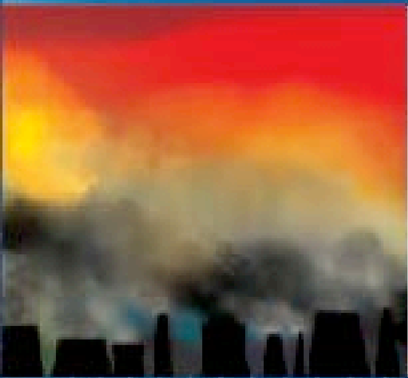
Republic of Mauritius

TECHNOLOGY NEEDS ASSESSMENT



BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR MITIGATION

ENERGY INDUSTRIES
TNA REPORT II

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List of Acronyms

BHP	Boiler Horsepower: 1 boiler horsepower = 9.81055407 kilowatts
CDM	Clean Development Mechanism
CEB	Central Electricity Board
CER	Certified Emission Reduction
CF	Capacity Factor
CLD	Causal Loop Diagram
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
EE	Energy Efficiency
EIA	Environmental Impact Assessment
EPA	Energy Purchase Agreement
ER	Emission Reduction
FDI	Foreign Direct Investment
FI	Financial Institution
FiT	Feed-in Tariff
GEF	Global Environment Facility
HFO	Heavy Fuel Oil
IPP	Independent Power Producer
IRR	Internal Rate of Return
kW	Kilowatt
kWh	Kilowatt hour
LC	Local Currency
LPA	Logical Problem Analysis
LPG	Liquefied Petroleum Gas
MoEPU	Ministry of Energy and Public Utilities
MoFED	Ministry of Finance and Economic Development

MW	**Megawatt**
MWh	**Megawatt hour**
NGO	**Non-Governmental Organisation**
NPV	**Net Present Value**
OT	**Objective Tree**
PBT	**Pay Back Time**
PDD	**Project Design Document**
PPA	**Power Purchase Agreement**
PT	**Problem Tree**
PV	**Photovoltaic**
R&D	**Research and Development**
RE	**Renewable Energy**
RET	**Renewable Energy Technology**
ROI	**Return on investment**
RPS	**Renewable portfolio standard**
Rs	**Rupee (Mauritian)**
SIPP	**Small Independent Power Producer**
SSDG	**Small-Scale Distributed Generation**
TAP	**Technology Action Plan**
TNA	**Technology Needs Assessment**
URA	**Utility Regulatory Authority**
VAT	**Value-Added Tax**
WACC	**Weighted Average Cost of Capital**
WHR	**Waste Heat Recovery**

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Executive Summary

This report has discussed in details the barriers that prevent the promotion and diffusion of two mitigation technologies, namely (1) utility-scale wind energy, and (2) industrial and commercial waste heat recovery using boiler economizer. Both economic and financial barriers and non-financial barriers have been discussed. It has been observed that the economic and financial barriers are the most dominant in both cases. A proposition has been made that all barriers translate into risks from an investor's perspective, which would then increase the expected financial return on an investment in RE or EE technology. Detailed benefit-cost analysis has been carried out in both cases, and the analysis shows that the measures proposed to overcome barriers yield net sustainable development dividends when social (job creation), economic (reduction in energy bill) and environmental (reduction in GHG emissions) benefits are accounted using an incremental approach. The enabling environment and key stakeholders have been identified using the market mapping technique.

1. Energy Industries

The TNA Report (Government of Mauritius, 2012) has prioritized three technologies for the TAP process, namely two utility-scale RETs (wind and PV) and EE in the form of waste heat recovery in boilers. In the case of Mauritius, a GEF-funded project for the removal of barriers to solar PV power generation was endorsed in July 2011. The 4-year project seeks to achieve significant acceleration of the development of on- grid PV systems by removing institutional barriers and through technology transfer, and sustainable delivery models and financing mechanisms. It applies to PV installation of up to 15 MW. Notwithstanding project monitoring and evaluation, the PV project has eight components, which together with the expected outcomes are summarised in Table 1.

Table 1. Summary of the components and outcomes of approved GEF PV project in Mauritius.

Components	Outcomes
Institutional, policy planning and legal framework and decision-making.	Adapted enhanced legislative and regulatory framework for solar photovoltaic (PV) development. Approved policy framework for stimulating investment in systems up to 400 kW and up to 15 MW PV plants. Policy barriers to grid-connected PV systems removed.
Building public awareness of solar PV technology.	Increased social acceptability and public awareness of the benefits of PV.
Assessment of the solar energy resource endowment and identification of specific sites.	Power developers using the solar and resource map/reports for PV and other project developments. Commercial on-grid solar PV power generation systems designed in solar energy resource rich areas of the country.
Capacity building in public and private sectors and NGOs	Increased human capacity and resources in the private sector, NGOs and government institutions to identify, design, appraise, manage and implement sustainable energy projects.
Strengthening the technology support and delivery system through technology transfer.	Enhanced technical and planning know-how of stakeholders and market chain for PV developed.
Capacity building in the financial sector.	Easily accessible and affordable financing schemes for purchase, installation and maintenance of PV panels. Banks/FIs financing solar PV projects and other RE-based power generation projects.
Removing technical barriers.	Enforced norms, standards and codes for the manufacture, installation and operation of solar PV systems.
Demonstration projects.	Public-private partnerships and investments enhanced. Stakeholders' acceptance of viability of PV technology enhanced. PV projects designed, assessed, constructed and put in operation.

The total project cost is US$ 21, 073,000 with GEF funding (including PPG) of US$2,005,000 and co-financing to the tune of US$18,988,000. For more details see http://www.thegef.org/gef/project_detail?projID=4099 – accessed 8 October 2012.
Details of the project are from the PIF found at http://www.thegef.org/gef/project_detail?projID=4099 – accessed 8 October 2012.

Since barriers for the uptake and diffusion of utility-scale PV in Mauritius are currently being addressed, the TAP will focus only on utility-scale wind energy technology and waste heat recovery in boilers.

This report will start with preliminary targets for technology transfer and diffusion. Then the barriers for the two selected technologies and the possible measures to overcome these barriers are identified and analysed in section 1.2 and 1.3. Based on the analysis about the linkages of the barriers and possible solutions to them, section 1.4 will offer some suggestions on how the barriers can be addressed. More precisely, the resource requirements, strength and weaknesses of each solution will be discussed. An overall strategy for overcoming the barriers for energy industries and how to achieve specific technology transfer, diffusion, and deployment targets in this sector will be formulated and described in Section 1.5. If the preliminary target sets in the beginning of this chapter may be found too ambitious or too conservative based on the barrier analysis and enabling framework formulation process, the final strategy may have a different technology transfer and diffusion target, which should be specified.

1.1 Preliminary Targets for Technology Transfer and Diffusion

Barriers and enabling measures are closely related to the technology transfer and diffusion targets to be achieved. In this section, a broad view of 'target' is used to encompass: (1) physical targets in terms of penetration of RETs and EE in energy policy; and (2) beneficiaries. The investment costs required for the technologies are treated in sections 1.2.2 and 1.3.2.

The Long-Term Energy Strategy 2009 – 2025 provides the blueprint for the development of the energy sector in Mauritius (Ministry of Renewable Energy & Public Utilities, 2009). Further, the Energy Strategy 2011-2025 Action Plan (please see Annex 2 of TNA Report) provides the future orientations of Mauritius concerning GHG emission reductions from a combination of energy efficiency measures and renewable energy technologies. There are no economy wide energy targets, but targets for RETs and EE do exist for electricity generation and consumption. These targets are summarised in Table 2 and Table 3, respectively. Table 2 shows the electricity mix between 2010 and 2025, while Table 3 shows the cumulative EE target in the electricity sector relative to the 2008 baseline year.

Table 2. Electricity mix targets, 2010-2025.

Fuel Source		Percentage of Total Electricity Generated			
Renewable		2010	2015	2020	2025
	Bagasse	16	13	14	17
	Hydro	4	3	3	2
	Waste-to-Energy	0	5	4	4
	Wind	0	2	6	8
	Solar PV	0	1	1	2
	Geothermal	0	0	0	2
Sub-total		20	24	28	25
Non-renewable	Fuel oil	37	31	28	25
	Coal	43	45	44	40

The Energy Strategy 2011 – 2025 Action Plan can be downloaded at http://www.gov.mu/portal/site/mpusite - accessed 5 February 2012.

Sub-total	80	76	72	65
TOTAL	100	100	100	100

Table 3. Energy efficiency targets in the electricity sector, 2010-2025

Year	2010	2015	2020	2025
Target (%)	2	4	6	10

For the purpose of this report, further analysis of the technology targets is necessary. For wind energy, the updated Energy Strategy Action Plan 2011 – 2025 provides a timeline for installed capacity, as summarized in Table 4.

Table 4. Installed wind capacity to 2025, MW.

Year	2013	2014	2017	2020	2023	Total
Installed capacity (MW)	22	18	20	20	20	100

EE targets for the stationary combustion of fossil fuels (e.g. boilers in commercial and industrial settings) do not exist. The updated Energy Strategy Action Plan 2011-2025 mentions that guidelines for energy management in industry would be developed in 2012, and for mandatory energy audits to be carried out in industry as from 2013. Further, the Action Plan states that EE programmes based on voluntary agreements would be created for industry between 2011 and 2014. Although, targets for EE in boilers (waste heat recovery) will be revisited in Section 1.5, it is possible to provide an indication of the theoretical potential of interventions based on a top-down approach. Table 5 lists the total number of boilers in operation in Mauritius along energy source and geographical distribution. The numbers in brackets correspond to the total number of enterprises housing the boilers.

Table 5. List of boilers installed in Mauritius at march 2012.

	Diesel	LPG	Electricity‡	HFO	Coal	Paper/wood
Grand Port	2 (2)	1 (1)	16 (7)	3 (3)	0	0
Black River	0	0	0	2 (2)	0	0
Pamplemousses	10 (9)	9 (7)	59 (36)	23 (14)	4 (3)	1 (1)
Port Louis	2 (1)	0	5 (4)	4 (3)	0	0
P Wilhems	28 (22)	16 (12)	126 (69)	57 (37)	6 (5)	1 (1)
Flacq	10 (5)	16 (11)	36 (17)	1 (1)	1 (1)	
Moka	15 (11)	14 (11)	44 (29)	8 (8)	0	1 (1)
Savanne	8 (6)	8 (2)	29 (10)	8 (4)	1 (1)	0
R du Rempart	1 (1)	3 (2)	7 (6)	2 (2)	0	0
Total No. boilers	76	67	322	108	12	3
Total No. enterprises	57	46	178	74	10	3
% of total number of boilers	12.9	11.4	54.8	18.4	2.0	0.5

‡ These are electric geysers of less than 100L capacity that offer marginal incremental efficiency gain. Members of sectoral working group said that electric heaters could be left out of the analysis.

As is discussed in Section 1.3, this study has targeted boilers using LPG and diesel as primary energy sources – i.e. a total of 143 boilers representing 24.3% of all boilers used in industrial and commercial applications.

1.2 Barrier Analysis and Possible Enabling Measures for Wind Technology

This section provides an analysis of barriers that impede the uptake and diffusion of wind energy in Mauritius. In particular, LPA is used to identify the root causes of main barriers. Barrier decomposition is carried out to generate a Problem Tree (PT), and an Objective Tree (OT) that mirrors the PT has been developed to identify possible measures to overcome the root causes. All PT and OT can be found at Annex 1. First, an overview of wind energy technology is provided based on the TFS found at Annex 7(b) of the TNA Report.

1.2.1 General description of wind technology

A utility-scale wind turbine primarily consists of a main supporting tower upon which sits a nacelle (the structure containing the mechanical to electrical conversion equipment). Extending from the nacelle is the large rotor (three blades attached to a central hub) that acts to turn a main shaft, which in turn drives a gearbox and subsequently an electrical generator (see Figure 1). In addition to this there will be a control system, an emergency brake (to shut down the turbine in the event of a major fault) and various other ancillary systems that act to maintain or monitor the wind turbine.

Modern turbines reach a conversion efficiency of approximately 50 percent, close to the theoretical limit (59%) and very close to the practical limit that is imposed by the drag of the blades. Nevertheless there is a significant body of ongoing global R&D into construction methods/materials for larger turbines, conversion efficiency refinements, lower cost components and improved reliability. The energy used and GHG emissions produced in the direct manufacture, transport, installation, operation and decommissioning of wind turbines are small compared to the energy generated and emissions avoided over the lifetime of wind power plants: the GHG emissions intensity of wind energy is estimated to range from 8 to 20 g CO2/kWh in most instances, whereas energy payback times are between 3.4 to 8.5 months (Wiser, et al., 2011).

