XLM-ENERGY INDUSTRIES TOOLKIT

User Manual

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Ministry of Social Security, National Solidarity, and Environment and Sustainable Development
(Environment and Sustainable Development Division)
Republic of Mauritius

XLM-Energy Industries Toolkit User Reference

About this manual

This manual, *XL-Mitigation Energy Industries User Reference*, forms part of a family of toolkits to compute and plot a number of other variables including GHG emissions for Energy Industries sector. The user reference has been written from an application developer's perspective. A fundamental conceptual and operational knowledge of Excel is assumed.

Disclaimer

Data used has been obtained from reliable sources. The Ministry of Social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division) assumes no responsibility for errors and omissions in the data provided. Users are, however, kindly asked to report any errors or deficiencies in this product to the Ministry. The choices of calculation made in this tool are derived from TNC Report (2016).

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XLM-Energy Industries Toolkit

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XLM-Energy Industries Toolkit

1.0 Introduction

This document refers to the Energy: Energy Industries sector.

The mitigation for the Energy Industries sector was assessed in the Third National Communications (TNC) Report (2016) for a Business-as-Usual (BAU) and 6 other scenarios, sequential in nature, after a screening exercise to select the most feasible options. The mitigation scenarios propose to achieve 35% renewable energy target in 2025 and maintain it up to 2030. The technologies envisaged to reach these targets comprise energy efficiency and renewable energy technologies (e.g. solar photovoltaic (PV), wind, renewable biomass, and waste-to-energy). A hierarchy was applied in the scenario building process wherein it is assumed that the energy efficiency option will be implemented first, followed by wind, then solar PV and so on.

The XLM-Energy Industries Toolkit performs basic calculations that take into account the penetration of RE technologies and Energy Efficiency measures. Users of the XLM-Energy Industries Toolkit can adjust the scenarios by choosing appropriate parameters/assumptions to suit their needs for the mitigation analysis.

2.0 Overview of the Energy Industries sector

FACTS (2016): (Statistics Mauritius, 2016)

- Total primary energy requirement: 1,550.4 ktoe
  - Fuel sources: (~85.4% met from imported fossil, rest from local renewable sources);
  - Imported fossil fuel share-out: [coal (29.4%) and petroleum products (56.0%) split as follows: fuel oil (16.11%), diesel oil (13.6%), gasoline (11.5%), kerosene (9.6%) and Liquefied Petroleum Gas (LPG): 5.2%)];
  - Renewables and others (~14.6%): Biomass (13.3%), hydro (0.6%), wind (0.1%), photovoltaic (0.1%), LFG (~0.1%), fuelwood (~0.4%);
  - Energy intensity: 0.47 Toe per Rs100,000 GDP at 2006 prices;
  - Import cost of petroleum products and coal: 21,133 million MUR (~12.8% of total imports);
- Total installed capacity (MW): 778.2 (2013);
- Total effective generation capacity (MW): 687.3 (2013);
- Total amount of electricity generated (GWh): 3,042.2;
- Total electricity consumption (GWh): 2,658.3 (2013);
- Peak power demand (MW): 441.1 (2013); 467.9;
- Primary energy (Hydro, Landfill, Photovoltaic): 156.0 GWh;
- Secondary energy (Gas turbine/kerosene, diesel & Fuel oil, bagasse and Coal): 2,578.7 GWh;
- Electricity Production (Independent Power Producers (IPP): Central Electricity Board): 57.1:42.9;
- Fuel Mix (GWh): Fuel oil: 1072.9; Coal: 1138.1; Bagasse: 365.7; Hydro: 99.5 Kerosene: 2.1; Solar PV: 23.4; Wind: 14.5; SSDG/MSDG: 3.3;
- Energy consumption: 951 ktoe;
- Per capita consumption of electricity sold: 2025 KWh;
- GHG Emissions: ~2386.4 Gg CO2e (2013)

Avoided energies: Solar water heaters; Liquefied Petroleum Gas (LPG) consumptions (no data)
Since 2013, increasing penetration of solar photovoltaic systems – rooftops and farms.
In 2016, a new wind farm at Plaines des Roches of 9.35 MW became operational;

Fuel combustion activities dominates the energy sector landscape of the Republic of Mauritius (RoM). With no natural energy resources, RoM has no choice but to depend heavily on imported petroleum products to meet most of its energy requirements including electricity generation and transport.

