pipeline leakages.

- Coal mine methane: readily available technologies to recover and use methane from coal mines include oxidization of low concentration ventilation air methane, degasification systems that keep a safe level of methane concentration underground, and gas purification and contaminant removal which transfers gas to desired end-use.

Agriculture

The focus of SLCP mitigation in the agriculture sector includes: ban open-field burning of agriculture waste, intermittent aeration of continuously flooded rice paddies and improve manure management and animal feed. Banning open-field burning requires regulation initiated by policy makers, which is out of the scope of this study.

- Manure management (on a larger scale excluding cook stove biogas) can be achieved through increasing methane production and then burning it to collect biogas (UNFCCC, 2008a), using anaerobic digesters including technologies such as covered anaerobic lagoons, plug flow digesters and complete mix digesters (IEA, 2009). The aim is to abate manure methane emissions while generating an alternative income source.
- Feeding practices may reduce methane emissions by providing animals with an enriched diet to lower their enteric methane emissions per input unit (UNFCCC, 2008a).
- Rice management practices mainly involve water management. Different strategies can be developed to control the flooding and draining of the field.

[53] For more technical explanations of the technologies, please refer to IEA (2009).
[54] According to EPA (2015), replacing oil (wet) seals with dry seals on the rotating shafts of the centrifugal compressors can significant reduce methane emissions.

3.5.3 MARKET ENVIRONMENT

Waste management

Waste management is considered as a public good in economics (UNDP, 1994). It benefits the whole community once the service is provided, and anyone in the community can enjoy the benefits from waste management without reducing other's benefits (UNDP, 1994). Thus, a local government is usually the entity that is responsible for the provision of waste management service. However in recent years, Public-Private Partnerships (PPP) have been introduced into many public sectors to enhance competition, management flexibility and service quality where the government plays a big role in contract enforcement and incentive mechanism design. The cost recovery of waste management can theoretically be channelled through general revenues (UNDP, 1994). This will require strong budgeting and planning capability. This practice is especially prominent in developed countries where legal systems and business environments are mature. There are dominant private companies in waste management in developed countries such as in France and the US, e.g. Veolia, GDF Suez and Waste Management, Inc. etc. It may still be early for developing countries to develop comparable mechanisms, as the legal system, especially contract enforcement in PPPs, is still weak. Methane mitigation technologies in the waste sector on the other hand are relatively mature and there may be commercially viable cases. However, it is evident that the private sector shows unwillingness to contract with local government to provide waste management service due to their concern over the government's credibility in meeting their payment obligations (UNDP, 1994).

Oil and gas (utility)

The pipeline operators are often state-owned and/or a very few large enterprises (and thus hardly suitable for setting up a SLCP FIF, and therefore less in the scope of this study). The financial evaluation of a project's feasibility may be complicated in developing countries due to lack of data. For instance, Brazil's NovaGerar Landfill Gas to Energy Project based on CDM has constructed financial models based on assumptions suitable for developed countries. After the inception of the project, the generated CERs volume is smaller than expected (WB/UNEP, 2013).

Agriculture

From past project experience, small-scale biogas projects have been supported with grants from the World Bank. For example, Community Development Carbon Fund Biogas Project in Nepal utilised subsidised small-scale digester to generate energy for the use of cooking and heating purposes (WB/UNEP, 2013). However, this is different from the larger-scale methane utilization. Larger quantities of methane capture and electricity generation requires higher capital investment and more complicated technology issues as well as grid connection issues. High technological barriers, financial barriers and public awareness barriers still exit in the agriculture sector with regard to methane mitigation. These barriers should be removed before involving commercial banks in the sector.

3.5.4 COMMERCIAL VIABILITY AND FINANCING

Waste management

Landfill gas recovery is a relatively mature and commercially viable technology (Yedla & Jyoti, 2001; Corti & Frassinetti, 2007). Developed countries were investing in landfill gas recovery projects in developing countries to gain Certified Emission Reduction (CER) units in the CDM programmes to offset emission reduction (Bogner & Lee, 2005). However the market deflation in CDM in 2012 brings uncertainty in the future investment trend in such projects. Moreover, according to IEA (2009), investors are concerned with risks related to the condition of the waste disposal sites in developing countries that the landfill gas has to go through. Other concerns over investment in landfill gas recovery in developing countries include the challenges in connecting the landfill gas power projects to the grids and the lack of general public awareness.