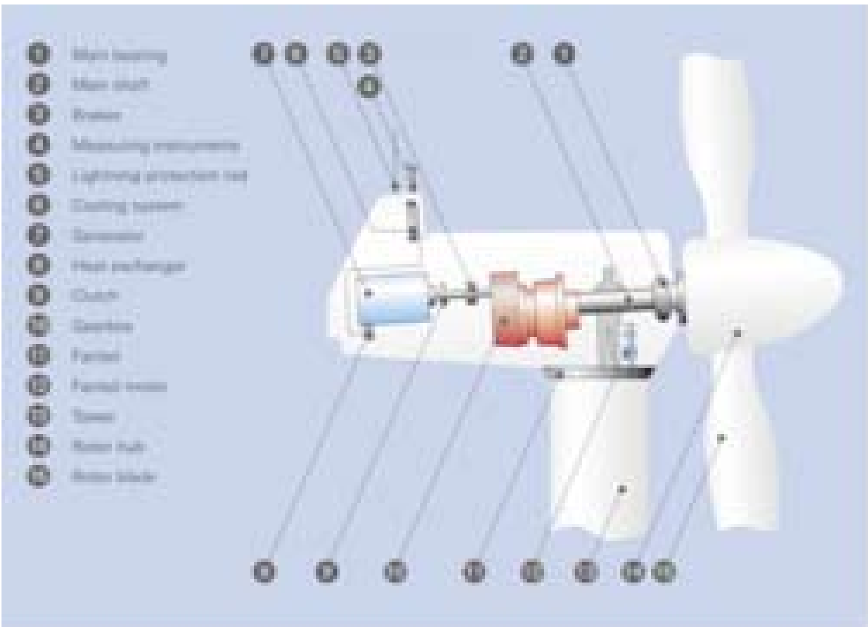

Figure 1. Transverse view of a typical wind turbine (source ZF, 2010).

The main issue related to applicability of wind technology in Mauritius is its suitability to operate in cyclonic conditions, when wind gusts exceeding 250 km/hr can be experienced. This is a serious issue since wind energy demonstration projects in the 1980s were damaged by cyclones (Palanichamy, Sundar Babu, & Nadarajan, 2004). Hence, turbines with wind Class II ratings would be needed for weather conditions of Mauritius. One example is the newly designed 1 MW GEV HP wind turbine by Vergnet that is proposed to be installed in Mauritius at Plaine des Roches that can withstand Category 5 hurricanes (i.e. wind speeds up to 300 km/hr). Suzlon's Class IIa S95-2.1MW generator is also expected to be used at Plaine Sohie (see Section 1.2.2). The 2-blade rotor is designed such that it can be lowered with minimum effort during cyclones.

1.2.2 Identification of barriers for wind technology

Barrier analysis for wind technology has been built on stakeholder consultations (see Annex 2 for details), thorough literature review and the consultants own knowledge of the local context. It is pointed out that barrier analysis for wind technology was initiated at the TNA Report Validation & TAP Tools workshop that was held in Mauritius on 25 and 26 July 2012. In the following sub-sections, barriers are discussed using market mapping and LPA as analytical tools (Boldt, Nygaard, Hansen, & Traerup, 2012). Before going into such details, however, a review of generic barriers facing wind technology diffusion has been carried out (Wiser, et al., 2011) (UNDP, 2008).

Technical barriers: Onshore wind energy is already being deployed at a rapid pace in many countries, and no insurmountable technical barriers exist that preclude increased levels of wind energy penetration into electricity supply systems. Nonetheless, in most regions of the world, policy measures to overcome barriers are still required to ensure rapid deployment. The Long-Term Energy Strategy and updated Action Plan 2011 – 2025 already provide the policy support for the deployment of wind energy in Mauritius (Ministry of Renewable Energy & Public Utilities, 2009). Even if Mauritius is prone to cyclonic conditions, wind energy technologies supplied by Vergnet and/or Suzlon are being contemplated for installation in Mauritius;

Operational barriers: Wind energy has characteristics that pose new challenges to electric system planners and operators, such as variable electrical output, limited (but improving) output predictability, and location dependence. Detailed analyses and operating experience suggest that, at low to medium levels of wind electricity penetration (up to 20% of total electricity demand), the integration of wind energy generally poses no insurmountable technical barriers and is economically manageable. Looking at the proposed penetration targets (see Table 2), it would seem that operational barriers should not be an issue in Mauritius. However, a grid-stability mapping exercise carried out by CEB has shown that the current grid could accommodate up to 30 MW of RET of intermittent source without modifications to the network. All that would be required is close monitoring of fluctuations in renewable electricity generation using proper interface electronics (AfD, 2010). The penetration of RETs of intermittent sources can increase when additional base load power plants are added to the electricity system. According to the updated Energy Strategy Action Plan 2011 – 2025, an additional grid capacity expansion of 100 MW coal-fired power plants will be added between 2014 and 2023 (50 MW each in 2014, 2015, 2019 and 2023). An increase of bagasse-generated base load electricity by 1.5 is also expected in 2015. Consequently, these base load capacity expansions justify the projected wind energy installed capacity given in Table 4.

Trade related barriers: An emerging feature in the development of indigenous markets for RETs (including wind energy) is the enactment of policies that put in place trade-related barriers for protecting local manufacturing and jobs (REN21, 2012). High domestic subsidies, regulations, and/or incentives that require or favour local content have been used to secure and maintain domestic benefits, but have also resulted in unfair competitive advantages. Under the rules of the WTO, such policies are very complex. Any restriction of international competition as a result of limiting free trade could inhibit the development and deployment of renewable energy globally.

The country-specific barriers are discussed in the following two sections, and the main results of the analysis are summarised in tabular form for ease of reference. However, before proceeding further, it is important to highlight the relationship between barriers and risks, especially from an investor's perspective. This is an important consideration and it will be further discussed in Section 1.2.3. Investing in utility-scale wind energy is capital intensive, and the objective of any investor would be to minimize risks associated with this investment. One way or another (either directly or indirectly), barriers (financial & economic barriers and non-financial barriers) increase the investment risks. These relationships are shown by the CLD in Figure 2. The '+' sign means that a change in one variable gives rise to a change in the same direction in the other variable – i.e. an increase in barriers causes an increase in risks.

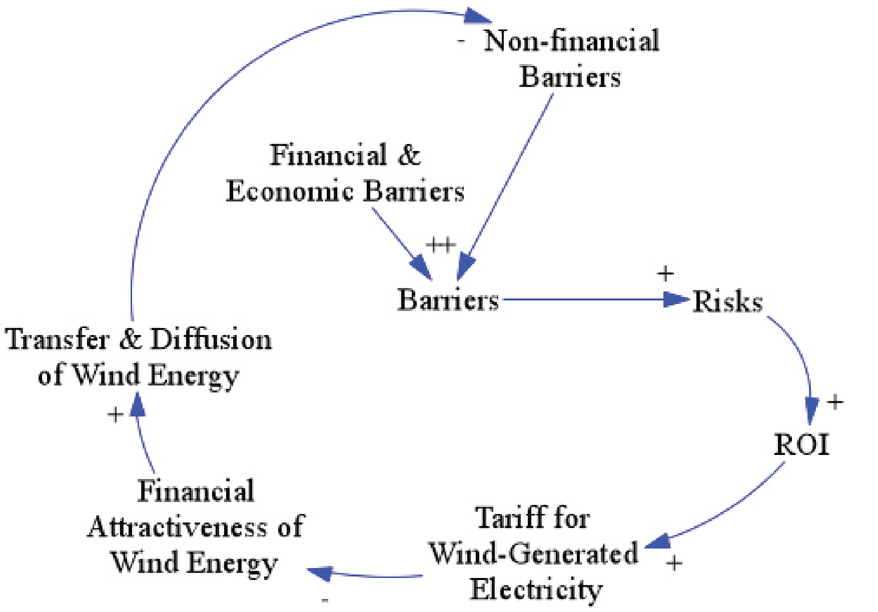

Figure 2. CLD to illustrate the positive feedback loop between barriers, risks and diffusion of wind energy.

Increasing risks would imply that the technology would require a higher ROI (say in terms of IRR) for being financially attractive. In the case of utility-scale wind energy, a higher IRR translates directly into a higher price of electricity that needs to be paid to the investor for producing renewable electricity. These causal relationships give rise to a vicious circle that prevents the uptake of utility-scale wind energy (or other types of RETs). In the CLD, the low uptake of utility-scale wind energy would also have a detrimental impact of at least maintaining non-financial barriers in place. For instance, the lack of wind farms could maintain the perception that wind energy may be technologically risky. The CLD shown in Figure 2 is useful since it shows that although barriers may be broken down into the two broad categories discussed in the next sections, they can also be interrelated. The linkages are discussed in Section 1.4. A CLD is developed in Section 1.2.3 to show how measures reduce underlying barriers and risks, resulting in the uptake and diffusion of utility-scale wind energy.

1.2.2.1 Economic and financial barriers for wind technology

Although the earlier wind farming attempts resulted in failure, considering the world-wide practicing magnitude of wind farming, its cost effectiveness, the expansion possibilities, the well-matured status, it is always better for a developing island nation like Mauritius to go for proven technology (Palanichamy, Sundar Babu, & Nadarajan, 2004). The current and ongoing question in Mauritius is not a matter of access to capital for investment in utility-scale wind energy technologies as evidenced by forthcoming PPP projects like Plaines des Roches and Plaine Sophie, or even the willingness of existing power sector actors like Omnicane Ltd to invest in wind technology at Britannia. As discussed earlier, an investor's perspective is rather on ROI (defined in IRR terms) that is intricately linked with the issue of differential tariff that would be proposed to prospective investors for the sale of electricity to the CEB. Another important consideration of risk associated with utility-scale wind energy is that close to 75% of the lifetime total cost of wind energy is related to upfront costs for the wind turbine, geotechnical and civil engineering, and grid interconnection (Krohn et al, 2009). The need for financial instruments to address barriers and reduce investment risks are already recognized by policy makers, since the updated Energy Strategy Action Plan 2011 – 2025 proposes two supporting initiatives, namely: (1) the setting of cost-reflective electricity tariffs and financial support schemes for renewables over the 2012-2013 timeframe, and (2) introducing preferential FiTs for electricity generation from renewable energy sources for plants above 50 kW.

This analysis shows that the energy strategy already recognizes that the tariff for the sale of electricity is a significant barrier for the deployment of utility-scale wind farms. To emphasize the scale of impact of differential tariffs for the promotion of RETs, it is timely here to make a parallel with FiT that has been put in place in for selected RETs at the decentralized scale and having installed system capacity lower than 50 kW. In order to gauge the significance of the FiT, a comparison is made with the electricity tariffs practiced by CEB for the sale of grid electricity. The FiT for SSDGs and CEB tariffs are shown in Table 6 and Table 7, respectively. For Greenfield projects, the FiTs are 15% lower than those shown in Table 6. Comparison of the electricity tariffs listed in Table 6 and Table 7 unambiguously shows the significance of financial incentives to support the uptake and market development of RETs at the decentralized generation level. Both the long-term duration of the FiT scheme and guaranteed access to the grid are important features of the financial incentive scheme.

Table 6. FiT for decentralised RETs (SSDGs).

Installed Capacity (kW)	FiT for 15 years (Rs/kWh)		
	Wind	Hydro	PV
Micro (up to 2.5 kW)	20	15	25
Mini (2.5 – 10 kW)	15	15	20
Small (10 – 50 kW)	10	10	15

http://www.omnicane.com/index.php?tid=70&lang=1 – accessed 26 November 2012.
The differential tariff would be compared against the cheapest alternative to provide an equivalent amount of electricity. In the case of Mauritius, the cheapest option would be coal. It should be noted that the updated Energy Strategy Action Plan 2011 – 2025 (http://www.gov.mu/portal/goc/mpu/file/plan2806.doc or Annex 2 of TNA Report) already makes provision for increased coal-fired power plant capacity by 100 MW by 2015.

It is pointed out that FiTs for renewable energy systems for installed capacities less than 50 kW already exist. Please follow the SSDG (Grid Code) at http://ceb.intnet.mu/ - accessed 26 November 2012.

Table 7. Selected consumer tariffs applied by CEB.

Consumer category	Tariffs (Rs/kWh)	Remarks
Domestic (110/120/140)	3.16 to 8.77	There is an increasing scale based on quantity consumed. The highest rate is applicable for every unit consumed after the first 300 kWh per month.
Commercial (215)	10.01	This is the flat-rate running charge. There are also other types of tariffs based on KVA used and power factor.
Industrial (315)	5.40	This is the flat-rate running charge. There are also other types of tariffs based on KVA used and power factor.

In the case of SSDGs, the FiTs are fixed and applicable for a period of 15 years. After the initial contract has lapsed, the rate of sale of electricity to the utility is equal to the marginal cost of electricity generation by CEB. The utility signs a contract with the SIPP guaranteeing the conditions of sale of electricity to the grid. This long-term contract provides clear visibility for the investor and the PBT for investment is of the order of 7 – 8 years. The initial scheme was opened up to a maximum of 2 MW of installed SSDGs, and this ceiling was recently increased to 3 MW.

