

CTCN – Technical Assistance Response Plan

Assessment and identification of technology needs and best practices for reducing the GHG emitting potential of the energy sector in Mauritius

Request ID No. 2015000025

Final and Nationally Consolidated Report for Outputs 2, 3 and 4
of the CTCN Rapid Response Plan for Mauritius

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NRE, CTCN and the Mauritian Ministry of Environment



Executive Summary

Mauritius is determined to reduce their national GHG emissions. When the mix of energy sources for electricity generation are considered it is very interesting to see the magnitude of electricity being generated from Fuel oil and Diesel (36.5% in 2016 and 37.4% in 2017) compared to electricity generated from Coal (41.6% in 2016 and 2017). Bagasse as a source of energy for electricity generation decreased from 16.3% in 2016 to 14.7% in 2017. These three sources of energy are the main contributors to electricity generation while Hydro electricity generation contributed 3.3% in 2016 and 2.8% in 2017 and Photovoltaic electricity generation contributed 1% in 2016 and 2.4% in 2017. Mauritius is therefore still heavily reliant on fossil fuels for electricity generation.

Even though renewable energy is expected to form an increasing proportion of the energy mix, the existing coal and bagasse will have to abide by energy and environmental related safeguards. The safeguards will (amongst other benefits) help decrease the CO₂ emissions.

The CSIR was contracted by the Climate Technology Centre and Network (CTCN) to consult on the Technical Response Plan and provide assessments and identification of technology needs and best practices for reducing the GHG emitting potential of the energy sector in Mauritius.

This report details the consolidated information of two site assessments conducted, capacity building provided during both visits covering Outputs 2, 3 and 4 of the work. Output 1 having been covered by a prior report.

Output 2: Baseline study

Output 3: Technical, Process and Operational Related Recommendations

Output 4: Capacity Building of National and Local Officials on Monitoring and Assessment of Environmental and Energy Related Performance.

The first mission was conducted in November 2018 to Omnicane St Aubin and the second mission was conducted in July 2019 to the Terragen Plant at Plaine Des Papayes. Both of these plants were assessed and reports delivered to plant personnel and the Mauritian Ministry of Environment.

The consolidated report takes a broader view of the Mauritius Independent Power Producers (IPPs) included in this study and provides comment on the energy and environmental performance and seeks to provide recommendations as to improvement opportunities.

In short the following recommendations and observations were made:

Output 2: Baseline study

Mauritian thermal power plants compare well with global small scale power plants. There are technology improvements that can be applied but this should be viewed in the context of replacement timelines, available funding and the relatively stagnant national power demand.

Thermal plant efficiencies range between 33-37% with best practise efficiencies exceeding 40%. The Terragen efficiency was 30.2% for the period June 2017 – June 2018 highlighting an area for improvement but it should however be qualified noting the rate and scale of Mauritian power grid fluctuations that influence this metric. Newer technologies would include: small scale fluidised bed coal plants, small scale coal gasification combined cycle (CGCC) plants and the ability to discard coal fines more effectively than large plants.

Flue gas treatment measures essentially comprising of electrostatic precipitator are minimal and we suggest that a denitrification (deNox) unit and fluegas desulphurisation plant should be mandated in coal fired power plants.

Output 3: Technical, Process and Operational Related Recommendations

Recommendations regarding opportunities at the different plants included:

- Boiler control and monitoring upgrades
- Turbine efficiency issues that may have been caused by deposits, corrosion or erosion on turbine blades
- VFD controls on cooling tower fans that could improve their performance
- Check the feasibility of a bagasse dryers that could significantly improve the efficiency during crop season
- Development and implementation (tracking performance) of energy baselines and water baselines

Assuming all 5 thermal power plants in this study represent similar savings opportunities the cumulative energy and cost savings could conservatively be greater than **MUR 560M annually**.

Other key parameters that were discussed included the fuel and energy mix where the following recommendations were made regarding renewables:

- Optimisation and maximising bagasse use.
- Offshore wind power generation.
- Pyrolysis of rubber tyres (latest technologies with low temperature pyrolysis).
- Waste to energy in the form of biogas can be investigated at waste water treatment facilities.

Coal Ash recommendations included, in order of execution:

- Improve boiler combustion efficiencies with more effective air:fuel ratio controls,
- Install, maintain and operate fly-ash refeeding systems to reduce the unburnt carbon levels in both fly- and bottom ash to levels below 10.0%, and ideally target 5.0% and

Thereby obviate the need for a costly CBO unit and directly use final fly-ash residues in the building construction brick manufacturing process.

Business risk to the IPPs were also discussed as a Key parameter. The reported delays and uncertainty around the renewal of power supply contracts by CEB for Mauritian IPP thermal power plants, especially

in the case of the Terragen and Alteo plants, serves to delay critical decision making relating to plant upgrades and funding arrangements.

Output 4: Capacity Building of National and Local Officials on Monitoring and Assessment of Environmental and Energy Related Performance.

Capacity building was provided to 34 delegates in total. The training constituted a course on steam systems and a course on performance measurement. These courses were selected based on two distinct delegate groups as identified in the training needs assessment conducted together with the Mauritian Ministry of Environment (Government Officials and Independent Power Plant Personnel) and the courses were adapted to suit the stakeholder needs.

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1. Output 2: Baseline study

This section outlines Output 2 of the Assessment and identification of technology needs and best practices for reducing the GHG emitting potential of the energy sector in Mauritius. Output 2 focusses on developing a baseline for the Mauritian Independent Power Producers (IPPs) in terms of technology utilised, fuels used to generate power, energy performance, environmental performance as well as benchmarking Mauritian IPPs against international best practises.

1.1 Baseline Study of Technology (Equipment, Plant, Soft and Hardware)

The plant and equipment and soft and hardware control technologies used by the 5 Mauritian IPP thermal power plant identified for the CTCN study, unsurprisingly revealed many similarities and some interesting differences. In an island nation state the size of Mauritius with a strong French legacy and influence, common plant and process designs were expected. Table 1 below provide the names and details of the 5 IPP thermal power plants identified by the Mauritian Ministry of the Environment and CTCN for the study.

Table 1: Original study scope

Power Plant	Contact Person	Contact details
Omnicanne Thermal Energy Operations (St Aubin) Ltd	Mr Frederic Robert	Email: frobert@ctds.intnet.mu Tel: (230) 54227323
Terragen Ltd	Mr Jean Michel Gerard	Email: jmgerard@terragen.mu Tel: (230) 54991964
Omnicanne Thermal Energy Operations (La Baraque) Ltd	Mr Yash Jahazeeah	Email: yjahajzeeah@omnicane.com Tel: 52565410
Alteo Energy Ltd	Mr Dominique Perrier	Email: DPerrier@alteogroup.com Tel: (230) 54233304
Consolidated Energy Ltd	Mr Dominique Perrier	Email: DPerrier@alteogroup.com Tel: (230) 54233304

During the information sharing, data gathering and plant analysis that occurred in output 1, CTCN and the Ministry accepted our proposal to narrow the study to a deeper assessment at 2 selected IPP thermal plants, viz. Omnicanne Saint Aubin and Terragen, as opposed to shorter scoping audits at all 5 plants.

Based on the plant specifications submitted by the 5 IPP thermal power plants and the 5 year information shared by Terragen and Omnicanne Saint Aubin, during output 1, and information obtained during the assessments at these two plants we were able to develop the following plant, equipment and control

technology baseline for the period just prior to the commencement of our assessments in November 2018.