Oil and gas (utility)

The commercial viability of the selected technologies is summarised below:

- Pipeline leakage: cost-effective opportunities vary from country to country in methane emissions reduction in the oil and gas sector. The commercial viability depends on the concentration of emission source, the condition of the infrastructure and the local price of natural gas, etc. The cost of leakage measurement equipment and training are high; cost-effectiveness may be achieved where the pipeline operator can sell the saved volume to recover the cost. However, in places where the pipeline operator is only responsible for delivery service and is not punished if there is leakage, then there will not be any financial incentive for them to reduce pipeline leakage (UNFCCC, 2008b).
- Coal mine methane: coalmine methane projects are not cost-effective with standard power market rates. Thus these projects are generally not commercially viable for banking and business involvement (IEA, 2009).

Agriculture

The analysis of the commercial viability of different technologies is summarised below.

- Larger scale manure methane projects require high capital costs and the market energy tariff rate is not sufficient to cover the costs of the projects (IEA, 2009). Thus manure methane projects are generally not commercially viable. UNFCCC (2008a) also confirms that there lacks financial incentives among farmers and producers to implement mitigation practices through manure management[55].
- There are no guaranteed results by changing feeding practice. And the expensive feeding practice is applied mainly to the most profitable animals.
- Rice management practices usually incur additional costs for farmers. For instance, the facilities required for composting rice straw and efficient irrigation and drainage systems required for managing flooding and draining demand a considerable amount of investment capital.

The existing project experiences in supporting waste and wastewater management practices by donors focus on introducing public awareness and waste source separation practice into municipalities. For example, the Ningbo Waste Minimization and Recycling Project in China was funded by World Bank with USD 4 million to incentivise waste source separation based on Results-based Financing (RBF) and Output-based Aid (OBA) (WB/UNEP, 2013). Currently the methane mitigation potential from a pure commercial point of view is not yet mature. Nevertheless, if the private sector participation is ensured by enhanced legal and business regulation, well-designed national-level regulation and raised public awareness, then it may be the time to introduce financing arrangements into the methane reduction approaches through the waste sector.

3.5.5 BARRIERS

Waste management[56]

Many barriers and challenges exist in the solid waste management sector in developing countries, which comprise human and technical, financial, organizational, structural and institutional, economic and social factors. These specific problems with solid waste management in developing countries are summarised below.

- **Human and technical barriers:** Qualified human resources with technical knowledge in waste management are lacking in policy making bodies.
- **Financial barriers:** The financial base for waste management is weak as waste management has a low–priority in the budget allocation of developing countries. In addition, the budgeting capacity in many developing countries is weak, which in turn makes waste management economically unsustainable. WB/UNEP (2013) also points out that the local environment for solid waste sectors are

[55] Note: the manure management analysis does not include small-scale manure management that is used to combust biogas for cooking which is discussed in the clean cookstove section.
[56] Source: Summary based on JICA (2005)

relatively poor since the municipality may not provide sufficient fees for waste disposal and newly elected officials may stymie the work of previous officials.

- **Organisational, structural and institutional barriers:** There is a lack of clear responsibilities and schedules among involved institutions, and a lack of an umbrella organization that serves a coordination function, as well as ineffective legal systems and legal provisions in relation to waste management and a lack of technical standards.
- **Economic barriers:** Poor infrastructure such as lack of roads will make the transaction costs of recycling too costly to implement. Poor industrial development will hinder the procurement and maintenance of machinery and equipment for waste management.
- **Social barriers:** Poverty related waste pickers form an extensive informal sector in developing countries, which have social implications for waste management policies. The interactions and opportunities for partnerships between the administrative authorities and citizens are rare.

Oil and gas (utility)

Different project types are faced with different sets of barriers. While financial, grid connection and awareness factors are common among project types, there are also barriers specific to certain project types (IEA, 2009).

- Barriers for methane mitigation in oil and gas leakage: 1) Pipeline operators are often state-owned enterprises. The financial barriers within the enterprises include competition for capital with other projects (lower fund allocation priority); low return for methane reduction projects compared with traditional operations; mismatch between the department that funds the project and department that recognises the additional gas revenue; and in places where the natural gas price is low, it is not economically viable. 2) Lack of service and technology providers in methane identification and mitigation. 3) Lack of awareness of the actual volume of methane emissions; 4) Most countries don't have a comprehensive policy framework for methane emissions from the oil and gas sector.
- Barriers for methane mitigation in coal mine methane: 1) with standard power market price, the coal mine methane projects are not cost-effective. 2) There are challenges with regard to ownership rights for coal, gas and the land. 3) Developing countries often lack the technologies to develop coalmine methane resources. 4) Challenges remain in connecting coal mine methane projects with the electricity grid. 5) Lack of strategies and policies on the development of coal mine methane projects.
- A general barrier faced in the oil and gas sector is that it is difficult to convince managers to put capital and human resources into methane reduction projects since companies need the resources in their core businesses and the return of the methane reduction projects may not pass the company's hurdle rate for internal decisions (WB/UNEP, 2013).