Bagasse, a by-product of the sugar cane industry, is the dominant contributor to the local energy supply as biomass energy. The other local and renewable energy sources are hydro (exploited to its near full potential by 10 hydro power plants dispersed around the island with a combined installed capacity of 59 MW), solar and wind energy.

Uncertainty in the price and supply of fossil fuels in the world market has triggered RoM to develop policies and strategies that call for energy security high in the agenda focusing on electricity generation and transport with emphasis on potential of renewable energy sources and the promotion of energy efficiency (Outline Energy Policy, 2007; Long Term Energy Strategy and Action Plan 2009-2025) in line with the Government's objective to promote sustainable development.

3.0 GHG Emissions from the Energy Industries sector

The largest GHG emitter remains the Energy Industries sector (46.7%) which in Mauritius is primarily electricity production (Figure 3.1).

The emission of this sector stood at ~2386.4 Gg CO2e in 2013, with an average annual growth being 4.3%. Over the years, the increase in the emission in the Energy Industries sector can be largely attributed to the change in lifestyle, increased demand for electricity in households, commercial infrastructures and industries.

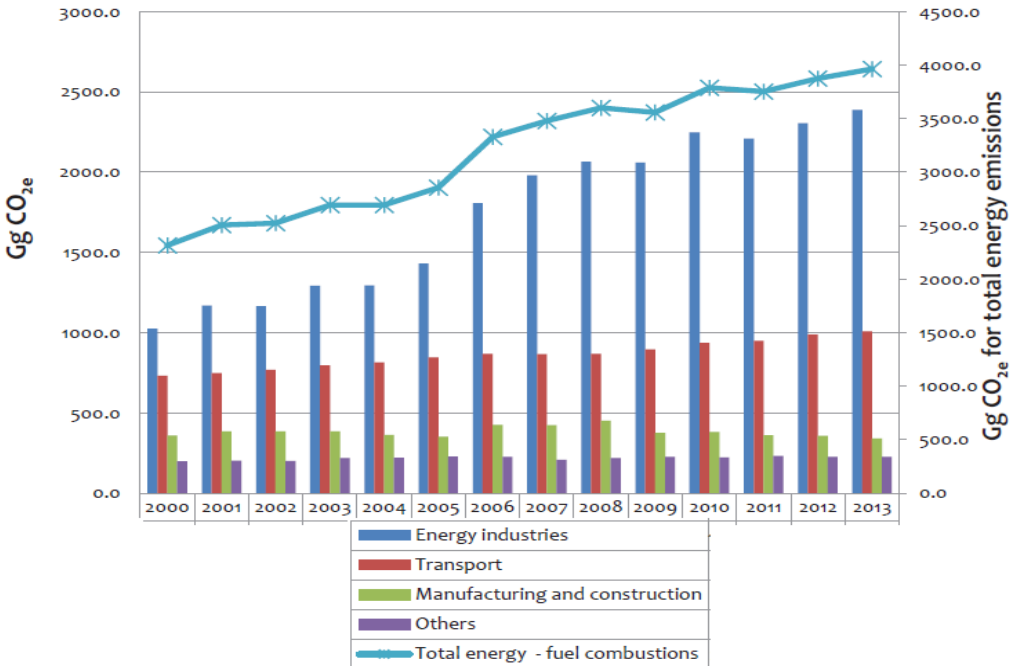

Figure 3.1: Comparison of Emission trend of Energy Industries against other components of the energy sector (source: TNC, 2016)

4.0 Mitigation Actions proposed under TNC for the Energy Industries sector

4.1 Mitigation Scenarios and Assumptions.

The objective in the Energy Industries sector is to reduce dependency on fossil fuels, encourage the use of renewable sources, and manage demand through energy efficiency measures while ensuring energy security. The Government has set a target for increasing generation from renewable energy sources by at least 35% by 2025 and for maintaining the same level until 2030.