Table 2: Technology Baseline

Technologies Applied	Terragen	Omnicanne Saint Aubin	Omnicanne La Baraque	Beau Champ	Alteo Energy
Boiler Manufacturer	Babcock Enterprise	Stein	Unknown	Babcock Enterprise	Unknown
Boiler Design	Water Tube	Water Tube	Water Tube	Water Tube	Water Tube
Fuel Feed Mechanism	Spreader Stoker	Spreader Stoker	Spreader Stoker	Spreader Stoker	Spreader Stoker
Boiler Passes	3	Unknown	Unknown	Unknown	Unknown
Boiler Fuels	Dual (coal, bagasse)	Coal only	Dual (coal, bagasse)	Dual (coal, bagasse)	Dual (coal, bagasse)
Turbine Manufacturer	Thermodyn	Unknown	Unknown	Thermodyn	Unknown
Turbine Operating System	SIEMENS DCS	Unknown	Unknown	ABB Freelance	Unknown
Turbine Technology	Extraction Condensing	Full Condensing	Extraction Condensing	Extraction Condensing	Extraction Condensing
Fluegas Treatment Technologies Applied	Mechanical Dust Collector Electrostatic Precipitator	Electrostatic Precipitator	Electrostatic Precipitator	Electrostatic Precipitator	Wet Scrubber
Age of Boiler(s)	19 years	14 years (recom)	12 years	21 years	20 - 35 years
Age of Turbine(s)	19 years	14 years (recom)	13 years	21 years	20 - 35 years
Data Management & Controls	Good parameter cover	Basic system being expanded	Unknown	Unknown	Unknown

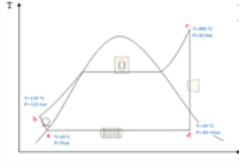
Sources: Proponent, EIA

1.1.1 Omnicanne

An analysis of the 5 year boiler and steam turbine data provided by Omnicanne St Aubin enabled us to develop power plant parameter profiles shared with plant management on our first day on site. The objective of these trend graphs served to identify anomalies and the coal feed rate data used by the plant appeared incorrect which impacted boiler combustion and overall plant efficiencies. Without the correct coal consumption data we are unable to provide specific recommendations relating to boiler combustion and overall plant efficiencies. The boiler efficiency calculation is an example of the uncertainty created by an incorrect coal feed rate, as demonstrated below. In this case we used the boiler efficiency value determined by our analysis of measured flue gas parameters.

Data Issues:

- Coal feed data options
- Conductivity data correction
- Feedwater pressure assumption
- Fluegas temperature



Stack losses are related to SSAT Boiler Efficiency as follows: SSAT Boiler Efficiency = 100% - Stack Loss (%) - Shell Loss (%)	
Shell Loss refers to the radiant heat loss from the boiler. Typically <1% at full load, 1-2% at reduced load.	
Input Data	
Stack Gas Temperature (°F)	375.9 °C
Ambient Temperature (°F)	33.7 °C
Stack Temperature - Ambient Temperature = 342°C	Warning - Temperature difference outside correlation range
<small>Note: Stack loss calculations have been done based on temperature differences between Stack Gas and Ambient at 250°F to 500°F. Temperature differences outside of this range are likely to give inaccurate results.</small>	
Stack Gas Oxygen Content (%)	4.81 %
<small>Note: Stack gas oxygen content is expressed on a molar or molar basis.</small>	
Results	
Estimated Stack Losses for each of the default fuels are as follows:	
Natural Gas	25.9 %
Number 2 Fuel Oil	21.3 %
Number 6 Fuel Oil (Low Sulfur)	20.9 %
Number 6 Fuel Oil (High Sulfur)	21.1 %
Typical Eastern Coal (Bituminous)	19.6 %
Typical Western Coal (Subbituminous)	21.1 %
Typical Green Wood	31.7 %

Efficiencies:

- Boiler Efficiency 2015 – 2017: **82.6%** (17tph coal feed rate)
- Boiler Efficiency 2017 – 2018: **22.65%** (62tph coal feed rate)
- Combustion and fluegas treatment Eff: – **89.7%** (146C fluegas temperature)

A new metering and EDM system was installed, prior to our visit, which provided the capability for improved key parameter monitoring and performance measurement in future. We noted inconsistencies in the understanding of parameters logged and measured amongst plant management.

1.1.2 Terragen

Data Collection for the Terragen Power Plant energy assessment was done in two steps. The first step was the compilation of a Data Request Questionnaire that collected qualitative and high-level quantitative information about the Terragen plant. The second level of data collection involved going through the plant's P&ID's and identifying critical and important instrumentation for use in the power plant energy assessment and analysis.

Each boiler is designed to generate 140 tph (tonnes per hour) of superheated steam at 525°C and 81 barg pressure. The fuel combustion takes place on a rotating grate of a Detroit Stoker type. Fly ash is collected by a mechanical dust collector and recirculated back into the combustion chamber via the secondary air fan. A feedwater economizer is used to recovery the heat energy from the stack. Additional equipment include electrostatic precipitators (ESPs), induced draft fan and stacks on the flue gas side. On the combustion air side, a LP steam coil air heater and a feedwater air heater (only during bagasse firing) is used for preheating the air. A venturi air flow damper is used for the combustion air. Both the forced draft fans (primary and secondary) and the induced draft fans are fixed speed drives driven by motors supplied by 11 kV.

In summary, the baseline study indicates the use of basic thermal power plant technologies with very limited use of advanced boiler, turbine and condenser technologies. It should be noted that newer and more efficient technologies are costly and its adaptation through significant capital expenditure programmes are guided, and at times restricted, by the lifespan of CEB IPP contracts. Maintenance challenges and equipment break-downs dilute the impact of advanced technologies, as evidenced by the inactive moving grate and combustion air circulation and the bottom ash reburn:recycle system at Omnicane and the faulty stack sensor at Terragen. Fluegas treatment measures, essentially comprising an

electrostatic precipitator are minimal and we suggest that a denitrification (deNox) unit and fluegas desulphurization plant should be mandated in coal fired thermal power plants. Supervisory control and data acquisition systems at the plant assessed ranged from basic to average. Plant management and ultimately generation efficiencies can be improved through more comprehensive parameter monitoring. Recommendations presented in Output 3 will address potential plant and process technology improvements.

1.2 Baseline Study of Fuels used in Mauritian Independent Thermal Power Plants

According to the “Energy and Water Statistics” report, published by Statistics Mauritius the Peak Power Demand reached 461.5 MW in 2017, down from 467.9 MW in 2016.

Figure 1 shows that electricity generated by CEB was 1174.5 GWh in 2016 and increased to 1234.7 GWh in 2017. Independent Power Producer (IPP) electricity generation also increased from 1563.1 GWh in 2016 to 1614 GWh in 2017. In total electricity generation increased from 2737.6 GWh (2016) to 2848.7 GWh (2017); a 4.1% increase.

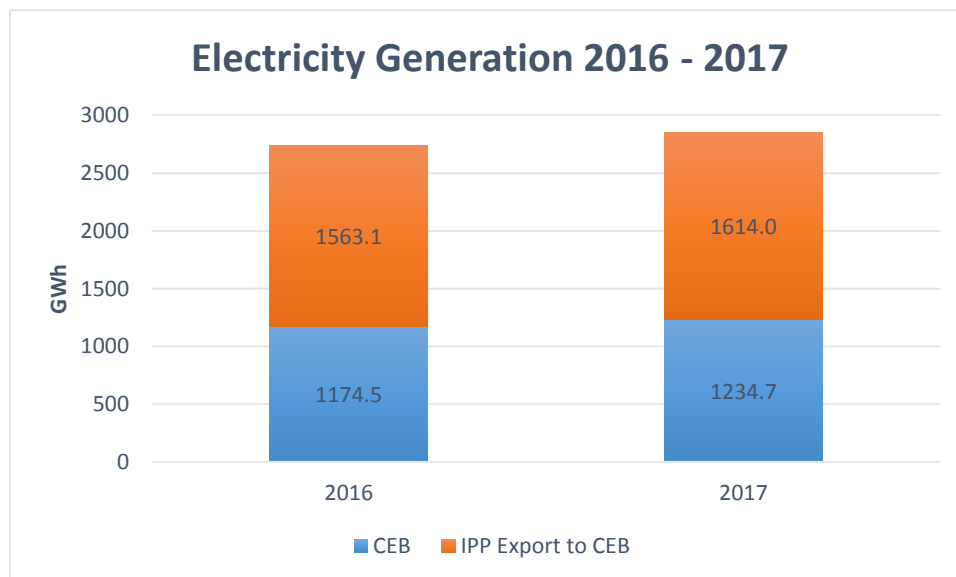


Figure 1: Electricity Generation by CEB and IPPs 2016-2017

When the mix of energy sources are considered (Figure 2) it is very interesting to see the magnitude of electricity being generated from Fuel oil and Diesel (36.5% in 2016 and 37.4% in 2017) compared to electricity generated from Coal (41.6% in 2016 and 2017). Bagasse as a source of energy for electricity generation decreased from 16.3% in 2016 to 14.7% in 2017. These three sources of energy are the main contributors to electricity generation while Hydro electricity generation contributes 3.3% in 2016 and 2.8% in 2017 and Photovoltaic electricity generation contributes 1% in 2016 and 2.4% in 2017.