The FiT scheme to support SIPPs has been hailed as a success story and it has certainly generated a market supply chain especially for PV. The FiT policy has attracted over 400 applications for residential and commercial systems (totalling 3.8 MW of capacity, overwhelmingly for PV systems) and over 80 applications from public, education, charity and religious organizations (totalling approximately 1 MW of capacity). Close to 1MW of capacity has already been installed and commissioned (Glemarec, Rickerson, & Waissbein, 2012). The financial sustainability of the SSDG programme – i.e. capitalization of the incentive scheme - remains to be seen. The FiT for PV systems smaller than 50 kW is being been supported by a tax on all fossil fuels used in Mauritius, but the revenues from these taxes are not sufficient to additionally support the development of systems larger than 50 kW (Glemarec, Rickerson, & Waissbein, 2012). Traditionally, the rate recovery of price premiums paid to IPPs has been difficult in developing countries, thereby undermining the long-term financial sustainability of such schemes (Woodhouse, 2005). In the prevailing socio-economic and political context, it is also unlikely that a rise in electricity tariffs would be implemented to cover at least partially the price premium of a FiT scheme for utility-scale wind energy.

So the financial viability of RETs, including wind energy, has two faces depending on the reference frame. The lack of financial sustainability of wind energy may be seen as a lack of preferential tariff – i.e. FiT – from the perspective of the investor, while it may be mirrored as a lack (means) of capitalization of the incentive scheme by the public authority or any institution that has to cover the price premium of wind-generated electricity. This issue is discussed further in Section 1.2.3.1 by looking at the transfer and diffusion of utility-scale wind energy within the larger context of an economy-wide or sectoral approach to GHG emission reductions.

The consumer categories and selected tariffs were obtained from http://ceb.intent.mu/ - accessed 26 November 2012.
This figure was provided by CEB as input to MCA during the technology prioritization step, and corresponds to

In order to gauge the financial and economic barrier facing utility-scale wind energy, a financial model has been developed to investigate the IRR for the assumptions given in Table 8. The financial model was developed for investigating the financial additionality of carbon finance, and it therefore covers a timeframe of 10 years (i.e. a fixed crediting period of 10 years under the CDM). The financial model has not taken inflation rate into account.

Table 8. Parameters used in financial model for utility-scale wind energy.

Parameter	Value
Installed Capacity	25 MW
Capacity Factor	25% (i.e. 2190 hr/yr)
Electricity generated	54,750 MWh/yr
Interest rate for debt	12% p.a.
WACC (discount rate)	14% (80% debt at 12% interest rate & 20% equity at 20% rate of equity return)
Carbon Finance	None
Capital investment (turbine)	€1,500 / kW
Exchange rate (€ to LC)	39

Based on these assumptions, the (minimum) tariff required to give an IRR equal to the interest rate on debt (12%) has been calculated as Rs 5.70/kWh. Assuming that the production of electricity in the existing baseline scenario has been taken as Rs 4.50/kWh, the analysis clearly shows that a price premium equal to at least Rs1.20/kWh has to be paid for utility-scale wind energy to be financially viable. Since the price of carbon credit is significantly depressed, including carbon-related revenues has a marginal impact on the price premium required to make utility-scale wind energy financially viable. The sensitivity of IRR on the price of wind-generated electricity is given in Table 9.

Table 9. Sensitivity analysis of electricity price on IRR.

Price of electricity (Rs/kWh)	5.50	5.75	6.00	6.25	6.50
IRR (%)	11.41	12.03	12.93	13.66	14.37

Although a FiT for utility-scale wind energy would be much lower than that provided under the SSDG scheme (see Table 5), the capitalization of the FiT scheme would be a much bigger issue because of the significantly larger volume of electricity generated by utility-scale wind farms as per the policy targets shown in Table 4.

It is understood here that economic barriers due to currency stability and inflation are not significant issues that would impede the transfer of wind energy technology to Mauritius. Further, it is expected that inflation would be accounted for in establishing the relevant FiTs to support the integration of utility-scale wind energy into the national grid. This would, therefore, be different from the existing FiT for SSDGs that offer a flat price premium over a 15-year period. It is also pointed out the exchange rate of LC relative to major currencies would probably be taken into account in setting the FiT for utility-scale wind energy (or any other RET) to cover cases when the debt component of capital investment is taken in foreign currencies. This is an issue that has not been taken into account in the present analysis since it has been assumed that both the debt and equity components of investment would be contracted and serviced in LC.

1.2.2.2 Non-financial barriers for wind technology

This section discusses the main non-financial barriers confronting utility-scale wind energy development in Mauritius. For completeness, emerging barriers that may not be applicable to Mauritius are also discussed since these issues provide insights into the wind energy market system in Mauritius. Hence, the discussion complements that on enabling framework given in Section 1.5.

Regulatory framework: The absence of an independent regulator can constrain the development of market structures conducive to private investment, and impede the enforcement of renewable energy policies. Currently, Mauritius lacks a strong, independent regulator. The Utility Regulatory Authority Act 2004 (No. 42 of

2004) provides for the establishment and management of a Utility Regulatory Authority (URA) that would act as an independent regulator. The URA shall principally regulate, control and supervise utility services. Initially, utility services would be only electricity services in the sense of the Electricity Act, 2004, but the Act foresees the inclusion of wastewater disposal services and services relating to the sourcing, collection, production, treatment, distribution or supply of water for domestic, agricultural, commercial, industrial or other purposes. The Utility Regulatory Authority (Amendment) Bill (No. XXIV of 2008) has been proposed to further provide for the Authority to examine and make recommendations to a licensee in respect of any:
(a) PPA proposed to be signed, or entered into by it;
(b) management services contract, operation and maintenance contract or any other contract which it proposes to enter into in relation to water services or waste disposal services.

It is worthwhile to note that the updated Energy Strategy Action plan 2011 – 2025 mentions that the URA would be established in 2011/2012. Despite the presence of supportive legal and policy frameworks, the URA is yet to be set up, and the lack of such a body continues to be a regulatory barrier.

Wind energy resources assessment: Although different potential investors in utility-scale wind energy have carried out individual and highly localized wind energy resources ground-truthing exercises, Mauritius still lacks a wind energy resources atlas. The lack of such an atlas has two interrelated consequences:

1. Potential investors do not have a good understanding of practical wind-energy development in Mauritius; and

2. It makes it difficult to set up a dynamic FiT for wind energy for Mauritius.

As discussed earlier, since all risks associated with the development of utility-scale wind energy eventually translate into relatively higher IRR, the second consequence of not having a wind atlas is further discussed in Section 1.4.

Human and institutional capacity: Lack of human skills to erect, operate and maintain wind energy technology is commonly referred to as main barriers for wind energy development. However, this is not expected to be a serious hindrance in Mauritius. The main reason is that regardless of the modality of wind farm projects (i.e. PPP or purely private) in Mauritius, the consortium of investors will have a partner that has all the required technical expertise in the erection, operation and maintenance of wind farms. In some cases, the consortium will have a manufacturer of wind turbines, such as in the case of the involvement of Suzlon in the proposed wind farm at Plaine Sophie.

Further, CEB has expertise in interconnecting and managing wind energy and PV to the national grid. Through ongoing negotiations, CEB is also building internal capacity to draft and negotiate EPAs with investors. Further, CEB (and any other government institutions like the MoEPU) are assisted by a Transaction Adviser in technical and legal matters pertaining to wind farms.

1.2.3 Identified measures for wind technology

A key challenge for policymakers is to create the conditions to make renewable energy attractive to investors and utilities without jeopardizing the attainment of other equally important development goals or placing an inequitable share of the cost burden on rate payers. In order to achieve these objectives, policymakers in developing countries have been exploring a broad spectrum of different policies, incentives and support mechanisms. Broadly, these can be grouped into policy and financial derisking instruments (Glemarec, Rickerson, & Waissbein, 2012):

• Policy derisking instruments seek to remove the underlying barriers that are the root causes of risks. As the name implies, these instruments utilize policy and programmatic interventions to mitigate risk and include, for example, support for policy design, institutional capacity building, information campaigns and training programmes, among others; and

• Financial derisking instruments do not seek to directly address the underlying barriers, but instead transfer the risks that investors face to public actors, such as development banks. These instruments can include, for example, loan guarantees, political risk insurance and public co-investments.

The approach is illustrated in Figure 3. A commercially unattractive investment opportunity can be converted into a commercially attractive one through two actions: (i) reducing the risk of the activity through say a regulatory policy – e.g. guaranteed access to the grid for IPPs; and (ii) increasing the ROI by creating financial incentives – e.g. FiT for renewable energy. This two-dimensional upscaling approach may not be sufficient to eliminate all risks, so that efforts to reduce risks can be complemented by additional financial incentives to compensate for any residual above-average risks and costs. Also the enabling framework that is conducive for technology transfer and diffusion needs to be in place as discussed in Section 1.5.

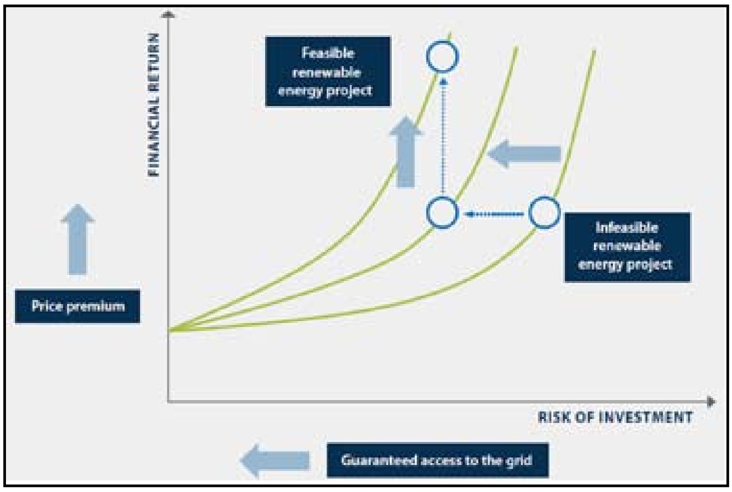

Figure 3. Shifting the risk-reward profile of RETs.

At this juncture, and within the broader context of the risk-reward framework shown in Figure 3, it would be good to look at the generic policy instruments that are available for the promotion of RETs including utility-scale wind energy (REN21, 2008). A brief description of the main policy instruments is summarized in Table 10.

Table 10. Renewable energy promotion policies.

Policy instrument	Brief description
Feed-in Tariff (FiT)	A policy that sets a fixed guaranteed price at which power producers can sell renewable power into the electric power network. Some policies provide a fixed tariff while others provide fixed premiums added to market- or cost-related tariffs
Renewable Portfolio Standard (RPS)	Also called renewables obligations or quota policies. A standard requiring that a minimum percentage of generation sold or capacity installed be provided by renewable energy. Obligated utilities are required to ensure that the target is met
Capital subsidies, grants, or rebates	One-time payments by the government or utility to cover a percentage of the capital cost of an investment, such as a solar hot water system or rooftop solar PV system

Policy instrument	Brief description
Investment or other tax credits	Allows investments in renewable energy to be fully or partially deducted from tax obligations or income
Sales tax, energy tax, excise tax, or VAT reduction	Various forms of indirect fiscal incentives given to investors on procurement of RET equipment and parts, and tax incentive on energy used to develop RET project
Tradable renewable energy certificates	Each certificate represents the certified generation of one unit of renewable energy (typically one megawatt-hour). Certificates provide a tool for trading and meeting renewable energy obligations among consumers and/or producers, and also a means for voluntary green power purchases
Energy production payments or tax credits	Provides the investor or owner of qualifying property with an annual tax credit based on the amount of electricity generated by that facility
Net metering	Allows a two-way flow of electricity between the electricity distribution grid and customers with their own generation. The customer pays only for the net electricity used
Public investment, loans, or financing	Capital financing provided by the public sector either directly in a project or as a loan
Public competitive bidding	Open and transparent public procurement processes that promotes competitive bidding for renewable energy projects. This is part of providing an environment conducive for capital investment in RETs

The use of measures to overcome barriers and hence risks associated with investment in utility-scale wind energy is shown in Figure 4. Measures reduce barriers (-ve polarity on red arrows) that reduce risks, and hence the need for a lower ROI. This would require a lower tariff for wind-generated electricity to make utility-scale wind energy financially attractive. In turn, this would increase the financial attractiveness of wind energy compared to the baseline scenario (thermal generation using fossil fuels) that would enhance technology transfer and diffusion, and further decrease non-financial barriers. The vicious circle shown in Figure 2 has, therefore, been transformed into a virtuous circle of technology transfer and diffusion using measures.