Agriculture

Various barriers for the implementation of methane mitigation measures in the agricultural sector are listed below.

- The barriers for manure methane projects include: 1) Lack of commercial viability. 2) Lack of awareness about the available technologies. 3) Lack of country strategy and framework to develop manure methane projects (IEA, 2009).
- The barriers for feeding practice include: 1) Mitigation potentials vary and field measurements are needed in implementation. 2) Novel feeding practice needs to be supported by reliable laboratory results. 3) Expensive feeding practice skews to the profitable livestock. 4) Side-effects of feeding practice on animals' digestion system (UNFCCC, 2008a).
- With regard to rice management practice, it is important to ensure that while reducing methane emissions from the rice field, it will not increase nitrous oxide emissions (UNFCCC, 2008a). In addition, the commercial viability of the practice is of concern because of the capital investment needed for building efficient drainage systems and composting facilities.

McKinsey (2009) points out that the current methane reduction techniques are very time consuming for farmers and sustainability in agriculture requires long-term implementation before there's evidence of payoff. This indicates, it is not commercially viable for farmers to invest in methane reduction technologies.

3.5.6 WAY-FORWARD FOR SLCP FIF

The bank's role in developing countries is limited in providing finance to the private sector participants in the *waste management sector* in order to facilitate waste treatment technology updates[57]. *The precondition for bank involvement will include more private sector involvement, a strong regulatory environment, good public knowledge and awareness on waste separation and recycling, and good legal framework that prevents contract infringement or expropriation.* The wastewater sector projects are very large and mostly implemented by either public bodies, or at least PPPs. Private sector involvement is limited, and certainly hardly a priority business case for any SLCP FIF for increasing private finance flowing into the sector.

Similar conditions prevail in the *oil & gas utility* sector. *Before introducing bank involvement in the sector, it is necessary for regulators to establish rules to give methane emissions a price to account for the negative externality emissions caused on environment and health*. If there is regulation asking polluters pay for methane emissions, then it will make it more attractive for polluters to upgrade their technologies. In other words, investors will be able to recalculate the returns that can be generated from technology improvements. Technology know-how is generally lacking in developing countries; this requires transfer of technological knowledge from developed countries into developing countries by means of TA supports. In addition, data aggregation on the level of methane emissions can be established to have a clear picture of the volume and potential effects of methane emission from the oil & gas sector. Thus similar to the waste sector, involvement of commercial banks would become feasible once the non-financial barriers in the oil and gas sector are removed – but *in any case this is not any priority sector for setting up an SLCP FIF*.

In the *agriculture sector, country-level policies* that price the negative impact from methane emissions and grant programmes that support first phase research in laboratory studies are needed as a first step forward mitigating methane through the agriculture sector. Here, the finance initiative- together with NGOs and development partners- may play a role in organizing events to raise public awareness.

[57] If the waste treatment service is provided solely by the public sector, then the financing of the waste service mainly comes from national / municipal budget. Only when there is private sector participation in the waste treatment sector will we consider the possibility of introducing financial mechanisms to facilitate such participation.

4. CONCLUSION

The objectives of the study are to assess the feasibility of a Finance Innovation Facility to help FIs remove internal institutional barriers to SLCP financing and build internal capacity for SLCP mitigation finance. The assessment, however, ascertains a range of significant non-financial barriers existing outside of the FIs, which hinder commercial financing of SLCP mitigation measures. Due to this, and the fact that the Finance Innovation Facility was originally envisioned to increase private financial flows in the SLCP mitigation sectors by removing barriers exclusively within the FIs, the facility's expected efficacy might be reduced. Table 22 shows a summary of these identified barriers.

Table 22: Summary of the opportunities and challenges for commercial financing in SLCP mitigation projects