Relative to the BAU scenario, the following mitigation actions, adopting a hierarchical approach, were developed by TNC (2016):

- Scenario 1 (SC1) relies upon major energy efficiency measures;
- Scenario 2 (SC2) calls for penetration of wind plants;
- Scenario 3 (SC3) calls for penetration of solar plants;
- Scenario 4 (SC4) calls for penetration of Waste-to-Energy (WTE) plants;
- Scenario 5 (SC5) calls for increased use of biomass;
- Scenario 6 (SC6), the cumulative outcome of the above scenarios.

The assumptions adopted by TNC for mitigations actions for the Energy Industries sector are summarized in Table 4.1.

The parameters used for the different scenarios appear in section 5.2.

Table: 4.1: Mitigation actions proposed by TNC (2016) and Assumptions Used. (Energy Industries)

Scenario		TNC Assumptions
BAU	Business-As-Usual	For this sector, a baseline emissions analysis has been carried out in TNC using through a comparative analysis of three sector models, namely, (i) MAED modelling carried out in the process of updating the LTES for MEPU, (ii) system dynamics modelling, and (iii) Mauritius 2050 Pathways calculator. The models provide reference or business-as-usual (BAU) scenarios up to the year 2050 – *see TNC Report (2016) for details*.
SC1	Energy Efficiency Measures	Implementation of Energy Efficiency measures
SC2	SC1+ Wind Energy Penetration	SC1+Wind penetration
SC3	SC2+ Solar Energy Penetration	SC2+Solar penetration
SC4	SC3+ WTE Penetration	SC3+WTE

SC5	SC4+ Biomass Energy Penetration	SC4+Biomass
SC6	SC5+ Additional RE Penetration	SC5 + Additional RE entering grid beyond 2030

4.2 TNC Targets under different scenarios

For this sector, the resulting reductions from the TNC studies in GHG emissions over time period 2020 to 2050 are given in Table 4.5 (see also Figure 4.1).

Table 4.5: 2016 TNC GHG Emissions in Energy Industries sector

Scenario		**TARGETS** *Expected GHG emissions and GHG Reductions (GgCO2e)*	**Remarks**
BAU	Business-As-Usual	BAU GHG Emissions: 2020: 3004; 2025: 3470; 2030: 3838; 2035: 4136; 2040: 4153; 2045: 4386; 2050: 4620;	
SC1	Energy Efficiency measures	Relative to BAU, emissions reductions of: 2020: 216; 2025: 459; 2030: 734; 2035: 1102; 2040: 1490; 2045: 1836; 2050: 2117;	
SC2	SC1+ Wind	Relative to BAU, emission reductions of: 2020: 280; 2025: 523; 2030: 798; 2035: 1165; 2040: 1554; 2045: 1900; 2050: 2181;	
SC3	SC2+ Solar	Relative to BAU, emission reductions of: 2020: 399; 2025: 642; 2030: 917; 2035: 1284; 2040: 1673; 2045: 2019; 2050: 2299;	
SC4	SC3+ WTE	Relative to BAU, emission reductions of: 2020: 618; 2025: 862; 2030: 1124; 2035: 1492; 2040: 1880; 2045: 2226; 2050: 2507;	
SC5	SC4+ Biomass	2020: 618; 2025: 965; 2030: 1228; 2035: 1595; 2040: 1984; 2045: 2330; 2050: 2610;	
SC6	SC5+	Relative to BAU, emission reductions of: 2020: 618; 2025: 965; 2030: 1305; 2035: 1673; 2040: 2071; 2045: 2484; 2050: 2871;	Additional RE post 2030 till 2050