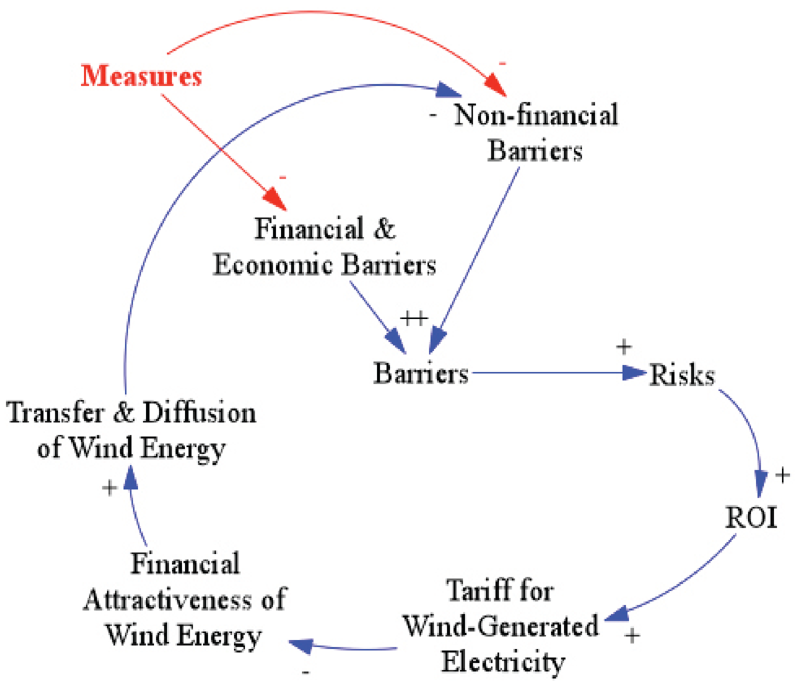

Figure 4. CLD showing how measures promote diffusion of wind energy by reducing barriers and risks.

1.2.3.1 Economic and financial measures for wind technology

Based on the barrier analysis in Section 1.2.2.1, it is evident that the main barrier to the diffusion of utility-scale wind energy remains a financial one, namely the presence of an attractive and transparent FiT. Before proceeding with the detailed analysis of the local context, a review of the global status of the merit and significance of economic and financial measures for RETs is timely here. This is warranted since the risk reward profile of Mauritius may not be different from other countries from an investor's perspective, meaning that lessons learned elsewhere may well be transposed to the local context. Box 1 summarizes some lessons learned from various recent studies.

As discussed in Section 1.2.2.1, the capitalization is of key importance for the financial sustainability of any FiT initiative. So, an integral part of the measure should be to identify clearly utility cost-recovery processes (DB Climate Change Advisors, 2011). This constitutes an important aspect of providing security, and hence confidence, to investors.

Based on the analysis given in Section 1.2.2.1, it is proposed that a price premium of Rs 6/kWh would be paid to investors to generate renewable electricity from wind. In order to calculate the full extent of this financial measure, its benefit-cost analysis has been performed. The costs and benefits have been calculated to 2025, which is the time horizon for the existing energy strategy. The calculations have made several assumptions and these will be discussed where relevant. All costs and benefits have been calculated in present value using a discount rate equal to WACC (i.e. 14% as per Table 8).

Total cost of financial incentives for utility-scale wind energy

The cost of this measure is the incremental cost of the preferential tariff or FiT. Hence, the cost of the measure is taken as Rs1.5/kWh (i.e. Rs6/kWh – Rs4.5/kWh). As per the methodology used here, the total quantity of electricity that is expected to be generated by wind through to 2025 has to be calculated. To do this, the CF of each proposed wind farm has to be known. CF is site specific and in the absence of knowledge of sites where future wind farms will be installed, a threshold CF = 20% has been used. It is assumed that wind farms with the highest CF are built first and that future wind farms would have decreasing CF. The annual electricity generated from wind is summarized in Table 11.

Year	2013	2014	2017	2020	2023
Installed capacity (MW)	22	18	20	20	20
CF (%)	25	20.7	20.5	20	20
Electricity generated) (MWh/yr	48,180	32,640	35,916	35,040	35,040

The next step was to calculate the cumulative yearly generation of electricity in MWh/yr, which when multiplied by Rs1,500/MWh (equivalent to Rs1.5/kWh) yields the cumulative yearly cost of the measure. The NPV of the cost of the measure has been calculated as Rs 937,695,079. It is pointed out here that this calculation has:

- Excluded the effect of inflation;
- Excluded the effect of learning curve of wind energy technology that would lead to cost parity over the long-term (i.e. no incentive required in the long-term);
- Assumed that a FiT of at least 15 years would be provided to investors (the period studied here is 13 years)

Benefits of financial incentives from utility-scale wind energy

To calculate the benefits derived from the financial incentives given to promote wind energy technology, the following benefits have been quantified to 2025:
1. Global environmental benefit from GHG emission reduction using the long-term price of CO2e;
2. Incremental job creation; and
3. Reduction in energy bill through import substitution. Although this will change depending on the price of imported oil and price volatility, potential future increases in the price of oil have not been taken into account here. The analysis has used a weighted average of fossil fuels used to generate electricity over the past 3 years.

The methodology for calculating the benefits are shown at Annex 3.

Benefit-Cost ratio of financial incentives
The calculations of NPV of costs and benefits of the financial measures give a benefit-cost ratio equal to 4.84. This shows that the benefits of the financial measures far outweigh its direct costs. The benefit-cost ratio can be expected to be higher since it would be reasonable to expect that both the price of CERs and imported fossil fuels would increase in the future, thereby increasing the monetary value of benefits.

1.2.3.2 Non-financial measures for wind technology

In order to create the conditions for private and public sector financing initiatives to be effective, there is often the need for customized technical assistance, capacity building, planning assistance or other non-financial support for domestic renewable energy markets (DB Climate Change Advisors, 2011). The successful application of FiT for the promotion of utility-scale wind energy (or other RETs) require a good fit with national circumstances, especially policy, regulatory and legal frameworks. A discussed in Section 1.2.2.2, the main non-financial measures are:

1. URA is set up as an independent energy regulator and it is fully functional and capacitated to fulfil its mandate ; and
2. Establish a wind energy resources atlas that will provide the multiple benefits of: (i) providing visibility to potential investors; (ii) forming the basis for establishing a dynamic FiT scheme; and (iii) allow the determination of the threshold wind energy potential needed for the technology to be financially viable. It is pointed out that the Government of India is currently assisting the MoEPU to carry out wind energy resources assessment and to develop the wind atlas for Mauritius. Hence, the cost of this measure has not been accounted for in order to avoid duplication.

As discussed in Section 1.2.2.2, the regulatory framework for setting up the URA has been in place for several years. The setting up of the URA will take place through a political process that is beyond the scope of this study.

1.3 Barrier analysis and possible enabling measures for boiler economizer

An analysis of the main barriers that impede the uptake and diffusion of waste heat recovery using boiler economizers in industrial and commercial applications is provided in this section. The procedure for identifying the root causes of these barriers is the same as in the case of utility-scale wind energy. The PT and OT for scaling-up the use of economizers can be found at Annex 1.

1.3.1 General description of boiler economizer

An economizer is a gas-water heat exchanger that allows the recovery of part of the heat contained in the boiler's flue gases, heating the water fed to the boiler. The hot waste flue gases give up the heat and are then vented to the atmosphere. The economizer consists of a shell, which is installed in the flue line, inside which there is a bundle of finned tubes through which the water to be heated circulates, and outside which gases circulate. Thus, the temperature of the flue gas is reduced and boiler efficiency is increased. Most boilers, particularly fire-tube boilers, are not sold with an economizer, unless the user so requires, which is not generally the case in Mauritius.

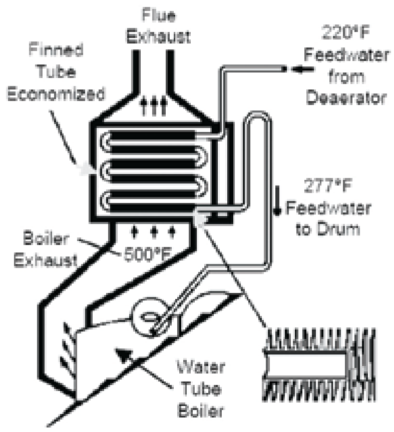

Figure 5. Finned-tube boiler economizer (US Department of Energy, 2008).

The cost of the economizer depends on the size of the boiler in which it is installed, since a larger economizer is required for a greater flow of gases. In general, its installation is justified for boilers with a capacity of more than 300 BHP (diesel) or 700 BHP (residual) and with a continuous operation of more than 5000 h/year. The energy saving usually achieved is up to 3% ((Institute for Applied Ecology, 2003)).

A significant advantage of an economizer is that it can be designed and retrofitted onto an existing boiler. The lifetime of a typical industrial boiler is between 10-20 years.

1.3.2 Identification of barriers for boiler economizer

The analysis of the main barriers relevant to Mauritius is provided in Sections 1.3.2.1 and 1.3.2.2 based on information provided by local market players (suppliers and end-users of economizers). The corresponding LPA is found at Annex 1. First, the generic barriers for the adoption of economizers for waste heat recovery from industrial and commercial boilers have been reviewed.

While some of barriers are specific to the given context (see Sections 1.3.2.1 and 1.3.2.2), many are crosscutting across several waste heat recovery (WHR) applications. They reduce the effectiveness of existing heat recovery systems and, in some cases, prevent recovery systems from being installed. In this section, key restrictions are presented by cost (economic/financial), heat stream composition, temperature, process and application specific constraints, and inaccessibility/transportability of certain heat sources (US Department of Energy, 2008) (de Gouvello, Dayo, & M, 2008). The barrier analyses of selected CDM PDDs using AMS-II. B. Supply side energy efficiency improvements – generation have also been reviewed (UNFCCC, 2012). The generic barriers preventing the diffusion of boiler economizers are summarized in Table 12, and their relevance (or irrelevance) in the local context is highlighted.

Table 12. Summary of generic barriers to WHR.

BARRIERS	REMARKS
Cost (financial and economic barrier)	
Long payback periods	Costs of heat recovery equipment, auxiliary systems, and design services lead to long payback periods in certain applications.
Material constraints and costs	Certain applications require advanced and more costly materials. Not applicable in Mauritius through exclusion of boilers running on HFO.
Economies of scale	Equipment costs favour large-scale heat recovery systems and create challenges for small-scale operations.
Operation and maintenance	Corrosion, scaling and fouling of heat exchange materials lead to higher maintenance costs and lost productivity.
Temperature restrictions (technical barrier)	Temperature restrictions (technical barrier)
Lack of an end use	Many industrial facilities do not have an onsite use for low temperature heat. Not applicable in local context since recovered waste heat is used for pre-heating water to boiler.
Material constraints and costs	Low temperature – Liquid and solid components can condense as hot streams cool in recovery equipment, leading to corrosive and fouling conditions. The additional cost of materials that can withstand corrosive environments often prevents low temperature recovery. High temperature – Materials that retain mechanical and chemical properties at high temperatures are costly. Therefore, waste heat is often diluted with outside air to reduce temperatures. This reduces the quality of energy available for recovery. The heat flow in some industrial processes can vary dramatically and create mechanical and chemical stress in equipment.

The lifetime can be as long as 20 years in local operating and maintenance conditions when the boiler is run on LPG. When run on diesel, the lifetime is reduced because of the sulphur content in the fuel, albeit at around 40-50 ppm. Communication with Mr Bernard Domingue, Vivo Energy – 19 December 2012.
The screening of selected PDDs using the small-scale methodology allows the contexts prevailing in developing countries to be assessed. These have been used to substantiate the prevailing practice in Mauritius.

BARRIERS	REMARKS
Heat transfer rates	Smaller temperature differences between the heat source and heat sink lead to reduced heat transfer rates and require larger surface areas. Not a problem in local context where heat differentials in excess of 80°C are experienced.
Chemical composition (technical barriers) – None are applicable in this report by excluding boilers running on HFO that contain high contents of sulphur that leads to the generation of highly corrosive sulphuric acid.	
Temperature restrictions	Waste heat stream chemical compatibility with recovery equipment materials will be limited both at high and low temperatures.
Material constraints and costs	Streams with high chemical activity require more advanced recovery equipment materials to withstand corrosive environments.
Operation and maintenance costs	Streams with high chemical activity that damage equipment surfaces will lead to increased maintenance costs.
Environmental concerns	Waste heat recovery from exhaust stream may complicate or alter the performance of environmental control and abatement equipment.
Product/Process control	Chemically active exhaust streams may require additional efforts to prevent cross-contamination between streams.
Heat transfer rates	Deposition of substances on the recovery equipment surface will reduce heat transfer rates and efficiency.
Application specific constraints (operational barrier)	
Process/quality control	Heat recovery can complicate and compromise process/quality control systems. Interview with market actors has shown that this is not an issue in the local context.
Inaccessibility/Transportability constraints (operational barriers)	
Limited space	Many facilities have limited physical space in which to access waste heat streams (i.e., limited floor or overhead space).
Transportability	Many waste heat gaseous streams are discharged near atmospheric pressure (limiting the ability to transport them to and through equipment without additional energy input).
Inaccessibility	It is difficult to access and recover heat from unconventional sources such as hot solid product streams (e.g., ingots) and hot equipment surfaces (e.g., sidewalls of primary aluminium cells). Not applicable in local context where boilers are used for producing steam or hot water.
Lack of knowledge/awareness	
Opportunities and benefits of WHR unknown	Potential end-users of economizers often lack knowledge about WHR opportunities and their benefits
Conflict of investment priorities	The lack of knowledge about the opportunities and benefits of WHR results in little or no allocation of capital budget for EE.
Lack of best practices	Absence of best practice guidance prevents benchmarking and possibility for replication. There is no post-mortem analysis of economizers that can be used by potential end-users to guide investment decision-making.
Lack of energy managers	Energy managers are seldom employed in operations resulting in ad hoc interventions on EE at best.