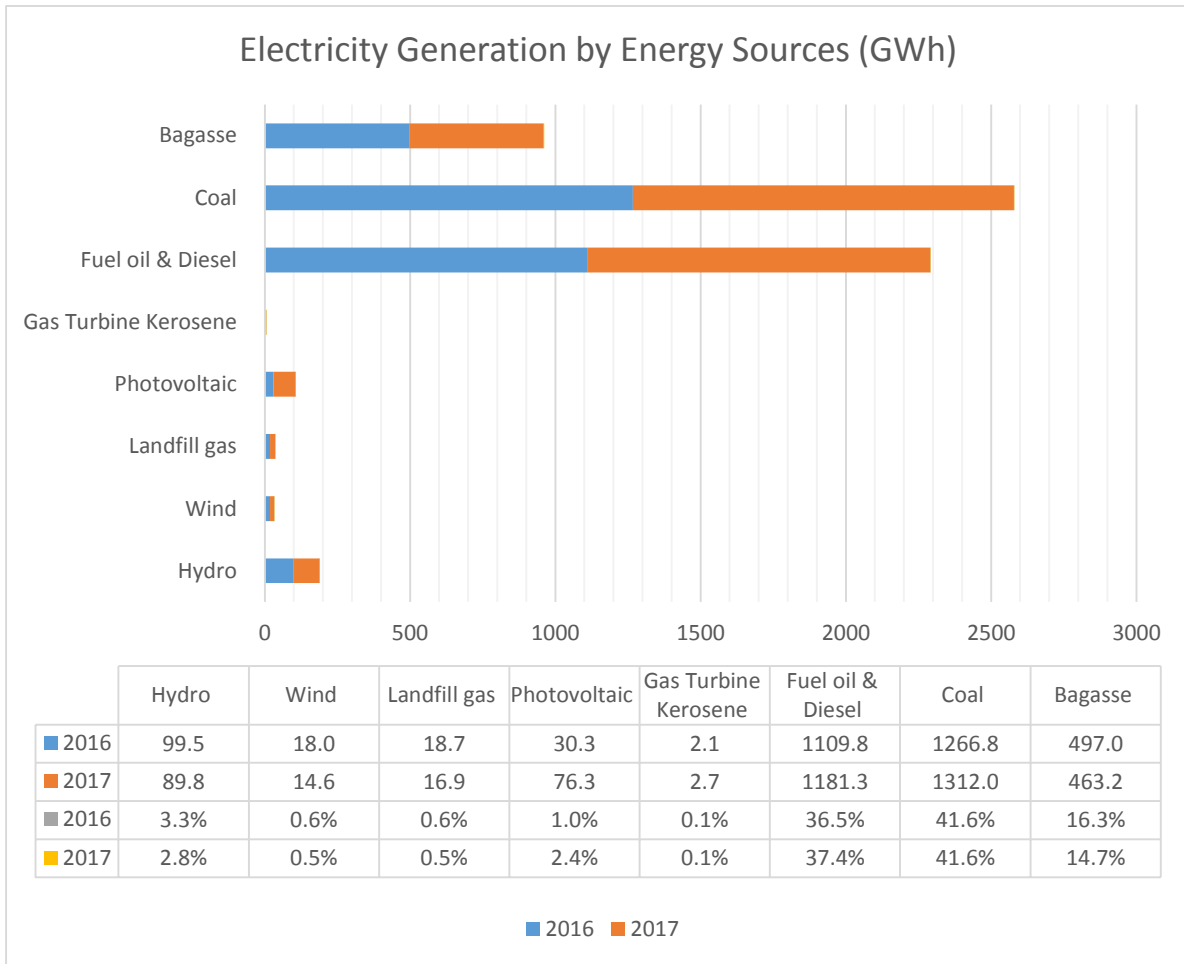


Figure 2: Energy Sources utilised to Generate Electricity 2016 to 2017

Figure 3 shows the electricity tariffs available to Mauritians as reflected on the Central Electricity Board’s website: <https://ceb.mu/customer-corner/electricity-tariffs-and-applicable-rates>

Tariffs are categorized according to usage with a few options available to each category. Industrial customers are charged based on “Time of Use” tariffs with Day tariffs applicable from 06:00 to 20:30 and Night tariffs applicable from 20:30 to 06:00. Some Industrial tariffs (as shown in Figure 5) that are not available to new customers includes a Day tariff (06:00 to 18:00), Peak tariff (18:00 to 21:00) and Night tariff (21:00 to 18:00). Tariffs applicable to customers using electricity for irrigation purposes are charged Peak rates (18:00 to 20:30) and Off Peak rates (20:30 to 18:00).

Commercial (Figure 4) and Industrial (Figure 5) customers are charged for maximum demand. Customers are charged maximum demand equal to the highest maximum demand charge for the past six months. Maximum demand is measured each month or any part thereof and for many of the Industrial customers it has a minimum of 20 kVA. Commercial customers are also charged for Power factors that are below 0.9 based on an excess kVA calculation as detailed in Figure 4.

Usage	Tariff	Connection Fees	Security Deposit
Domestic	110A, 110	Rs 750	Rs 200
	120	Rs 750	Rs 600
	140	Rs 750	Rs 1200
Commercial & Bulk	215, 217, 225, 245, 250, 255	Single - Phase Rs 750 Three - Phase Without CT Rs 1500 Three - Phase With CT Rs 3000	Rs. 500 per kW or fraction thereof of total connected load
Industrial	313, 315, 317*, 320*, 323, 325*, 330*, 340, 350	Single - Phase Rs 750 Three - Phase Without CT Rs 1500 Three - Phase With CT Rs 3000	Rs. 400 per kW or fraction thereof of total connected load
Sugar Factories	421, 422	Tariff 422 - Rs 3000/- every year	Not applicable
Street Lighting & Traffic Lights	510	One Connection Rs 400 More than one connection Rs 350 per connection	Not applicable
Pumping for Irrigation	515	Single - Phase Rs 750 Three - Phase Without CT Rs 1500 Three -Phase With CT Rs 3000	Rs. 300 per kW or fraction thereof of total connected load
Temporary Supply	615	Single - Phase Rs 750 Three - Phase Without CT Rs 1500 Three -Phase With CT Rs 3000	Not applicable

* Please note these tariffs are no more applicable to new customers

Tariff schedule for Commercial Customers under Tariff 255 - [General Notice No. 1488 of 2018](#)

Tariff schedule for Prosumers under the CEB 2015 Net-metering Scheme - [General Notice No. 252 of 2016](#)

Conditions and Tariff schedule for Domestic Social Tariff 110A - [General Notice No. 2552 of 2015](#)

Tariff schedule applicable as from 1st December 2010 - [General Notice No. 2287 and 2288 of 2010](#)

Rates applicable for [Rechargeable Services](#) as from 1st July 2017

[Meter Rental](#) applicable as from 1st January 2008

Archived Tariff schedule : [1st April 2008](#) / [1st September 2007](#)

Figure 3: Electricity tariffs available on CEB website

CENTRAL ELECTRICITY BOARD
TARIFF APPLICABLE TO COMMERCIAL CONSUMERS
UNDER TARIFF 255 WITH EFFECT FROM 1st September 2018

Tariff 255 - **MAXIMUM DEMAND TARIFF FOR COMMERCIAL CONSUMERS SUPPLIED AT HIGH VOLTAGE HAVING A DECLARED LOAD EXCEEDING 500 KVA; TARIFF APPLICABLE TO ACCREDITED DATA CENTRE OPERATORS HOLDING AT LEAST A TIER 3 CERTIFICATION OF CONSTRUCTED FACILITY**

Demand Charge	Rs 136.00 per kVA of Maximum Demand, subject to a minimum of 20 kVA
Running Charge	Rs 2.97 per kWh
Minimum Charge	A sum equal to the highest Demand Charge paid in any one of the preceding six months of account

POWER FACTOR CLAUSE

A surcharge of Rs 81.00 per kVA, irrespective of application of minimum charge or not, shall be levied on the excess kVA recorded for the month or part thereof if the calculated average power factor for the month or part thereof is less than 0.90.