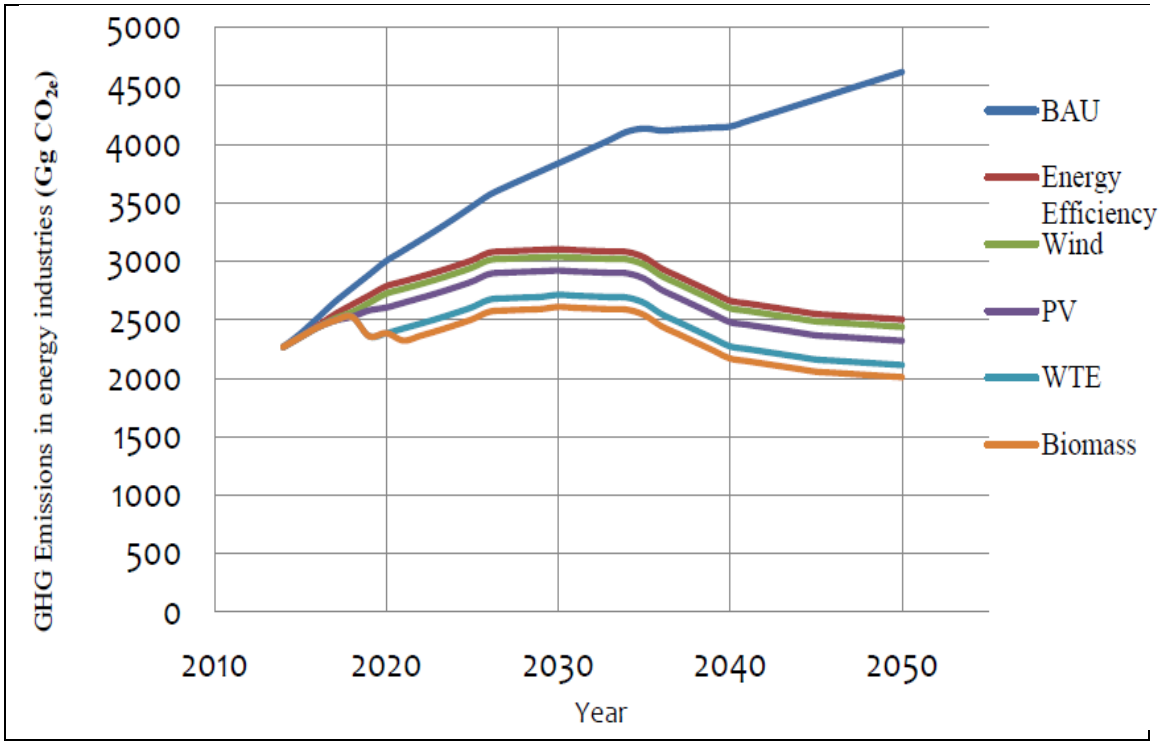

Figure 4.1: GHG emissions scenarios for Energy Industries (source: TNC, 2016)

The results of the Business-As-Usual (BAU) and mitigation scenarios analysis show difference between successive curves (starting with the 'Energy efficiency' option), and gives the potential GHG emission reduction for the listed mitigation action. For example, implementation of all the proposed measures under TNC (2016) (SC5 scenario) could result in reduction of 1.228 million tonnes CO2eq in 2030 to reach 2.61 million tonnes CO2eq in 2050 compared to the BAU pathway (Table 4.5).

5.0 XLM Toolkit – Energy Industries

The structure, methodology, and components/modules of the XLM Toolkits has been described in the main User Manual.

5.1 Energy Industries Data

Data used in this toolkit is from TNC (2016) and from Statistics Mauritius.

5.2 Energy Industries Parameters

Table 5.1 defines the major parameters used for the Energy Industries sector.

Table 5.1: List of Parameters for the Energy Industries sector (TNC, 2016)

Grid emission factor, combined margin			
	CP1	CP2	CP3
wind/PV	0.9661	0.9661	0.9661
other	0.915	0.864	0.864

5.3 Energy Industries Assumptions

The assumptions used for the Energy Industries sector are listed in Table 5.2.

Table: 5.2: List of Assumptions for the Energy Industries sector*

1	Energy Efficiency Measures
2	Extent of Penetration of Renewable Energy Technologiess

** sequential in nature (see TNC Report (2016)*

5.4 Graphic Analysis and Reporting

The list of figures useful to the User is given in Table 5.3.