Fabiani Appavou, Energy Efficiency in Industry – Show me the money (http://www.gov.mu/portal/site/EEMOSite/ - accessed 27 November 2012).

1.3.2.1 Economic and financial barriers for boiler economizer

With the previous discussion serving as backdrop, it is timely to contextualize the low-penetration of boiler economizers in local industries and commercial applications. In order to better understand the context, bilateral meetings were held with both suppliers and end-users of the proposed EE technology. All the key stakeholders have singled out the high upfront capital cost of the equipment as the main impediment for the widespread diffusion of boiler economizers. One supplier also mentioned that the cost of installation is also very high since retrofitting economizers on existing boilers require substantial modifications.

1.3.2.2 Non-financial barriers for boiler economizer

Economizers can be used in cases where the primary energy source is LPG or diesel. So far it is not economical for boilers run on HFO because of the high sulphur content. During the heat recovery process the flue gas is cooled down, and, although cooling below the dew point of sulphuric acid can be avoided, there would still be condensation of water that would mix with the SO2 to form highly concentrated sulphuric acid. This acid would corrode the economizer in a short period of time, and lead to the technical barriers due to chemical composition listed in Table 12. One way to mitigate this constraint is to use high grade stainless steel that can resist corrosion from acids. This measure would increase the capital, and O&M costs, and therefore make the use of economizer non-economical at the end due to much longer payback periods. This was also confirmed by other technology suppliers and end-users. In order to avoid these barriers, the TNA project has targeted boilers that run on LPG and diesel only (please see Table 5).

Other barriers are:

• Low awareness of the technology: Facilities that do not employ engineers may not be aware and show any interest unless being approached by consultants that are already scarce on the local market. This lack of awareness of the benefits of EE and use of LCA imply that capital budgeting excludes investment in EE measures and focuses on operations;

• There is a lack of consultants who would conduct detailed engineering studies (with accurate measurements) to evaluate energy savings opportunities from flue gas within defined precision levels and provide guarantee of savings. This is an important factor necessary to convince Top Management to show interest and confidence in energy efficiency projects. Very often it is production that takes the lead and not energy efficiency.

Response provided by Dr Dinesh Surroop, Senior Lecturer, University of Mauritius, and Mr Soorianan Narsiah, Director, Energy Concept, Canada. Private communication through email on 6 December 2012; Mr Bernard Domingue, Vivo Energy, Mauritius. Phone communication on 18 December 2012; Ms Shyama Buctowar, RTKnits, Phone Communication on 19 December 2012.

Communications with Mr Fargy Romaly, Rey & Lenferna – 19 December 2012.
Response provided by Dr Dinesh Surroop, Senior Lecturer, University of Mauritius, and Mr Soorianan Narsiah, Director, Energy Concept, Canada. Private communication through email on 6 December 2012.

1.3.3 Identified measures for boiler economizer

1.3.3.1 Economic and financial measures for boiler economizer

Since cost is a key barrier to heat recovery, it is important that any efforts for technology development focus on reducing both the capital and operating costs of heat recovery equipment (US Department of Energy, 2008). Barrier analysis has revealed that the same key barrier prevails in the local context. Based on the barriers analysis in Section 1.3.2, it is evident that there are limits to the reduction of both capital and operating costs of heat recovery equipment. One way to achieve the same objective would be to provide economic and financial incentives to lower the capital investment costs and other barriers to investment. Currently, such incentives do not exist in Mauritius.

Overcoming the economic and financial barriers for the up-scaling of waste heat recovery has obvious costs. However, looking at the cost of economic and financial measures does not provide the full picture of the utility of EE in industry and commercial applications. In order to weigh the viability of the economic and financial measures, it is important to also consider the benefits of the measures. Since upfront capital costs are high, it is important to use the LCA to understand the benefits of WHR using boiler economizer. The CBA for economic and financial measures is discussed now.

Cost of economic and financial measures

The costs of the following items have been calculated to obtain the total cost of economic and financial measures:

1. Free energy audit for each boiler, including technical assistance for identifying the design and type of economizer;
2. Rebate scheme on capital investment;
3. Incremental cost of training of operational staff on energy management; and
4. Incremental O&M costs.

These measures are derived from the PT and OT for boiler economizer found at Annex 1. The first three constitute a package of measures designed to overcome the shortcoming of previous schemes, which suffered for lack of implementation due to inadequate investment capacity (see footnote 18).
The parameters for a typical economizer are summarized in Table 13.

Table 13. Summary of the cost of economic and financial measures for a typical economize

Measure	Cost (Rs)	Remarks
Energy audit	10,000 / unit	It is assumed that one energy audit will be carried out for each boiler for retrofitting an economizer. Each energy audit would require one day's work by a professional auditor. It is assumed that this would be carried out for free as an incentive for associated capital investment.
Rebate scheme on capital investment	327,986.7 / unit	20% of the capital investment will be provided as a rebate scheme (financial incentive). The capital cost is taken as Rs 1, 640, 000 for one unit.
Training of energy manager	5,402 / unit	Specialized agencies, such as EEMO and/or the Ministry of Industry, would provide training to energy managers at the level of 1 person per enterprise.
O&M	54,000 per unit per year	Once installed, it is assumed that O&M expenses would be negligible to 2025.

Enterprise Mauritius ran a fully-subsidized scheme in 2010 where selected enterprises were offered energy audits and recommendations for EE interventions. Since the companies were not provided with economic and financial incentives, they did not implement EE measures that required upfront capital investment. Private communication with Dr D. Surroop and Mr S. Narsiah – 6 December 2012.

In all cases, the lifetime has been taken as at least 13 years, implying that the replacement cost of an economizer need not be considered over the time horizon (to 2025) studied here.

Benefits of economic and financial measures

The benefits of a higher diffusion of economizers can be carried out at two levels, namely: (1) operational level of industrial and commercial users of boilers (bottom-up approach); or (2) macro socio-economic and environmental level for country-level aggregate (top-down approach). For ease of simplicity, the top-down approach has been adopted here (de Gouvello, Dayo, & M, 2008). Hence, the total benefits of a larger uptake of economizers have been quantified using the three parameters that were considered for utility-scale wind energy in Section 1.2.3.1.

For practical reasons, it was not possible to apply the bottom-up approach to estimate the quantity of fossil fuels used for heating in industry and commercial applications. A top-down methodology was, therefore, developed, and it consisted of the following steps:

1. Identifying fossil fuels sources: Since thermal power plants that use co-firing with coal already operate in cogeneration mode, the use of coal is excluded from the analysis. Also, since the sulphur content of HFO is very high, and the production of sulphuric acid leads to corrosion of economizers, boilers running on HFO are also excluded from the analysis. Hence, only LPG and diesel oil as primary sources of heat in boilers are considered here. Identifying the primary energy sources for heating in industry and commercial applications also sets up the boundary for boilers that are considered in this report. This is the rationale for the initial maximum target of 143 boilers identified in Section 1.1;

2. Calculating the quantity of fossil fuels: Total diesel oil consumed for industrial and commercial heating in a particular year was estimated by subtracting the amount used for transport and electricity generation from the total amount used. For LPG, the consumption for industrial and commercial heating was obtained by subtracting the amount used for transport and household from the total amount used;

All calculations of costs and benefits are shown at Annex 3.

Cost-benefit analysis
Based on the above calculations, the benefit-cost ratio is found to be 3.05, which shows the net benefit accruing from the measures identified.

Sensitivity analysis
There are several parameters that cannot be controlled and which may exhibit wide variations. Sensitivity analysis has been carried out to investigate the impact of benefit-cost ratio on the following:
• Capital cost: based on information gathered from stakeholders, the capital cost of economizers (depending on size) has been taken in the range of Rs1,640,000 to Rs2,500,000 per unit;
• Efficiency gains: For a well operated boiler, efficiency gains may be as low as 3%, but may reach up to 10 – 15% for poorly managed boilers.

The results of the sensitivity analysis are summarized in Table 14. Even at the higher capital cost and lower energy efficiency gain investigated here, the benefit-cost ratio is a relatively high value of 2.42 that would justify the application of the measures proposed. The capital cost that would yield a benefit-cost ratio of 1.3 (rule of thumb for investing in measures) for an efficiency gain of 3% has been calculated as close to Rs6,100,000 per economizer.

Table 14. Sensitivity analysis of benefit-cost ratio as a function of capital cost and efficiency gain.

Benefit-Cost Ratio	Capital cost (Rs1,640,000/unit)	Capital cost (Rs2,500,000/unit)
Efficiency gain (3%)	3.05	2.42
Efficiency gain (10%)	10.12	8.06

Data obtained from Dr D. Surroop, University of Mauritius, and Mr Bernard Domingue, Vivo Energy.
Information obtained from Mr Bernard Domingue, Vivo Energy – 19 December 2012.

1.3.3.2 Non-financial measures for boiler economizer

As shown in the PT and OT for boiler economizer shown at Annex 1, the non-financial measures that have been identified are predominantly:

• Availability of alternative and technologically less complex measures: In particular, preheating using low-temperature solar thermal appears to be an alternative to the use of boiler economizers. There are a few end-users in the industrial and commercial sectors that are using solar water heaters to pre-heat water used in boilers thereby reducing fossil fuels combustion. However, this measure has its own challenges, such as: (1) requirement for large space; (2) need for correct inclination and orientation of roofs; and (3) aesthetics, especially in hotels. The benefit-cost analysis discussed in the previous section has assumed that 20% of boilers will be able to accommodate water pre-heating using low-temperature solar thermal technologies;

• Energy managers: Most enterprises to not make use of energy managers or engineers which make the promotion of EE interventions in industry and commercial applications difficult. A measure to provide training to selected staff (1 per company) on energy management and energy auditing has been proposed here and fully accounted for in the benefit-cost analysis;

• Boilers run on HFO: The analysis presented here has excluded the retrofitting of economizers on boilers that are run on HFO due to its high sulphur content. Since 18.4% of all boilers are run on HFO, this assumption would seem as a missed opportunity for a larger EE impact. Since the benefit-cost ratio is quite large, it is quite possible and realistic to carry out additional analysis to investigate the impact of using higher quality steel (which would impact on cost) to resist the corrosion arising from the formation of sulphuric acid in the cooler and wet parts of the economizer. It is quite possible that this technical barrier may be overcome.

1.4 Linkages of the Barriers Identified

Linkages between barriers discussed in Sections 1.2 and 1.3 can be analyzed at two levels:
1. Linkages between financial and economic barriers, and non-financial barriers for a technology; and
2. Linkages between barriers across technologies.

Section 1.4.1 and 1.4.2 discuss this two-level decomposition.

1.4.1 Linkages of barriers for a technology

This section analyses the linkages between financial and economic barriers, and non-financial barriers for the two mitigation technologies.

1.4.1.1 Utility-scale wind energy

In the case of wind technology, electricity generation costs are decreasing with an increasing amount of "full load hours" (FLH) per year, or capacity factor (CF). With a "flat tariff design", also called "static FiT", an intervention which would facilitate the up-scaling of wind energy use would be a high tariff. This would allow a wide range of wind farms to be developed and thus electricity to be generated at high cost (less FLH or low CF) as well as low cost (more FLH or high CF). In other words, many locations are applicable for wind turbines and many investors are attracted. The disadvantage is that plants at sites with a high wind yield are over-subsidized and generate a high profit, which has to be typically paid by the electricity consumers. With a lower tariff, exploiting wind energy at sites with lower wind yield becomes unprofitable for the electricity producer. The wind farm capacity factor is used to show the impact of different wind energy resources on the IRR of a wind farm. All else being equal (using the parameters in Table 8), with CF = 20% a wind farm would generate 43.8 GWh/year. In this case, a price of electricity of Rs 6/kWh would yield IRR = 9.1% (down from 12.93% for CF = 25%). All else being equal, a profitable 25 MW wind has become non-viable financially.

Since wind energy potential is not uniform over the territory, the price premium that needs to be paid to potential investors would ideally need to be tailored to the individual sites. Among European Union countries, Cyprus, France, Germany and the Netherlands apply a system, where the tariff level varies according to the wind yield. For Ireland, Spain, Slovenia and Luxembourg the tariff levels depend on the plant size. The Czech Republic, Hungary and Portugal apply different tariff designs according to the time of day or season of the year. (Klein, et al., 2010)

These are called "stepped" or "dynamic" tariff designs. In France for example, during the first 10 years of operation (of an onshore wind farm) a tariff of 8.2 €Cents/kWh is paid. For the remaining 5 years of support the level of remuneration is determined by the average amount of electricity generated during the first 10 years (measured in full-load hours per year). In Cyprus, a similar system is used; however the tariff level was determined by the amount of full-load hours that the wind turbine had been operating during the first five years. The stepped tariff design decreases with an increasing amount of electricity produced. The lower producer profit of the stepped tariff design causes a reduction in costs for the electricity consumers. (Klein, et al., 2010) Ideally, and from a purely techno-centric approach, a dynamic FiT scheme that takes into account the geographical variation of wind energy potential would be desired. This is certainly a key issue in Mauritius where the surface area available for onshore wind farms is limited by the smallness of the territory, and the topography of the volcanic island of Mauritius making wind shear (and eventually FLH or CF) geographically variable, suggest that a dynamic FiT would be desirable in order to maximize the uptake of utility-scale wind farms. Tariffs would then be revised annually to account for the decline in costs caused by the technological learning.