SLCP Sector	Key opportunities	Key challenges (non-financial)	Key challenges (financial)	Current attract-iveness to private financing
Brick kiln	▪ Modernisation in the brick production process (e.g. Hybrid Hoffman kiln, tunnel kiln) increase productivity, reduce energy consumption and save costs	▪ Lack of enforcement of regulations to modernise traditional brick kilns in developing countries ▪ Informal business nature of the brick kiln owners; kilns often do not meet the social & environmental standards	▪ Higher upfront investment is required for modernising brick kilns ▪ Perceived and real lending risks to the kiln owners	Low
Cookstove	▪ Large population in Asia, Africa and Latin America has no access to clean cooking facilities ▪ Faster payback period for the end-users (considering the fuel savings only)	▪ Lack of scalability of 'clean' cook stoves that reduce indoor air pollution and particulate matter (e.g. ISO cook stove standards) compared to wide-spread use of regular 'efficient stoves' ▪ Lack of customer willingness to adopt or ability to pay for cleaner cooking options	▪ Lack of working capital for distributors/retailers in scaling up sales ▪ Limited financing opportunity at the end-user level (except for high-end products such as LPG stoves).	Low/medium
Heavy-duty diesel vehicles	▪ Developing countries that have adopted fuel standards (50 ppm) and at least Euro IV vehicle standards	▪ Inadequate fuel & vehicle standards in the developing countries ▪ Enforcement of regulations on vehicle & fuel standards ▪ Refinery investment is too large for local/national level FIs	▪ Limited commercial bank financing for upgrading fleets owned by the public transport owners	Low/medium
Waste	▪ Cost-recovering waste management projects which ensure proper tariff and public-private partnership (PPP) frameworks	▪ Waste collection & disposal facilities are mainly owned by the public utilities and as such there is a lack of private sector involvement ▪ Absence of effective PPP framework in the developing countries ▪ Complex business model for private sectors that requires co-operation from the local communities and government. ▪ Limited business cases for private operators that ensures full cost recovery	▪ Lack of bankable projects for the private financiers	Low

Oil & gas (utility)[58]	▪ Pipeline leakage projects that are cost-effective depending on the emission source; the condition of the infrastructure and the local price of fossil fuel.	▪ State owned enterprises dominate the sector = lack of private sector involvement ▪ Absence of effective PPP framework in developing countries ▪ Lack of regulation and in-adequate financial incentive for the operator to reduce pipeline leakage	▪ Weak financials of the public utilities ▪ Lack of access to private sector finance	Low
Agriculture (livestock manure management)[59]	▪ Livestock manure projects which ensure commercial business models for the investors	▪ Lack of financial incentives to the investors ▪ Lack of commercial business models for the investors for managing manure management projects	▪ Lack of bankable interventions for the private financiers	Low
HFCs	▪ HFC free technologies are commercially available worldwide ▪ Energy efficiency of the new HFC free sys-tems is also made su-perior than other technologies available in the market meaning more energy savings for the clients.	▪ HFC free technologies are still at the pilot/demonstration phase in developing countries = technologies have not reached yet commercial scale. ▪ Lack of HFCs phase out policies in the developing countries	▪ Higher upfront investment costs for upgrading to HFC free systems ▪ Limited private sector financing experience in new HFC-free techno-logies	Low/medium

The non-financial barriers mentioned above are largely sectorial and regulatory in nature; as a result they cannot be resolved solely through the implementation of a technical assistance programme aimed at leveraging private finance through a SLCP Finance Innovation Facility. Instead, addressing the full range of barriers requires the coordinated action of a broader range of relevant financial and non-financial stakeholders. Besides sectorial and regulatory barriers, within the commercial banks there are information gaps and a lack of awareness and credit exposure to SLCP mitigation sectors. This means that banks generally lack the ability to assess the potential of SLCP financing. In order to demonstrate possible SLCP financing areas, the study identifies potential collaboration strategies for private financiers; which mainly include awareness raising about the market and technologies, an investigation about potential business models, financing mechanisms and supply and demand scenarios, and linkages with potential funding sources etc. In the short term, these collaboration strategies will likely yield little to no private finance leverage ratios without the creation of strong regulatory and market enabling environment for the SLCP financing sectors which are ready for immediate upscaling. In the medium to long run, these actions should leverage private finance effectively by creating the opportunity to design a full-fledged TA facility for implementing the SLCP finance programme inside the banks.

[58] In the oil and gas sector only utility scale investment was considered in the analysis. Oil and gas producers were not considered for assessment, as production stage energy efficiency investment in oil & gas sector is quite large which are only within the financial capacity of a very few national level commercial banks

[59] In agriculture sector, livestock manure management was considered for assessment; Agricultural good practices for reducing methane such as rice management, open field-burning were not considered to be taken up by the commercial FIs, but to be promoted with involvement of NGOs, government and other agencies.

To address both the financial and non-financial barriers across all SLCP sectors the following staged approach can be taken by the Finance Initiative:

***Firstly, by addressing the barriers to the mobilisation of SLCP finance that occur outside the FIs*:** Many of the challenges identified for achieving commercial finance at scale occur outside of FIs and are regulatory or sectorial in nature. To successfully address these barriers it is necessary that the CCAC sector initiatives play a role. By providing financial advisory and technical assistance services the Finance Initiative can enable CCAC sector initiatives to consider and embed a financial dimension (potentials, challenges, and needs associated with the availability of finance, especially private finance, for SLCP-mitigation investment) into the design of core sector strategies and projects.