Graphic analysis in the '*Query'* worksheet provides the following choices for the type of plots:

Sector	Type of Plot	Plot numbers
Energy Industries	All	1-53;
	Existing Renewables	1–9;
	Projected Renewables	10-19;
	Combined Existing and Projected Renewables	44–53;
	Baseline & EE Matters	20-22;
	Energy Consumption	22-28;
	GHG Emissions Reduction	29-36;
	Total GHG Emissions (TNC)	37-43;

Table 5.3: XLM Energy Industries Toolkit Plots

1	Existing RE: Biomass (GWh)
2	Existing RE: Hydro (GWh)
3	Existing RE: LFG (GWh)
4	Existing RE: Solar PV (GWh)
5	Existing RE: Wind (GWh)
6	Existing RE: WTE (GWh)
7	Existing RE: Ocean (GWh)
8	Existing RE: Other Sources (GWh)
9	Existing RE: TOTAL (GWh)
10	Projected RE: Biomass (GWh)
11	Projected RE: Hydro (GWh)
12	Projected RE: LFG (GWh)
13	Projected RE: Solar PV (GWh)
14	Projected RE: Wind (GWh)
15	Projected RE: WTE (GWh)
16	Projected RE: Ocean (GWh)
17	Projected RE: Other Sources (GWh)
18	Projected RE: TOTAL 2030 (GWh)
19	Projected RE: TOTAL 2030+ (GWh)
20	BAU: Modelled Demand-Side Modelled (GWh)
21	EE Estimated (GWh)
22	BAU: Baseline (BAU - Existing RE) (GWh)
23	Sc1: Energy Consumed thru' EE (GWh)
24	Sc2: Energy Consumed thru' EE and Wind (GWh)
25	Sc3: Energy Consumed thru' EE, Wind and Solar (GWh)
26	Sc4: Energy Consumed thru' EE, Wind, Solar, and WTE (GWh)
27	Sc5: Energy Consumed thru' EE, Wind, Solar, WTE and Biomass (GWh)
28	Sc6: Energy Consumed thru' EE, Wind, Solar, WTE, Biomass and RE2030+ (GWh)
29	BAU: GHG Emissions (Gg CO2e)
30	Sc1: GHG Emission Reduction with EE (Gg CO2e)
31	Sc2: GHG Emission Reduction with EE and Wind (Gg CO2e)
32	Sc3: GHG Emission Reduction with EE, Wind and Solar (Gg CO2e)
33	Sc4: GHG Emission Reduction with EE, Wind, Solar and WTE (Gg CO2e)
34	Sc5: GHG Emission Reduction with EE, Wind, Solar, WTE, and Biomass (Gg CO2e)
35	Sc6: GHG Emission Reduction with EE, Wind, Solar, WTE, Biomass, and added RE 2030+ (Gg CO2e)
36	GHG Emission Reduction - Supply side RE 2030 (Gg CO2e)
37	BAU: GHG Emissions (Gg CO2e)
38	Sc1: GHG Emissions with EE (Gg CO2e)
39	Sc2: GHG Emissions with EE and Wind (Gg CO2e)
40	Sc3: GHG Emissions with EE, Wind and Solar (Gg CO2e)
41	Sc4: GHG Emissions with EE, Wind, Solar and WTE (Gg CO2e)
42	Sc5: GHG Emissions with EE, Wind, Solar, WTE, and Biomass (Gg CO2e)
43	Sc6: GHG Emissions with EE, Wind, Solar, WTE, Biomass, and added RE 2030+ (Gg CO2e)
44	Total Existing and Projected Biomass (GWh)
45	Total Existing and Projected Hydro (GWh)
46	Total Existing and Projected LFG (GWh)
47	Total Existing and Projected Solar PV (GWh)
48	Total Existing and Projected Wind (GWh)
49	Total Existing and Projected WTE (GWh)
50	Total Existing and Projected Ocean (GWh)
51	Total Existing and Projected Others (GWh)
52	Total Existing and Projected (GWh)
53	Total Existing and Projected (2030+) (GWh)