Figure 6 shows the change in price premium for wind-generated electricity with changing CF in order to maintain an IRR around 13%.

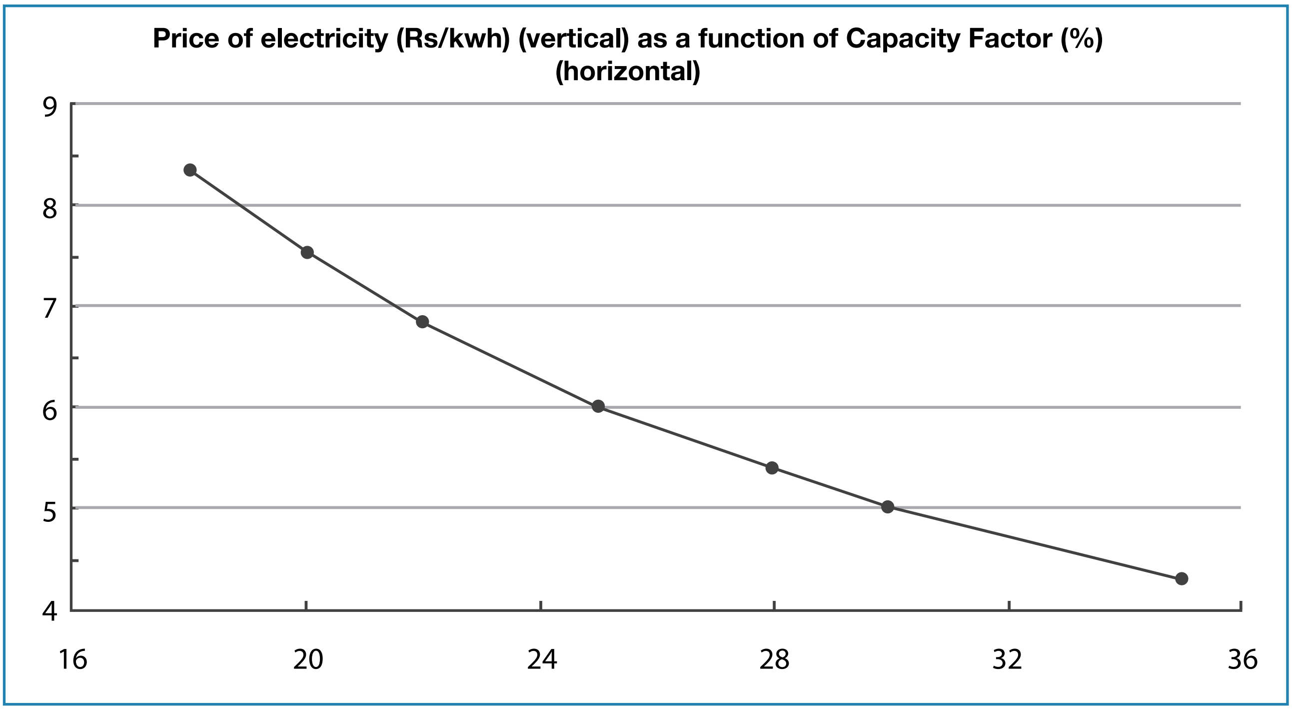

Figure 6. Variation of price of electricity with wind farm capacity factor for IRR = 13%.

1.4.2 Linkages of barriers across technologies

The analysis shown in Section 1.3 has clearly shown that the main and common barrier to the transfer and diffusion of utility-scale wind energy and boiler economizers was the high upfront capital investment, and the lack of economic and financial incentives to promote the technologies.

1.5 Enabling Framework for Overcoming the Barriers in Energy Industries

The enabling framework encompasses the set of resources and conditions within which the technologies and target beneficiaries operate. In particular, it is those resources and conditions that are generated by structures and institutions that are beyond the immediate control of the beneficiaries that are relevant here. In ideal situations, the enabling framework should provide the environment conducive for the transfer and diffusion of mitigation technologies. This section will discuss what vital elements of the enabling framework should be enhanced to improve the quality and efficacy of technology transfer and diffusion.

The two mitigation technologies discussed in Sections 1.2 and 1.3 are capital goods that are deployed through market-based mechanisms. In order to better understand the market systems, market mapping has been carried out for each mitigation technology (Boldt, Nygaard, Hansen, & Traerup, 2012). The market maps are shown at Annex 1, including the enabling environment and service providers.

1.5.1 Enabling framework for utility-scale wind energy

The market supply chain for wind technology shown at Annex 1 is relatively simple because there are no technology providers in Mauritius. Since the technology is state-of-the-art and is not mass produced, it is unlikely that it will be manufactured locally in the time horizon covered here (i.e. to 2025). In this case, utility-scale wind technology will be imported from major manufacturers, most probably through the PPP modality. Under this modality, the entire suit of engineering solution required for the installation, commissioning, operation and maintenance of utility-scale wind farms will be transferred to Mauritius. Examples of the involvement of major manufacturers of wind turbines in utility-scale wind energy projects in Mauritius were provided in Section 1.2.1.

The main business and extension services are: (1) business permit facilitation (Board of Investment); (2) provision of financial and banking services (commercial banks); and (3) market information (mainly in terms of wind energy resources potential in Mauritius – i.e. wind atlas; and in terms of constraints (topography, land use plans, interference with civil aviation and other telecommunication systems, and proximity to sub-stations and HV transmission lines for grid interconnection). Awareness and information about wind technology would mostly be targeted at local communities for enhancing the social acceptability of this new technology, and such awareness would be crucial at the stage of public consultations that are mandatory during the process of obtaining an EIA. Training and capacity building will be targeted mainly to provide skilled technician for the maintenance of wind technology.

The main enabling framework for the promotion of utility-scale wind technology is composed of: (i) providing financial incentives to operators, and (ii) contract management for guaranteed access to the national grid and other legal and commercial clauses as stipulated in an EPA. Monetary policy will influence both the exchange rate of the local currency relative to major currencies. This would be a critical issue in tariff pricing in circumstances when investors would contract loans in foreign currency, whereas payments on electricity produced would be paid in LC. Also, monetary policy will influence the inflation rate that would affect the long-term pricing of wind-generated electricity. Fiscal policies in terms of corporate tax, VAT and import duties will also influence investment and return on investment. Corporate tax is applied at a flat rate of 15% in Mauritius and is unlikely to change considering that it is already low. It has been assumed here that since utility-scale wind technology will benefit from a FiT, the technology will operate under the existing VAT and import duty regime.

1.5.2 Enabling framework for boiler economizer

Annex 1 shows the market supply chain for boiler economizers. Since the technology does not find widespread uptake under the prevailing practices, the market map is fairly simple. Usually, economizers are not built in Mauritius but there are agents and representatives of large overseas suppliers, and the technology is supplied on a needs basis. There are about 4 suppliers of the technology in Mauritius and they liaise directly with the end-users without the need of intermediaries.

The main business and extension services are: (1) provision of financial and banking services (commercial banks); (2) EE promotion services (EEMO, Enterprise Mauritius, Ministry of Industry, etc.); and (3) consulting firms. There are also engineering companies that provide ancillary services during installation and maintenance of the equipment. Training and capacity building for energy managers and industrial auditors will be carried out under the GEF-UNDP-EEMO project for the removal of barriers to promote EE in industry.

The enabling environment is fairly similar to that of utility-scale wind energy with the exception of support provided to local suppliers. In fact, stakeholder consultations have revealed that the government is putting in place mechanisms to increase the number of local suppliers of economizers to support the up-scaling of the technology in commercial applications, namely the hotel and leisure service sector.

Communication by email with Dr Khalil Elahee, University of Mauritius and Chairperson of EEMO – 30 November 2012.

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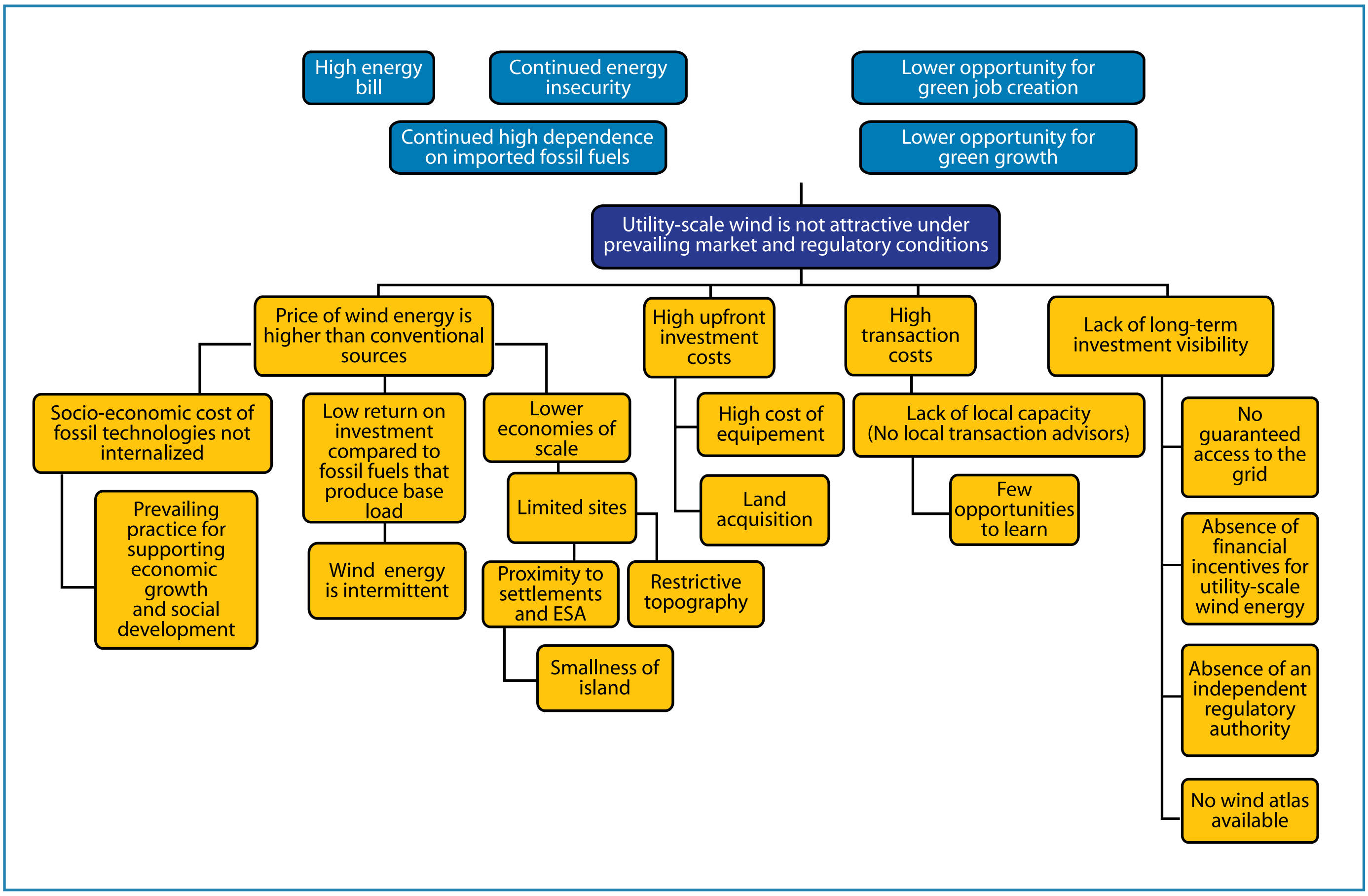
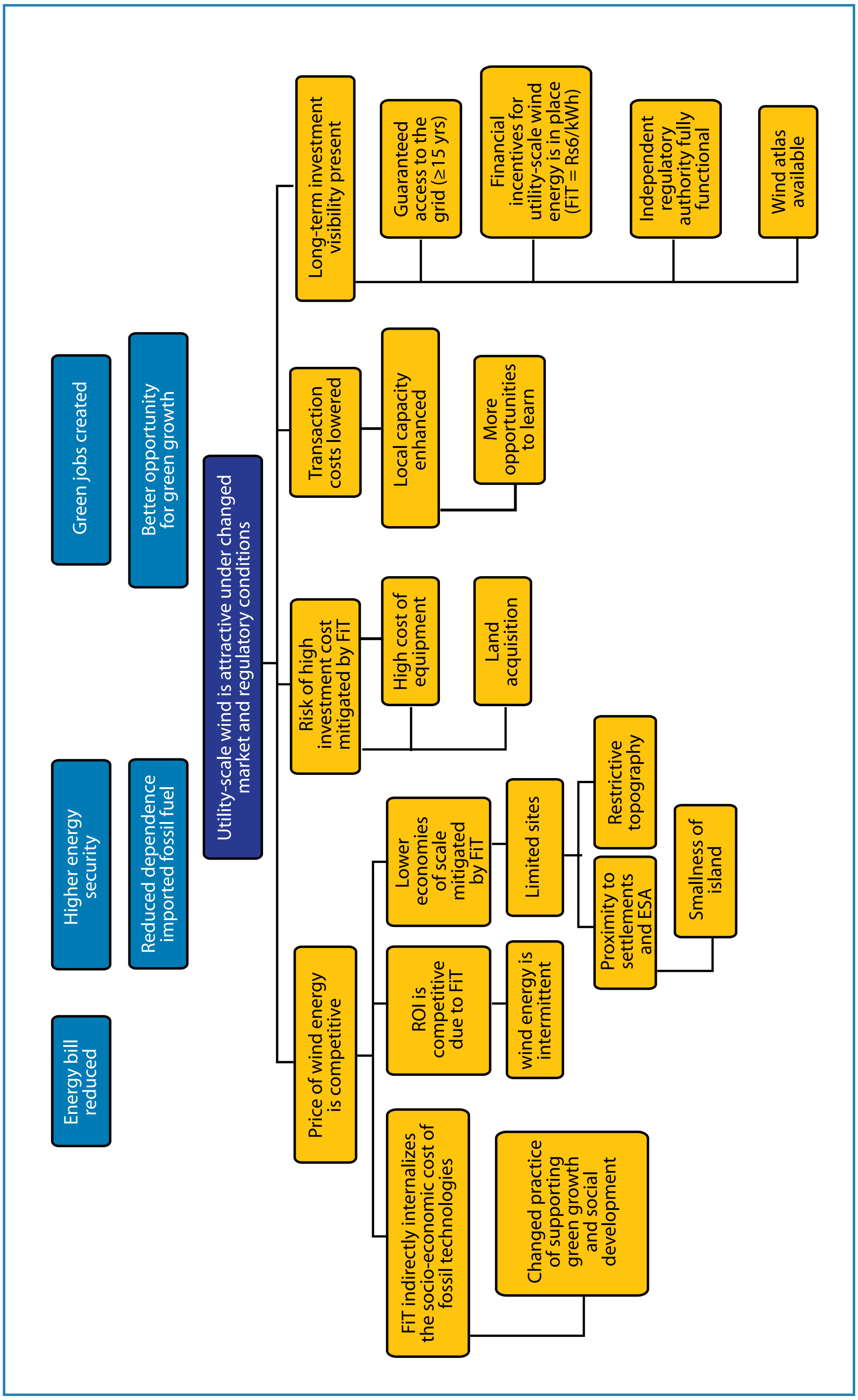
Annex 1 – Market Maps and Problem Trees.