The average Power Factor for a month is calculated from the ratio:

$$\frac{\text{kWh recorded for the month or part thereof}}{\text{kVAh recorded for the month or part thereof}}$$

Excess kVA is calculated from the formula $E = \frac{M \times (0.90 - P)}{0.90}$

Where **E** = Excess kVA

M = Maximum Demand in kVA recorded for the month or part thereof

P = Calculated Average power factor for the month or part thereof

SECURITY DEPOSITS

Rs 500.00 per kW or fraction thereof of total connected load

Figure 4: Commercial customer's tariffs

- Tariff 313 - Maximum demand Tariff for Industrial Consumers
- Tariff 315 - Flat Rate Tariff for Industrial Consumers.
- Tariff 317* - Maximum demand Tariff for Industrial Consumers possessing an export enterprise certificate.
- Tariff 320* - Maximum demand Tariff for Industrial Consumers possessing an export enterprise certificate and supplied at Low Voltage.
- Tariff 323 - Maximum demand Tariff for Industrial Consumers supplied at High Voltage.
- Tariff 325* - Maximum demand Tariff for Industrial Consumers possessing an export enterprise certificate and supplied at High Voltage.
- Tariff 330* - Maximum demand Night Tariff for Industrial Consumers possessing an export enterprise certificate and supplied at High Voltage.
- Tariff 340 - Maximum demand Tariff for Industrial Consumers possessing a Freeport Licence and supplied at Low Voltage.
- Tariff 350 - Maximum demand Tariff for Industrial Consumers possessing a Freeport Licence and supplied at High Voltage.

Tariff	Running Charge per kWh	Demand Charge per kVA	Minimum Charge
313	Rs. 3.12	Rs. 144.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
315	Rs. 5.40	-	Rs. 113.00 per month or part thereof per kW or fraction thereof of total connected load, subject to a minimum of Rs 113.00 per month
317*	Rs. 2.86 1st 250,000 kWh	Rs. 144.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
	Rs. 2.51 all additional kWh		
320*	Rs. 2.86 (Day Rate)	Rs. 144.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
	Rs. 3.30 (Peak Rate)		
	Rs. 2.26 (Night Rate)		
323	Rs. 2.97	Rs. 136.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
325*	Rs. 2.78 1st 250,000 kWh	Rs. 136.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
	Rs. 2.44 all additional kWh		
330*	Rs. 2.78 (Day Rate)	Rs. 136.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
	Rs. 3.30 (Peak Rate)		
	Rs. 2.17 (Night Rate)		
340	Rs. 4.04 (Day Rate)	Rs. 150.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
	Rs. 3.19 (Night Rate)		
350	Rs. 3.83 (Day Rate)	Rs. 150.00 per kVA of Maximum Demand, subject to a min. of 20 kVA	A sum equal to the highest Demand Charge paid in any one of the preceding 6 months of account
	Rs. 3.08 (Night Rate)		

* Please note tariffs 317, 320, 325 and 330 are no more applicable to new customers

Figure 5: Industrial customers tariffs

Electricity prices remained constant from 2016 to 2017 and did not increase as can be seen from Figure 6. "Other" electricity consumers would include Residential, Street Lighting and Temporary Supply to customers. These consumers were paying the highest price for their electricity at 7.81 Rs/kWh. Irrigation consumers were paying the least at 2.78 Rs/kWh.

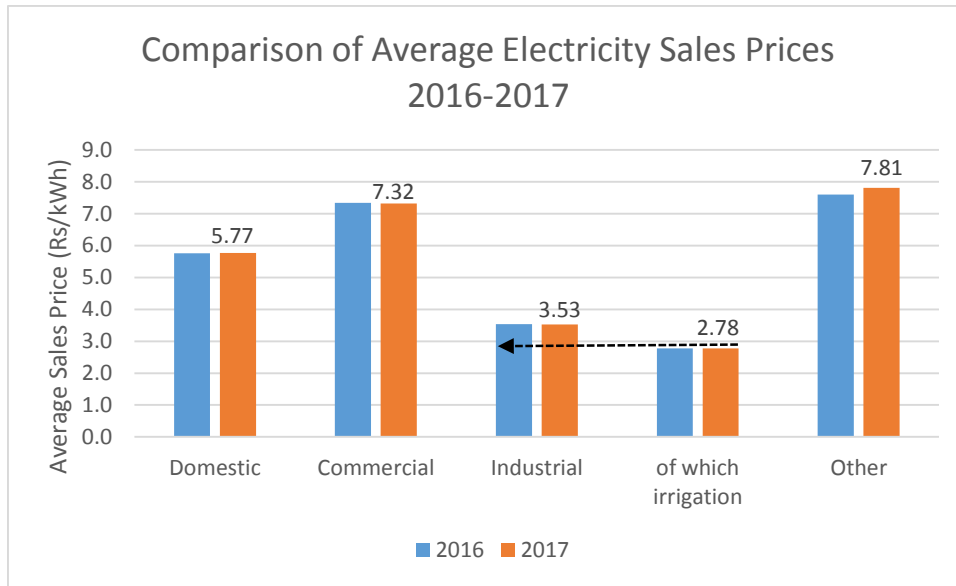


Figure 6: Comparison of average electricity prices 2016-2017

Figure 7 shows the electricity sales in 2017 to different types of consumers. Commercial customers contributed 36%, Domestic consumers, 33% and Industrial consumers 29%. Other consumers contributed 2%.

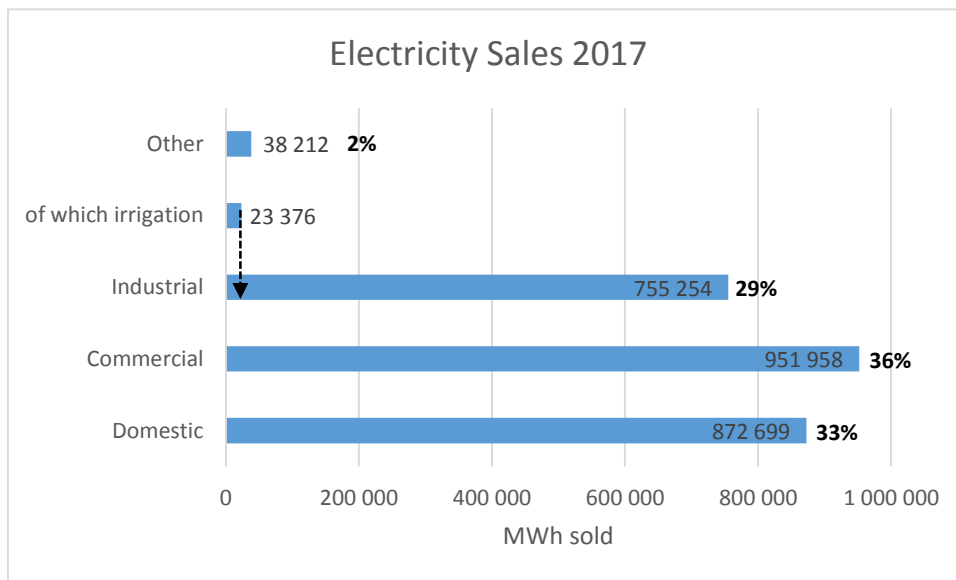


Figure 7: Electricity sales (MWh) in 2017

1.3 Baseline of Energy Performance

Parameters generally used to determine the efficiency of power plants include:

- Overall Power Station efficiency = Load available at generator terminal/(coal flow x Gross Calorific Value)
- Heat rate= Heat added to the steam boiler (kJ)/electrical energy exported (kWh)
- Specific Fuel Consumption = Fuel consumed in (kg/h)/Power generated (kW)

In addition the efficiency of components of the power plant can also contribute to the efficiency picture of a specific plant:

- Boiler efficiency: Calculated either by the direct or indirect method
- Turbine efficiency

The average global (Power Station) efficiency of Coal fired power plants is about 33% (in 2017) according to Mike Rycroft in his article “Efficiency improvement of coal-fired power stations” published in “ee Publishers” on 15 March 2017.

1.3.1 Boiler Efficiencies

The boiler efficiencies of the two power plants assessed in this study were:

- Omnicane: 89.7% (efficiency calculated from spot measurements taken during site visit in November 2018.)
- Terragen: **87.6%** (efficiency calculated from spot measurements taken during site visits in July 2019.) Notably this was for a period during which both coal and bagasse was being fed to the boiler. Based on data that was measured during **coal only operation (in 2018)** this number was **87.6%** and during times that **only Bagasse** was being fed to the boiler (in 2018) the efficiency dropped to **68.9%**. On average during dual firing periods efficiency was around 74.8% as calculated from 2018 data.