6.0 References

- Statistics Mauritius, Digest of Energy and Water, 2015
- **TNC (2016).** Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Mauritius, Port Louis
- **IPCC (2006).** Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

7.0 Appendices

A: List of Acronyms and Abbreviations

Toolkit		**Others**	
BAU	Business-As-Usual	IPCC	International Panel of Climate Change
GUI	Graphics User Interface	TNC	Third National Communications
UD1	User-defined Scenario – Case 1	GHG	Greenhouse Gas
UD2	User-defined Scenario – Case 2	GWP	Global Warming Potential
SC*i*	Scenario *i*		
XLMT	Excel Mitigation Toolkit		

B: Useful Links

Click for access to these links

IPCC Guidelines
TNC
Ministry of Energy and Public Utilities
CEB
Statistics Mauritius

C: Glossary

Energy intensity	Energy intensity is the ratio between the Gross Inland Energy Consumption (GIEC) and Gross Domestic Product (GDP) calculated for a calendar year. GIEC is calculated as the sum of the gross inland consumption of the five sources of energy: solid fuels, oil, gas, nuclear and renewable sources.
Mitigation	The elimination or reduction of the frequency, magnitude, or severity of exposure to risks, or minimization of the potential impact of a threat or warning.
Renewable Energy	Derived from resources that are naturally regenerative or are practically inexhaustible, such as biomass, heat (geothermal, solar, thermal gradient), moving water (hydro, tidal, and wave power), and wind energy
Energy efficiency	Percentage of total energy input to a machine or equipment that is consumed in useful work and not wasted as useless heat.
Sustainable development	Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
baseline emissions analysis	Baseline emissions refer to the production of greenhouse gases that have occurred in the past and which are being produced prior to the introduction of any strategies to reduce emissions.
system dynamics	The approach begins with defining problems dynamically, proceeds through mapping and modeling stages, to steps for building confidence in the model and its policy implications.

D. Governing Equations for the Energy Industries sector

The mitigation for the different scenarios are based on electricity generation from different energy sources such as fossil fuels, and renewables (wind, hydro, solar, etc) and appropriate emissions factors for each energy source or energy group. Thus, for instance the scenarios for electricity generation (supply) and demand, under different penetration scenarios for solar, wind, biomass, etc. have been derived. Other options include waste to energy.

The main governing equations are:

GHG emissions $E_i = EN_i \times EF_I$
where *E* = Emissions of GHG, Gg CO2 eq *EN* = Electricity (generated or consumed under different energy source) with projections, GWh *EF* =Grid emissions factor for different energy sources, Gg CO2 eq/GWh *i* = type of energy source (solar, wind, hydro, etc)

The build margin emissions factor is the generation-weighted average emission factor (tCO_2/MWh) of all power units m during the most recent year *y* for which electricity generation data is available (2012 in present case), calculated as follows:

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$
where: $EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year *y* (tCO_2/MWh); $EG_{m,y}$ = Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh); $EF_{EL,m,y}$ = CO_2 emission factor of power unit *m* in year *y* (tCO_2/MWh); *m* = Power units included in the build margin; and *y* = Most recent historical year for which electricity generation data is available.

[Source: UNFCCC's CDM, 2013]

In addition, the IPCC guideline provide the following equations for Energy Industries:

TOTAL EMISSIONS BY GREENHOUSE GAS

$$Emissions_{GHG} = \sum_{fuels} Emissions_{GHG,fuel}$$

where

GREENHOUSE GAS EMISSIONS FROM STATIONARY COMBUSTION

$$Emissions_{GHG,fuel} = Fuel\ \ Consumption_{fuel} \bullet Emission\ \ Factor_{GHG,fuel}$$

where

$Emissions_{GHG,fuel}$	= emissions of a given GHG by type of fuel (kg GHG)
$Fuel\ Consumption_{fuel}$	= amount of fuel combusted (TJ)
$Emission\ Factor_{GHG,fuel}$	= default emission factor of a given GHG by type of fuel (kg gas/TJ). For CO_2, it includes the carbon oxidation factor, assumed to be 1.

[Source: IPCC Guidelines, 2006]