Utility-scale wind energy

Problem Tree

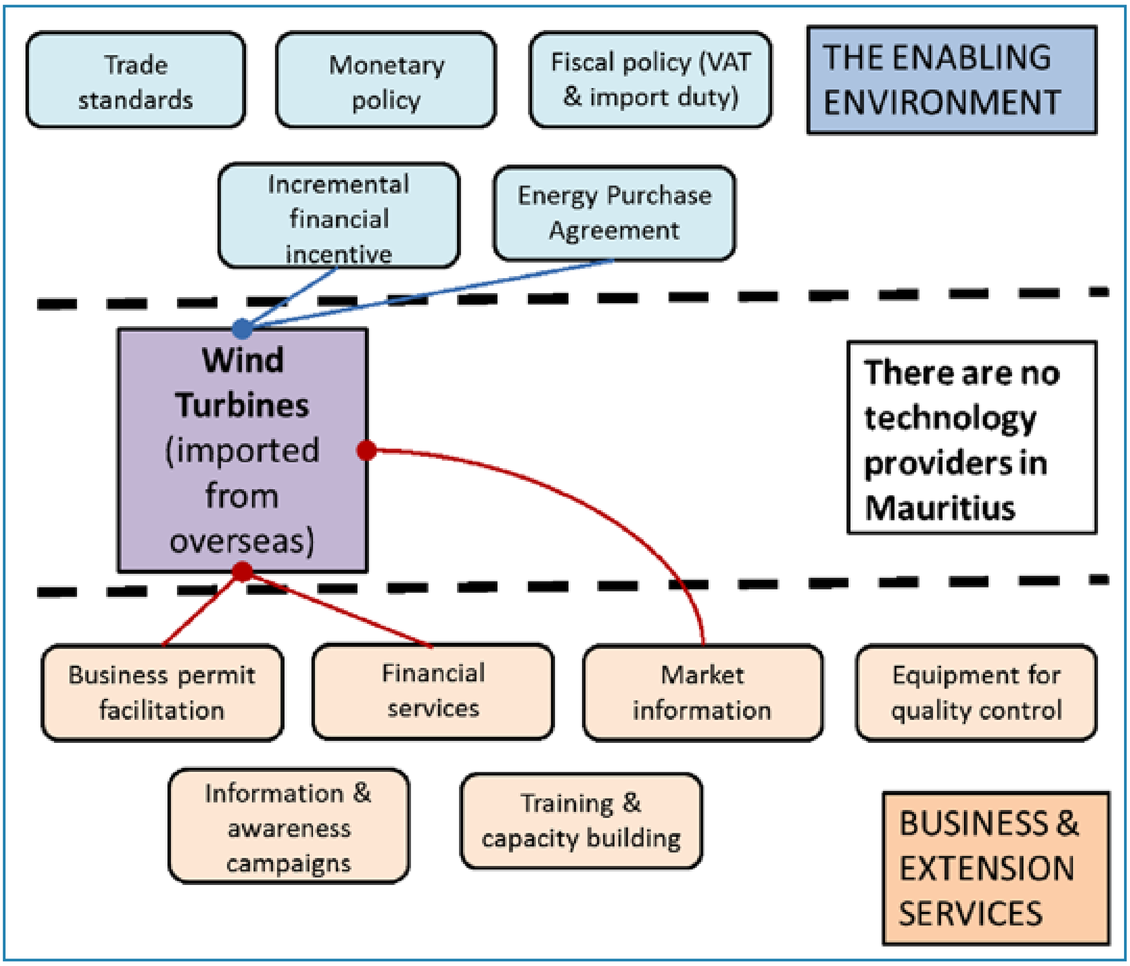


Objective Tree



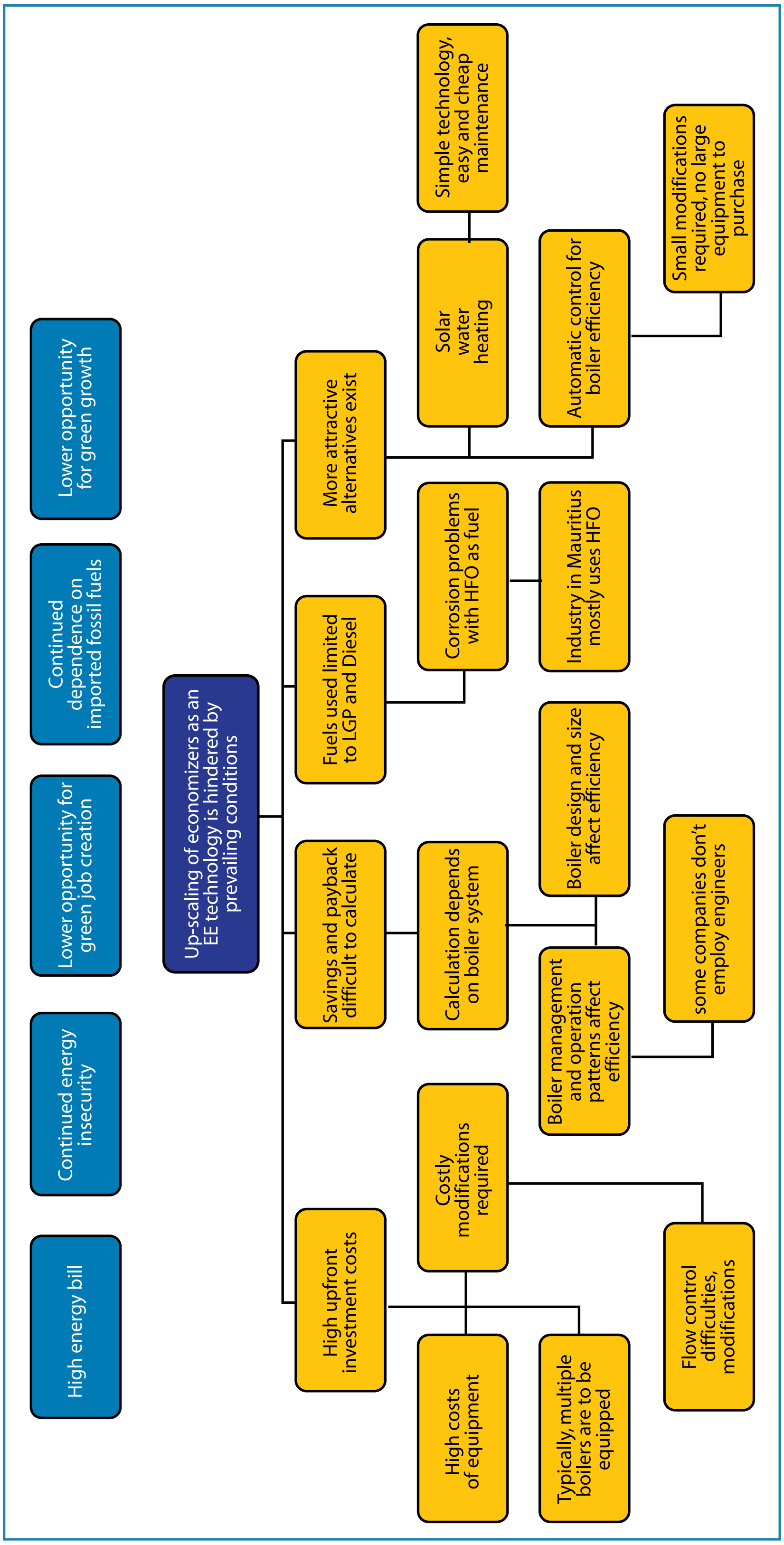
Market mapping

The market supply chain for utility-scale wind technology is very basic in Mauritius for the simple reason that there are no technology suppliers nor are there any intermediaries/agents. For any utility-scale wind farm, the technology will be transferred from overseas, including the supply of all engineering services related to the installation, commissioning and interconnection of the wind farm to the national grid. The enabling environment and extension and service providers are identified in the schematic below.

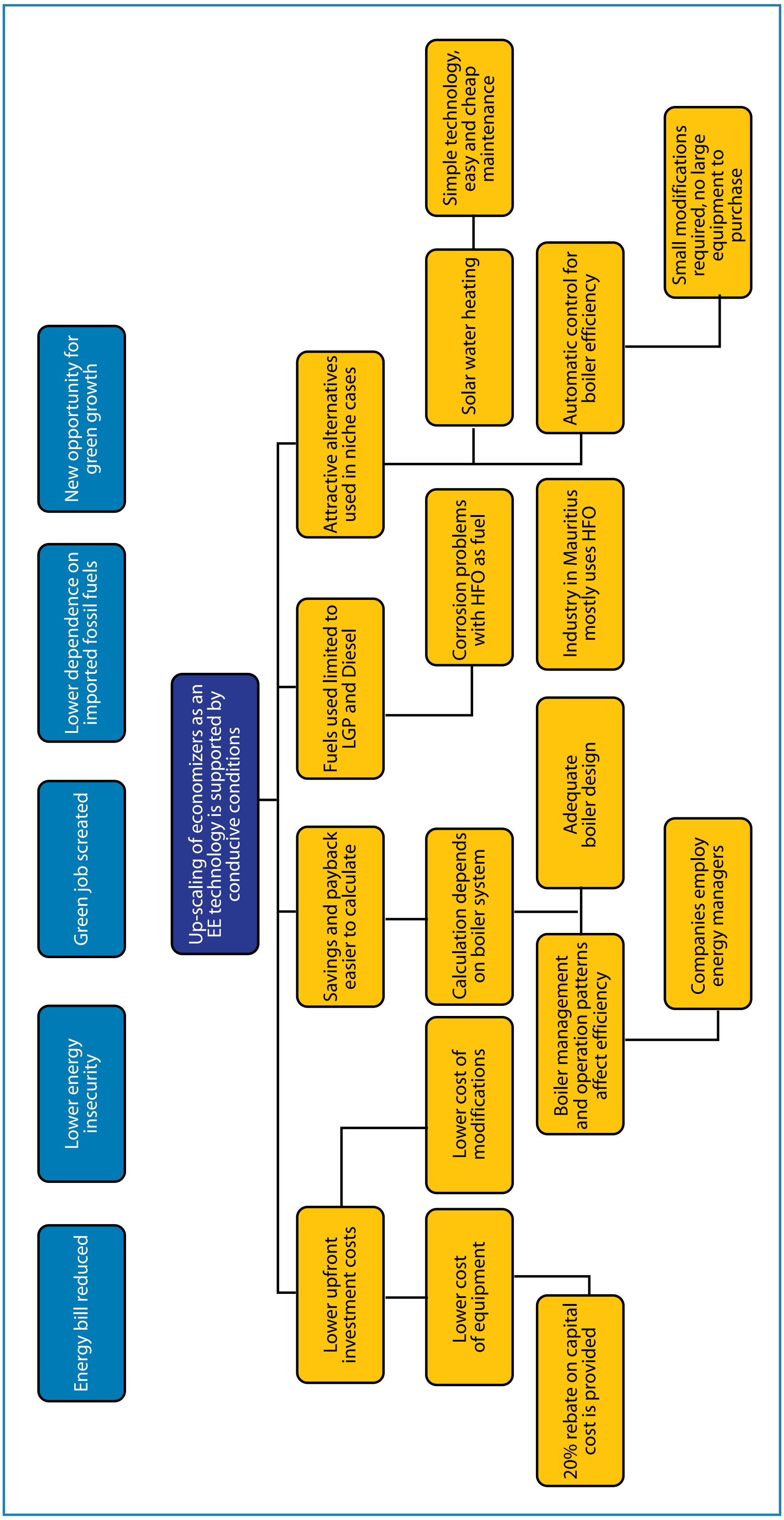


Waste heat recovery (economizer)