Secondly, by addressing the barriers to mobilisation of finance that occur within FIs by designing pilot demonstration cases or developing pilot financing programmes about SLCP technologies: To achieve this, the Finance Initiative may work with small group of FIs that have been identified as having expressed interest in exploring SLCP financing potential in their region. The Finance Initiative proposes that collaboration strategies are established with promising FIs by offering TA support for identifying potential SCLP financing areas. For FIs operating under strong regulatory and market enabling environment for SLCP financing, pilot financing programmes can be further developed and brought to scale.

***Thirdly, at the early stage of upscaling SLCP mitigation projects development organisations / donors should be engaged for channelling concessionary funding and designing innovative finance mechanisms for certain SLCP sectors*:** Commercial financiers alone cannot scale up SLCP financing programmes. This is because there will be demand for concessional funding to attract private investors to less commercially viable SLCP mitigation projects such as waste, agriculture etc. Moreover, multilateral development organisations/donors shall consider integrating SLCP financing into their lending strategy. To make SLCP mitigation technologies competitive with contemporary solutions, innovative finance mechanisms such as results-based finance need to be applied where payments can be made for measured the health and environmental benefits of SLCP mitigation. Recently a new accounting methodology has been developed by the Gold Standard Foundation that focuses on measuring emissions reductions of black carbon and could be used for introducing results-based finance in the clean cookstove sector. Similarly, the World Bank has introduced a pilot auction facility for methane reduction projects, which is a pay-for-performance instrument that uses auctions to maximise the use of limited public resources for climate change mitigation and leveraging private sector financing. The adoption of performance measurement tools at the programme level will be vital to direct financial flows to SLCP mitigation technologies.

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Annex 1: List of contacted FIs

No.	FI	Type	Country	Contact person
1	IDCOL	FI	Bangladesh	Mr. Nazmul Haque nhauque@idcol.org
2	Chamroeun MFI Ltd.	MFI	Cambodia	Mr. Pheng Raksa raksa@chamroeun.com
3	Visionfund Cambodia	MFI	Cambodia	Mr. Piseth Preap Piseth_Preap@wvi.org
4	Bank of Taizhou	Bank	China	Mr. Jörn Helms helms@tzbank.com
5	Changsha Bank/Innovative Carbon Investment	Bank	China	Ms. Li Li li.li@mailici.com
6	Solveigh	investment bank	China	Mr. Ernst Jan Kruis ejkruis@solveigh.com
7	ICICI	bank	India	Mr. Chandrakant Ingole chandrakant.ingole@icicibank.com
8	ESAF	MFI	India	Mr. Christudas K V chris@esaf.in
9	Yes bank	Bank	India	Mr. Nitin Sukh Nitin.Sukh@YESBANK.IN
10	cblalance/Godrej & Boyce Energy Financing	Consultant/FI	India	Mr. Vivek Gilani vivek@cbalance.in
11	Credit Union Keling Kumang (CUKK)	MFI	Indonesia	Mr. Yohanes RJ yohanezrj@gmail.com
12	Xacbank	Bank	Mongolia	Ms. Tuul Galzagd tuul.g@xacbank.mn
13	ACE Development Bank	bank	Nepal	Mr. Siddhant Raj Pandey siddhant@ace.com.np
14	Bank of Kathmandu	bank	Nepal	Mr. Raju Shrestha raju.shrestha@bok.com.np
15	Clean Energy Dev. Bank	Bank	Nepal	Mr. Dinesh Dulal dinesh.dulal@cedbl.com
16	CARD MRI	MFI	Philippines	Mr. Julius Adrian R. Alip jaralipnh@yahoo.com; bdequito@yahoo.com
17	Etimos Foundation	MFI/foundation	Sri Lanka	Mr. Davide Libralesso d.libralesso@etimosfoundation.org
18	TYM	MFI	Vietnam	Ms. Tran Thi Mai Thoa tymfund@tymfund.org.vn
19	LienVietPostBank	bank	Vietnam	Mr. Nguyen Thanh Binh binhnt1@lienvietpostbank.com.vn

FS-UNEP Collaborating Centre
Frankfurt School of Finance & Management
Sonnemannstrasse 9-11
60314 Frankfurt am Main

http://fs-unep-centre.org
www.frankfurt-school.de

E-Mail: fs_unep@fs.de
Phone: +49 (0)69 154008-614
Fax: +49 (0)69 154008-670