It is however very difficult to directly compare efficiency parameters since they are usually heavily influenced by many factors that include the type of technology, grade of coal or other fuel fed to the boiler etc.

1.1.1 Energy Performance Baselines

Performance baselines were developed for the Terragen plant that enables the comparison of current performance to historical performance of the plant. Omnicane was unable to provide data that was of the integrity to enable the development of such baselines.

All season's baseline

For Terragen the baseline that was developed to include “all seasons”, meaning January to December periods that include coal only, bagasse only as well as dual firing of fuel was:

$$\text{Total energy supplied (coal + bagasse in GJ/day)} = 609.77 + 12.62*(\text{MWh produced/day}) - 6.51*(\text{Tons per day LP steam extracted})$$

At a 95% confidence interval, the Standard Error (SE)_{savings} was as follows:

$$(SE)_{\text{savings}} = \pm t * \sqrt{n*(SE_{\text{model}})^2} = 73\,033 \text{ GJ/day}$$

Where:

- SE_{model} was given in the regression results for the model (1388.97)
- n = number of observations = 1020
- Degrees of freedom = $n-1 = 1020-1 = 1019$
- t (95%, degrees of freedom) = 1.64635

Coal only baseline

The model for energy consumption (**applicable January to June – Coal only**) is:

$$\text{Total energy supplied (coal + bagasse in GJ/day)} = 1661.17 + 12.63*(\text{MWh produced/day}) - 5.53*(\text{Tons per day LP steam extracted}) - 139.94*(\text{HDD})$$

At a 95% confidence interval, the Standard Error (SE)_{savings} is as follows:

$$(SE)_{\text{savings}} = \pm t * \sqrt{n*(SE_{\text{model}})^2} = 22\,187 \text{ GJ/day}$$

Where:

- SE_{model} is given in the regression results for the model (622.29)
- n = number of observations = 468
- Degrees of freedom = $n-1 = 468-1 = 467$

$$t \text{ (95\%, degrees of freedom)} = 1.648123$$

Bagasse only baseline

The model for energy consumption (**applicable June to December – Bagasse only**) is:

$$\text{Total energy supplied (coal + bagasse in GJ/day)} = -4528.29 + 12.10*(\text{MWh produced/day}) - 6.41*(\text{Tons per day LP steam extracted}) + 103.54*(\text{HDD})$$

At a 95% confidence interval, the Standard Error (SE)_{savings} is as follows:

$$(SE)_{\text{savings}} = \pm t * \sqrt{n * (SE_{\text{model}})^2} = 68\,017 \text{ GJ/day}$$

Where:

- SE_{model} is given in the regression results for the model (1757.08)
- n = number of observations = 552
- Degrees of freedom = $n-1 = 552-1 = 551$
- t (95%, degrees of freedom) = 1.647624

Baselines as discussed in this section can be used to determine the performance of the facility going forward (from 2019 onwards) and can be used to monitor and evaluate savings from implemented energy projects.

1.2 International Best Practise and Technology Benchmarking

In our attempt to benchmark Mauritian thermal power plant technologies with global best practice applications we list best practice small scale (50 – 350MW) thermal power technologies below and draw comparisons with the Terragen and Omnicane plants observed and assessed as well as with the broader original group of Mauritian thermal power plants in the study.

Leading small scale thermal power plants globally feature the following capabilities:

- Modular in design and construction. All 5 Mauritian thermal power plants are good examples of this with independent boiler, turbine and condenser configurations.
- Lower power generation cost than traditional power plants. The Terragen plant reported a generation cost of 7.6 cents US per kWh compared to the global levelized cost of generation of 9.5 – 11.9 cents US per kWh for traditional coal fired power plants.
- Operational flexibility that makes it capable of following the load very closely. Terragen reported a very impressive ramp-up capability of 2.7MWh/minute. If the other Mauritian thermal power plants in this study are capable of similar load following, then Mauritius benchmarks well against global best practice. The application of an advanced turbine sliding pressure operation and a variable steam supply capability can achieve good load following capabilities without the structural degradation caused by frequent load fluctuations.
- Global best practice thermal efficiencies exceed 40% and thermal power plant efficiency rates generally varies from 33 – 37% which, when compared to the calculated thermal efficiencies of the two boiler:turbine power units at Terragen, of 30.2% for the period June 2017 – Jun 2018, highlights a major area for improvement. It should however be qualified by noting that the rate and scale of the Mauritian grid power demand fluctuations, greatly influence this metric. Unfortunately no benchmarking data of this nature could be obtained to conduct a fair benchmarking comparison.
- Small scale fluidised-bed coal plants in standardised configurations. This technology is relatively new, very expensive and has not been adopted in Mauritius.

- Small-sized coal gasification combined cycle (CGCC) plants. This technology is very new and has not been adopted in Mauritius.
- The ability to use discard coal and coal fines more effectively than large plants. We were unable to establish a best practice benchmark measure

In summary, Mauritian thermal power plants assessed compares well with global small scale thermal power plant best practices. In terms of the technologies applied, there are many areas where it can be updated, within the context of plant replacement timelines, available funding and a relatively stagnant national power demand.

2. Output 3: Technical, Process and Operational related Recommendations

This section outlines Output 3 of the Assessment and identification of technology needs and best practices for reducing the GHG emitting potential of the energy sector in Mauritius. Output 3 centres around recommendations emanating from the assessments conducted at two of the five Mauritian IPP plants.

There are several international programmes aimed at improving efficiency of coal fired power stations (CFPS). Minimising heat losses is the greatest factor affecting the loss of CFPS efficiency, and there are many areas of potential heat losses in a power plant. Efficiency of older CFPS becomes degraded over time, and lower power plant efficiency results in more coal being used and more CO₂ being emitted per unit of electricity generated. The options most often considered for increasing the efficiency of CFPS include equipment refurbishment, plant upgrades, and improved operations and maintenance schedules.

Moving the current average global efficiency rate of CFPS from 33% to 40% by deploying more advanced off-the-shelf technology could cut 2 Gt of CO₂ emissions, while allowing affordable energy for economic development, thus, efficiency improvements are the first step on the road to major emissions reductions.

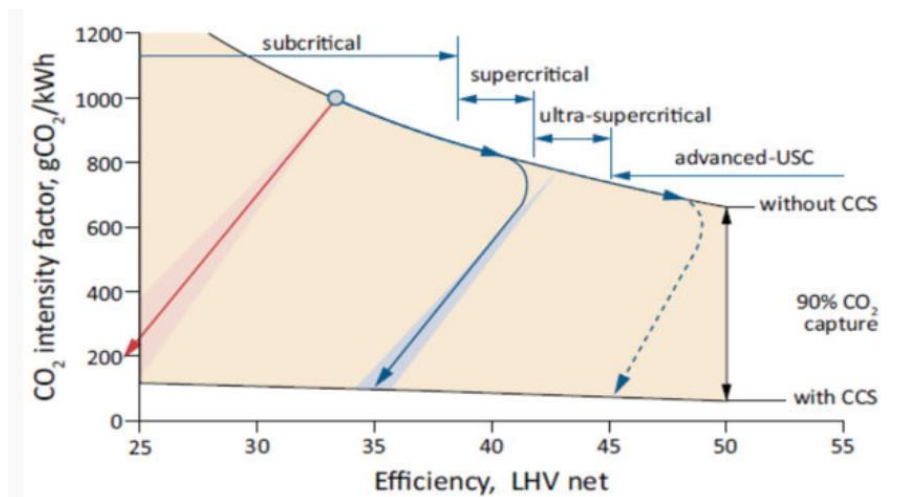


Figure 8: Effect of efficiency factors on various coal fired technologies

An effective and sustainable strategy for CFPS must integrate environmental imperatives with the legitimate aims of energy security and economic development, including poverty alleviation. This means that there must be a role for cleaner coal technologies, including high-efficiency low-emission (HELE) coal-fired power generation.

HELE technologies are commercially available and, if deployed, can reduce CO₂ emissions from the entire power sector by around 20%. They are the low-hanging fruit in global CO₂ mitigation which should be prioritised.