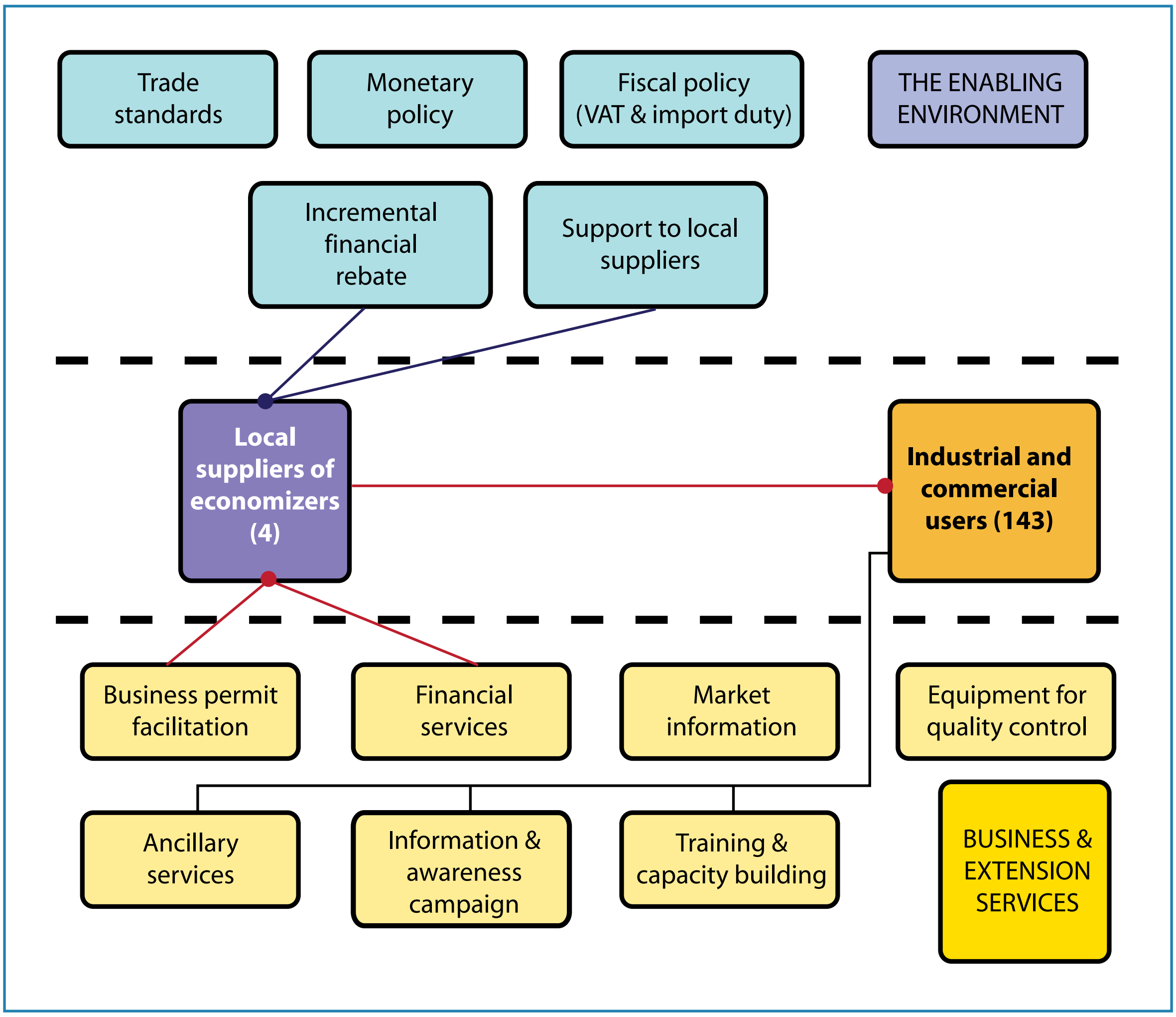
Problem Tree (PT)



Objective Tree (OT)



Market Map


Trade standards
Monetary policy
Fiscal policy (VAT & import duty)
THE ENABLING ENVIRONMENT
Incremental financial rebate
Support to local suppliers
Local suppliers of economizers (4)
Industrial and commercial users (143)
Business permit facilitation
Financial services
Market information
Equipment for quality control
Ancillary services
Information & awareness campaign
Training & capacity building
BUSINESS & EXTENSION SERVICES

Annex 2 – List of Stakeholders Involved and their Contacts.

Utility Scale Wind Energy

The stakeholder mapping was carried out by participants at the TNA Report Validation and TAP Inception Workshop that was held on 26 and 27 July 2012. The table also gives the roles and functions of the stakeholders.

Stakeholders	Contact details	Roles and Functions
Ministry of Energy and Public Utilities (MoEPU)	Level 10, Air Mauritius Centre, John Kennedy Street, Port Louis Tel: 405 6700 / Fax: 208 6497 Email: mpu@mail.gov.mu	Responsible for developing Energy Policy and Strategy of Mauritius and to put in place policy instruments to support EE and RETs
CEB	Head Office, Royal Road, Curepipe Mauritius Tel: (230) 601-1100 Fax: (230) 675-7958 Email: ceb@intnet.mu	Responsible for power generation, transmission and supply, and sale of electricity. CEB has plans to invest in utility-scale wind energy in the future.
Financial Institutions	There are several banking institutions.	Provider of finance for investment in wind energy projects.
Ministry of Finance and Economic Empowerment (MoFEM)	Ground Floor, Government House, Port-Louis, Mauritius Tel: (230) 201-1146 Fax: (230) 211-0096 Email: mof@mail.gov.mu	The ministry responsible for budgeting and has the role to develop financial instruments to fund the incremental cost of electricity produced from RETs.
Community Groups, NGOs,	Site specific and are usually identified during EIA stage.	Protect the interest of communities located geographically close to wind farms, as well as related to issues of biodiversity.
Mauritian Wildlife Foundation	Mauritian Wildlife Foundation, Grannum Road, Vacoas, Mauritius Tel: (230) 697-6097 Fax: (230) 697-6512 Email: executive@mauritian-wildlife.org (http://www.mauritian-wildlife.org)	MWF endeavours to protect biodiversity, especially endemic plants, animals and mammals.
Board of Investment	10th Floor, One Cathedral Square Building, 16, Jules Koenig Street, Port Louis, Mauritius Tel: (230) 203 3800 Fax : (230) 208 2924 Email : contact@investmauritius.com	Institution responsible for attracting FDI in Mauritius.
Department of Civil Aviation	SSR International Airport, Plaisance, Plaine Magnien, Mauritius Tel: (230) 603-2000 Fax: (230) 637-3164 Email: civil-aviation@mail.gov.mu	Responsible for providing clearance for wind farms siting so that farms do not interfere with the flights in the Mauritian air space.
Ministry of Housing and Lands	Level 7, Ebène Tower, Cybercity, Mauritius Tel: (230) 403 4086 Fax: (230) 454 6397	Responsible for providing land development permits for wind farms.
Ministry of Environment and Sustainable Development	Ken Lee Tower, Cnr Barracks & St Georges Streets, Port-Louis, Mauritius Tel: (230) 203 6200 - 6210 Fax: (230) 211 9524; (230) 212 8324 Email: menv@mail.gov.mu	Responsible for providing EIA license for wind farm development.
Research institutions	There are several institutions such as: MITD, UoM, MRC, UTM etc.	Active in the fields of research for the promotion of RETs. Activities include renewable energy resources mapping, development of energy futures, etc …

Heat Recovery (EE boilers)

Stakeholders	Contact details	Roles and Functions
Ministry of Energy and Public Utilities (MoEPU)	Level 10, Air Mauritius Centre, John Kennedy Street, Port Louis Tel: 405 6700 Fax: 208 6497 Email: mpu@mail.gov.mu	Responsible for developing Energy Policy and Strategy of Mauritius and to put in place policy instruments to support EE and RETs.
EEMO	8th Floor, C&R Court, 49, Labourdonnais Street, Port-Louis Tel: (230) 210 7143, (230) 210 7345 Fax: (230) 210 6978 (http://publicutilities.gov.mu)	Facilitates the promotion of EE in all sectors of the economy, including industry and commercial activities. It also carries out capacity building and training on energy auditing.
Ministry of Industry, Commerce and Consumer Protection	Industry Division, Level 7, Air Mauritius Building, Port Louis Tel : 210-7100 Fax: 211 0855 Email: mind@mail.gov.mu	An objective of the ministry is to support green, socially responsible and quality initiatives in enterprises. In this context, the ministry teams up with other institutions to support EE in industries.
Financial Institutions	There are several banking institutions.	Provider of finance for investment in wind energy projects.
Enterprise Mauritius		Provides energy audit services through funding schemes for industry.
Ministry of Finance and Economic Empowerment (MoFEM)	Ground Floor, Government House, Port-Louis, Mauritius Tel: (230) 201-1146 Fax: (230) 211-0096 Email: mof@mail.gov.mu	The ministry responsible for budgeting and has the role to develop financial instruments to fund the incremental cost of electricity produced from RETs.
Mr Sharma Buctowar (Chemical & Environmental Engineer)	Peupliers Ave SLDC New Industrial Estate Pte Aux Sables Tel : 206 8888 Mob: 251 5793 Email: sharma.b@rtkshare.com	End-user on textiles sector.
Mr Bernard Domingue	Vivo Energy - 941 1226	Service provider (consulting, maintenance)
Mr Fargy Romaly	Rey & Lenferna - 422 5382	technology supplier
Research institutions	There are several institutions such as: MITD, UoM, MRC, UTM etc …	Active in the fields of research for the promotion of RETs. Activities include renewable energy resources mapping, development of energy futures, etc …

Annex 3 – Cost-Benefit Analysis

Please see Excel file named: “CBA – mitigation technologies.xlsx”

Annex 4 – Policy Factsheets.

Key:	
Minimum requirements	
Recommended/ good to have	
POLICY: Name of Policy	Long-Term Energy Strategy 2009 - 2025
Name of field:	Content
Date Effective:	2009 with an updated action plan in 2011
Date Announced:	2009
Date Promulgated:	not an Act of Parliament
Date Ended:	2025
Unit:	CC|RE|EE : EE and RE
Country:	Republic of Mauritius
Year:	2009
Policy Status:	In force
Agency:	Ministry of Energy and Public Utilities
Funding:	The strategy is not accompanied by dedicated funding but actions are funded through a range of means including capital budget, MID Fund, or bilateral and multi-lateral funding
Further Information:	http://www.gov.mu/portal/site/mpusite - accessed 5 February 2012.
Enforcement:	Various including CEB, EEMO
Penalty:	Not applicable
Related Policies:	Not applicable
Policy Superseded by:	N/A
Policy Supersedes:	N/A
Stated Objective:	Climate change mitigation; Market transformation; Advancing industrial competitiveness; Energy security;
Evaluation:	Initial action plan was updated in 2011
Policy Type:	Energy
Policy Target:	Please see Section 1.1 of report.
URL:	http://www.gov.mu/portal/site/mpusite - accessed 5 February 2012.
Legal References:	None.
Description:	In April 2007, the Government of Mauritius adopted the "Outline of the Energy Policy 2007-2025-Towards a Coherent Energy Policy for the Development of the Energy Sector in Mauritius" which outlines in broad terms Government's long term vision for the energy sector. Based on this Outline, an energy study jointly funded by the EC and UNDP/UNEP was carried out from August to December 2007. The aim of the study was to support the development of a 25 year comprehensive energy policy, including a Master Plan for Renewable Energy sources. Based on the policy document, the Long Term Energy Strategy and Action Plan has been elaborated. This document is a blue print for the development of the energy sector up to year 2025. It lays emphasis on the development of renewable energy, reduction of our dependence on imported fossil fuel and the promotion of energy efficiency in line with Government's objective to promote sustainable development in the context of the Maurice Ile Durable vision.

Ministry of Environment & Sustainable Development

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