The average efficiency of CFPP around the world today is 33%. This is well below the state-of-the-art rate of 45% and even “off-the-shelf” rates of around 40%. Increasing the efficiency of CFPP by 1% reduces CO₂ emissions by between 2 and 3%.

In addition to CO₂ abatement, and probably more important for economic expansion, comes the reduction in use of coal/kWh and hence reduction in running costs, plus overall reduction in the use of coal and extension of the lifetime of coal reserves. Reduction of 20% in CO₂ emissions implies a reduction of 20% in coal usage.¹

Areas where efficiency losses typically occur

Several studies and ours have been done to identify areas where efficiency losses occur. Much of the energy loss is associated with auxiliary equipment such as pumps, mills and fans, and attention to these items can bring about great improvement.

Improved maintenance

¹ Source: Mike Rycroft, EE Publishers

The first area that can give efficiency gains with the least amount of disruption is improved maintenance, which may also be combined with improved monitoring and control. Improvements related to improved maintenance are in the range of 1 to 3%.

Flexible operation control

The increasing amount of renewable energy in the network means an increasing requirement for plant to operate in cyclical or flexible mode. Flexible operation refers to the ability of a plant to operate at part load and in load-following and cycling (on and off) modes. Operating conditions under flexible operation can result in reductions in plant efficiency and increased degradation and maintenance requirements on components due to constant swings in operating temperature and pressure. Various studies have identified cost-effective capital modifications and adjustments to plant operating procedures to improve heat rate during cycling operation.

Other plant improvements

Table 3 below shows efficiency gains that are possible with improvements to various items of plant. It would appear that gains are possible in every section of the power train, from the boilers to the flue gas cleaners.

Control system upgrades

Changing the control system is perhaps one of the least disruptive efficiency moves to consider, and can give significant gains in performance. Newer systems allow more monitoring and control of the various stages of combustion, steam and turbine operation, allowing each to be optimised.

Remote monitoring centres (RMCs) have been used for many years to track and improve equipment reliability, and in many cases, these same RMCs have thermal performance software installed for monitoring heat rate. The value of finding and fixing reliability issues can often be quantified, but placing a value on heat rate monitoring is not so easy. A study evaluating the use of remote monitoring systems as it relates specifically to heat rate improvement reported that all of the companies surveyed were able to verify heat rate improvements based on the activities of the monitoring centres in addition to improvement in equipment reliability.

In many cases, the heat rate improvements were significant and well surpassed the incremental costs for monitoring heat rate in addition to reliability. Heat rate improvements in the range of 2,5 to 4% have been reportedly attributed to the actions resulting from improved monitoring.

Table 3: Potential improvement projects and savings

Category	Area of improvement	Net efficiency gain (%)
Combustion systems	Pulveriser and feeder upgrades	0,3
	Air heater repair or upgrade	0,25

	Sootblower improvements	0,35
	Excess air instrumentation and control	0,2
Steam cycle	Feedwater heater repairs	0,4
	Heat transfer tube upgrades	0,6
	Steam turbine blades	0,5
	Cycle isolation	0,4
	Condensor repairs	0,5
O&M	O&M training	Included in combustion and steam cycle gains. Efficient operation realised over the long term
	Computerised maintenance and management systems and reliability centred maintenance	
	Distributed control systems	
Combined total		3,5%

Not all 30 - 40 year old power plants will be retired though, and there are many ways of improving the efficiency of existing plant through life extension, without major replacement of plant or reconfiguration. Several studies have shown that up to 5% improvement in efficiency can be achieved by modifications and maintenance.

2.1 Omnicane Assessment Findings

2.1.1 Boiler specific Recommendations to Improve Energy and Environmental Performance

- Improved key boiler parameter data management, monitoring and controls and broader dissemination of performance metrics with plant management eg. boiler efficiency, turbine efficiency, blowdown rate, turbine exhaust pressure, fluegas temperature relative to the acid dewpoint, fluegas oxygen content, unburnt fuel in fly ash, etc,...
- A rapid and effective response to boiler operation anomalies and significant deviations beyond agreed control limits.
- The prioritisation of the repair critical boiler equipment and components.

- Blowdown management which seeks to reduce blowdown losses and blowdown flash steam recovery to capture heat from blowdown.
- Procure a basic set of measurement equipment eg. thermal imaging camera, hobo data loggers and temperature gun to encourage spot measurements that enables trouble shooting.

2.1.2 Plant specific Recommendations to Improve Energy and Environmental Performance

- Plant life extension and refurbishment options is an important consideration for the aging Alteo, Beau Champ and Terragen plants, to extend that plant's capability and add flexible operation. Uncertainty around the renewal of CEB contracts for these plants serve to dis-incentivise sorely needed capex projects. Similarly the load on the rebuilt boiler at Omnicane Saint Aubin warrants monitoring.
- Improve turbine generator efficiency. The turbines were operating lower than the design rated condition and improved maintenance of the turbines, notably removing impeller blade deposits will serve to elevate turbine performance.
- Recommended plant upgrades such as changing to a boiler:turbine sliding pressure operation, variable frequency drives for main cycle and auxiliary equipment, mill and burner control schemes as well as more comprehensive control systems will serve to exploit some of the inherent advantages of existing plant configuration.
- The cooling tower efficiency was calculated to be 65% some way below best practice efficiencies of 70 – 80% for thermal power plant cooling towers. Considering the Mauritian wet-bulb temperature profile, a variable frequency drive (VFD) was recommended for the cooling tower fans to improve efficiency and secure significant energy saving. It should be noted that VFD parameters may require tuning to operate successfully in all ambient conditions and the control scheme may require troubleshooting to operate as desired.
- Establish energy (boiler fuel) consumption baselines to track and report generating unit performance weekly and timeous detection of failures.
- Introduce a basic competency and awareness induction and plant operator level training to achieve greater plant wide appreciation of plant operating objectives.

2.2 Terragen Assessment Findings

2.2.1 Boiler specific Recommendations to Improve Energy and Environmental Performance

- Boiler blowdown automated control upgrade to utilise the instruments and sensors already in place at Terragen. The conductivity and pH signals from the steam drum water can be fed to a controller which would send a signal to a modulating or a ON/OFF solenoid valve to control the amount of blowdown from the boiler.

- Boiler blowdown flash steam recovery. Installing a flash tank to flash blowdown and use the resultant flash either in the Low pressure header or the deaerator.

2.2.2 Plant specific Recommendations to Improve Energy and Environmental Performance

- Evaluating the current condensing turbine section operating conditions, it was found that the actual isentropic efficiency of the condensing section was lower by a couple of percentage points compared to the design rated conditions. Plant personnel are encouraged to possibly further inspect and evaluate the condensing turbine section to see if the impeller blades have any deposits, corrosion, erosion, etc.
- This can possibly be done in the next turnaround. Additional due diligence by further detailed data analysis can also be done in the meantime to really evaluate turbine performance with a higher fidelity to confirm this energy efficiency improvement opportunity.
- Implementing VFDs at the four 110kW Cooling Tower Fans and controlling the speed of the fan based on circulating water temperature, designed as a PID loop with circulating water temperature as the process variable. In addition, cooling tower operators should be provided with the ability to bias the target set-point as required to ensure the lowest cooling water temperature outflow to the condenser, noting the range of Mauritian wet-bulb temperature over a 12 month period.
- Drying bagasse with a moisture content between 48-50% to a moisture content of 40%. A feasibility study is currently underway but plant management mentioned that financial and political support from government is lacking when these efficiency and environmental projects are undertaken.

An improvement of 10% in cogeneration efficiency can translate into more power that can be generated or more steam that can be generated from the available bagasse. If it is considered that the sugar mill does not necessarily require more steam, it can be assumed that all of the additional energy would be transformed into additional power that can be supplied to the Mauritian electricity grid or the replacement of coal (in part) as a fuel.

2.3 Estimation of Impact of Recommendations

The cost of all projects recommended for implementation at Terragen amounted to MUR 136M ranging in individual payback periods less than 2 years to 18.5 years. Some of the recommended low cost projects required no capital expenditure and can be paid for from the plant operating expenditure (maintenance) budget. Assuming all 5 thermal power plants in this study represent similar savings opportunities the cumulative energy and cost savings could conservatively be greater than **MUR 560M annually**.

2.4 Key Parameter Recommendations

2.4.1 Fuel and energy Mix

According to the World Energy Resources 2016 Report “Sufficient and secure energy is the main enabler for welfare and economic development of a society. As energy-related activities have significant environmental impacts, it is indispensable to provide an energy system which covers the needs of the economies and preserves the environment.”

The Energy Trilemma is described as the main drivers of changes in the energy sector, called energy transitions. The Energy Trilemma is:

- Securing energy supply,
- increasing competitiveness by using least-cost approaches and
- environmental concerns

Principle drivers around the world that drives change in the energy sector was stated to be:

- The Paris Agreement and the pledges made by the governments of various countries.
- Record increase in renewable energy deployment.
- Decrease (halving) of the market price for oil.
- American shale gas boom.
- Decrease in global coal consumption, mainly caused by China’s transition to less energy intensive society.
- Progress in the implementation of Carbon Capture Utilisation and Storage (CC(U)S) in North America.
- Increase in electrification, particularly in the Transport sector (particularly electric vehicles).

Challenges in the world energy sector are currently:

- The rate of improvement towards cleaner energy is slower than that needed to meet emissions targets and public acceptance remains a challenge (such as the “Not in my back yard”; attitude – “NIMBY”).
- Uncertainty in energy prices resulting in risk which renders projects with long payback periods less appealing.
- Oil and gas companies are struggling without diversification and a review of their business models. Incentives provided to renewable energy companies have created a boom however, some companies may not be viable without these incentives.
- Rare earth elements, used especially in renewable energies create new dependencies in the value chain and could become barriers to future growth.
- There is a need to balance environmental considerations, increase resilience and security of supply. Long term planning becomes critical and failing to timely upgrade to smart infrastructure could hinder new energy developments.

- Carbon dioxide emissions from natural gas is set to surpass that of coal. Planning should include replacement of baseload power stations or risk unreliable power supply.

Figure 9 shows a comparison of the world’s primary energy consumption from 2005 to 2015. Notably there is an increase in coal consumption as well as gas consumption and Hydro. Oil consumption as well as nuclear saw a decrease. Wind, solar and other renewables increased as primary energy source. The world consumed 29.2% coal, 32.9% oil and 23.9% gas during 2015. Nuclear was 4.4%, hydro 6.8%, wind 1.4%, Solar 0.5% and other renewables 0.9%.

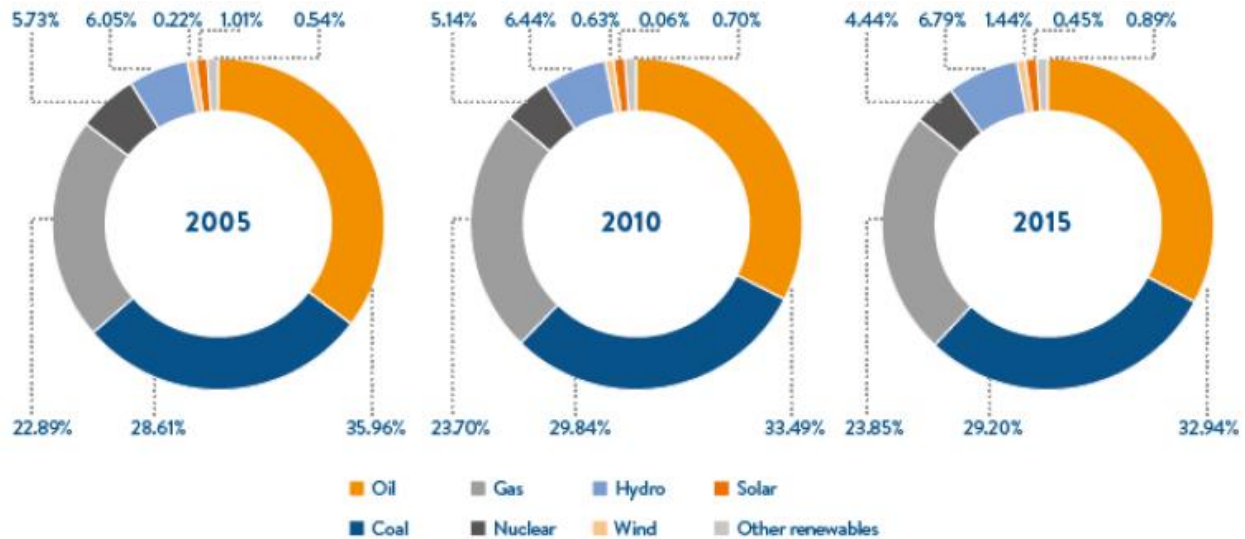


Figure 9: Primary energy consumption comparison over 15 years, 2005 to 2015

Section 1.2 details the Mauritian energy sources for electricity generation in Figure 2. Coal is the highest contributor (41.6% in 2017) to electricity generation, Fuel oil and Diesel (37.4% in 2017) is the second highest contributor, Bagasse (14.7% in 2017) the third highest. Hydroelectricity (2.8% in 2017) and Photovoltaic (2.5% in 2017) electricity adds small contributions and even smaller contributions from Landfill gas (0.5% in 2017) and Wind (0.5% in 2017) contributes even smaller amounts.

Comparing the energy consumption of Mauritius and the rest of the world the writers of this report believes that that there should be a concerted effort to move away from coal and increase renewable electricity generation. The use of bagasse and the use of cane field residue to generate power as piloted by the Terragen plant should be optimised. Mauritius has a few opportunities for increasing their renewables:

- Optimisation and maximising bagasse use.
- Offshore wind power generation.
- Pyrolysis of rubber tyres (latest technologies with low temperature pyrolysis).
- Waste to energy in the form of biogas can be investigated at waste water treatment facilities.

Mauritian demand for electricity is not growing very fast and any new installations should have as their focus renewables.

2.4.2 Emissions

Flue treatment at all 5 plants in the original scope of study were inadequate in terms of global thermal power plant and environmental standards. Fluegas treatment ranged a basic wet-scrubber to an electrostatic precipitator and mechanical dust removing, as best. We strongly recommend a phased conformance with global thermal power plant and air quality emission standards and suggest the following scaled implementation to accommodate funding planning and plant layout design:

1. The installation and operation of an electrostatic precipitator (ESP) as a minimum within 12 months,
2. The installation and commissioning of a denitrification (NeNOx) unit within 24 months and
3. The installation and commissioning of a desulphurisation (FGD) system within 36 months.

This should serve to align Mauritian coal fired thermal power plants with best practice American, European and African emission and air quality environmental practices. The figure below demonstrates the fluegas abatement practices at the 600MW Vattenfall Reuter West CHP plant in Berlin, Germany and what can be achieved in Mauritius in 3 years. This plant also used a Babcock boiler and equipment similar to that in use at Terragen.

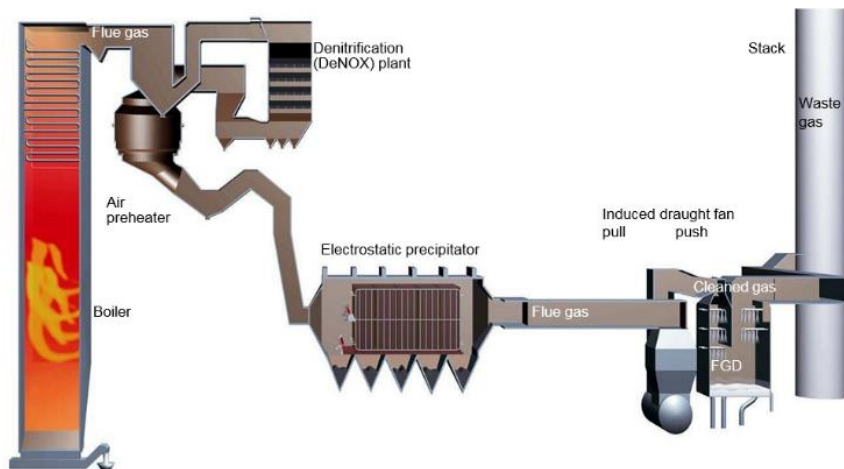


Figure 10: Vattenfall CHP Reuter West Berlin CHP Plant's Fluegas Purification Systems

2.4.3 Fly and Bottom Ash

The 3-year (2016 - 2018) average levels of unburnt carbon in the bottom- and fly-ash at Omnicane Saint Aubin (30.0% - 50.0%) and Terragen (16.6% - 38.7%) respectively are excessively high. This presents both a combustion efficiency improvement opportunity as well as a disposal challenge and a potential environment risk. At the Omnicane St Aubin plant, its relatively new ash reinjection system designed to re-combust unburnt carbon in coal-ash, was not operational during our visit, whereas the Terragen fly ash is re-injected into the boiler through a secondary fan. The combined final fly ash volumes generated, by both plants, ranging from 120 to 150 tons per day is collected by truck and taken to the Carbon Burn-Out Unit (CBO) at the Omnicane, La Baraque plant.

An extract from the Omnicane St Aubin's August 2017 Environmental Report (OTEA SA EIA) below, submitted to the Ministry of Environment, confirms compliance with the "complete combustion" of coal, 4% particulates and reuse of fly- and bottom-ash.

12	The furnace technology shall provide for complete combustion of coal to ensure that the particulates do not exceed 4% of the volume of the bottom ash.	✓	With the furnace technology and with the installation of the ESP, the particulates concentrations from the stacks are well below the prescribed standards.
13	The disposal of the fly ash and bottom ash shall be done to the satisfaction of the Ministry of Local Government and the Ministry of Environment and shall not give rise to any environmental problems. Prior to start of operation, the proponent shall submit to the Ministry of Local Government and the Ministry of Environment & NDU details on the use of the fly ash and bottom ash in the cement industry or highway and civil engineering applications as well as a copy of the agreement reached with the potential users.	✓	<p>Fly ash and bottom ash is reused in agricultural applications namely in sugarcane fields as stipulated in section 6.3.3.2.1 of the EIA. We ensure traceability in terms of tonnage and location where the ash is being applied. We also ensure that the fly ash from the dry silo is wetted up to 30% through simultaneous injection of water during loading of lorries. Furthermore, the lorries are covered with tarpaulin to avoid air borne risks during transportation.</p> <p>We wish to inform that the Ministry of Environment has been informed of the above protocol through:</p> <ol style="list-style-type: none"> 1. Site visit effected by the Post EIA monitoring team of the Ministry of Environment in 2007.

We reviewed and were satisfied with the Terragen test for unburnt carbon (TGEN-INS-CHE-002 Rev02), so the accuracy of the reported levels of unburnt carbon are credible. An extract from the July 2019 fly-ash test conducted for Terragen by Socor, reports 14.7% carbon, lower than the 16.6% reported by the plant and will be influenced by the coal:bagasse proportions or may possibly represent a measure of improvement.

Paramètres analytiques	Résultats	Unités	Méthodes	Détection	Références de qualité	CONFRAC
Analyse sur le produit						
Analyses physiques						
Humidité totale	0.3	% brut	Méthode interne PA256			#
Matières sèches	99.7	% brut	Méthode interne PA256			
Analyse de base						
Perte au feu à 975°C sans correction liée aux sulfures	17.6	% sec	Calcination			
Perte au feu à 975°C sans correction liée aux sulfures	17.8	% brut	Calcination			
Analyse élémentaire						
Carbone organique total (COT)	14.7	% sec	NF EN 13137			

Figure 11: Socor fly-ash test results (July 2019)

The Mauritian Government’s Environment Ministry authorised Omnicane to develop a Carbon Burn-Out Unit at La Baraque, L’Escalier. This project could, eventually, reduce the price of the cement because the company is planning to use bottom and fly ash residues from all Mauritian coal fired thermal power plants as an additive for cement. The burning of coal in grid boilers produce fly- and bottom ash, and this was, until recently buried in sugar cane field cavities and depressions, in what is also termed “de-rocking”. Not only are such sites limited, but it also pose a potential environmental risk to ground water reserves and sugar cane quality. It became imperative to seek alternative modes of disposal. We were unable to obtain a copy of the environmental study conducted which allegedly confirms the safety of coal ash buried under sugar cane crops.



Figure 12: Omnicane La Baraque's Carbon Burn-out Unit

The idea behind Omnicane’s Carbon Burn-Out (CBO) plant is to burn the extra carbon in the power plants’ fly ash and bottom ash, using a Thermax circulating fluidised-bed boiler, and reduce the carbon content from 20% to 5%. The final product obtained is mixed with bulk cement for the construction industry, with the advantage of additional steam and power generation at the CBO plant. Of the 70 000 tonnes of ash the CBO plant receives from the 3 Omnicane owned plants annually, it generates 42 000 tonnes for cement additives production, 18 000 tonnes for the production of construction aggregates and use 10 000 tonnes for the production of steam.

Our recommendations for correcting this problem are listed below, in order of execution:

- Improve boiler combustion efficiencies with more effective air:fuel ratio controls,
- Install, maintain and operate fly-ash refeeding systems to reduce the unburnt carbon levels in both fly- and bottom ash to levels below 10.0%, and ideally target 5.0% and
- Thereby obviate the need for a costly CBO unit and directly use final fly-ash residues in the building construction brick manufacturing process.

The American Coal-Ash Association's November 2018 report highlights the growing re-use of coal-ash in the following ways:

- Concrete production because fly ash improves concrete durability and significantly reduces greenhouse gas emissions associated with concrete production,
- Use of CCP in pond closure activities in line with ramped up compliance with environmental regulations which requires an end to the practice of wet disposal. Fly ash and bottom ash were used in the construction of new permanent disposal facilities,
- Use of fly ash and bottom ash in structural fills,
- Boiler slag is utilized in the production of blasting grit and roofing granules and ☐ Approximately 148,000 pounds of cenospheres were sold in 2017, up from zero in the prior year and
- Cenospheres are a very valuable form of ash harvested from wet disposal impoundments.

2.4.4 Working Conditions (Health and Safety)

Mauritius published their Occupational Health and Safety Act in 2005 and it was updated in 2013 (Act No. 13 of 2013).

General adherence to the act was observed and the CSIR team as visitors to both the Omnicane as well as the Terragen plants were subjected to all the health and safety requirements. Clear signs as to risks and hazards and required PPE were posted at both plants and the team was accompanied by plant personnel throughout the plant walk-throughs.

Installation of metering was performed by plant electricians with the guidance from the team as to how they should be installed. Spot measurements were taken and all health and safety regulations were observed throughout.

The only health and safety incident that was mentioned was that at Terragen when an employee contracted Legionnaires disease. The plant had tight controls on the wearing of facial masks around the cooling towers.

One area that could potentially be improved was the wearing of long sleeved shirts when working around the boilers themselves.

2.4.5 Business Risk

The recommended improvements would generally be considered low to medium cost upgrades. However, at the higher cost end are major plant retrofits and upgrades (i.e. upgrading the Alteo power plant), which would raise efficiencies more substantially. The general conclusion is that where life extension is possible, this should also result in an improvement in efficiency which would justify the extension of life of power plant. The option of upgrading some of the existing Mauritian IPP thermal power plants is also a possibility rather than total replacement.

The reported delays and uncertainty around the renewal of power supply contracts by CEB for Mauritian IPP thermal power plants, especially in the case of the Terragen and Alteo plants, serves to delay critical decision making relating to plant upgrades and funding arrangements.

The lifespan of coal fired power plants generally range from 40 – 50 years and the cost of building small scale coal fired power plants range from MUR 100 000 to 140 000 per kW (excluding finance costs) depending on the technology employed. This renders the cost of building a 60MW Terragen plant approximately MUR 7.2B (excluding finance costs). Assuming build cost amortisation periods ranging from 25 to 30 years, the shorter term CEB contracts highlights the risks and difficulty it present to sound business investment.

Electricity generation technologies all have their advantages and disadvantages. Renewable technologies such as solar and wind use ‘free’ resources and don’t produce greenhouse gas emissions, but are not always available when needed and require significant amounts of land. Technologies such as coal and nuclear power produce electricity in large quantities, reliably and continuously, but coal combustion produces significant greenhouse gas emissions and in the case of nuclear power generation, considerable waste disposal issues. The figure below provides an assessment of relative benefits and impacts of the power generating technologies available today and the differences in its construction cost, electricity cost, land use, water requirements, CO₂ emissions, non CO₂ emissions, waste products as well as the availability and flexibility of these technologies. (IEA). The Mauritian Government faces the dilemma of balancing its power needs, environmental needs, available technologies and cost to the fiscus in charting its way forward, knowing, that decisions taken today will have lasting impacts on the quality of life on the island.

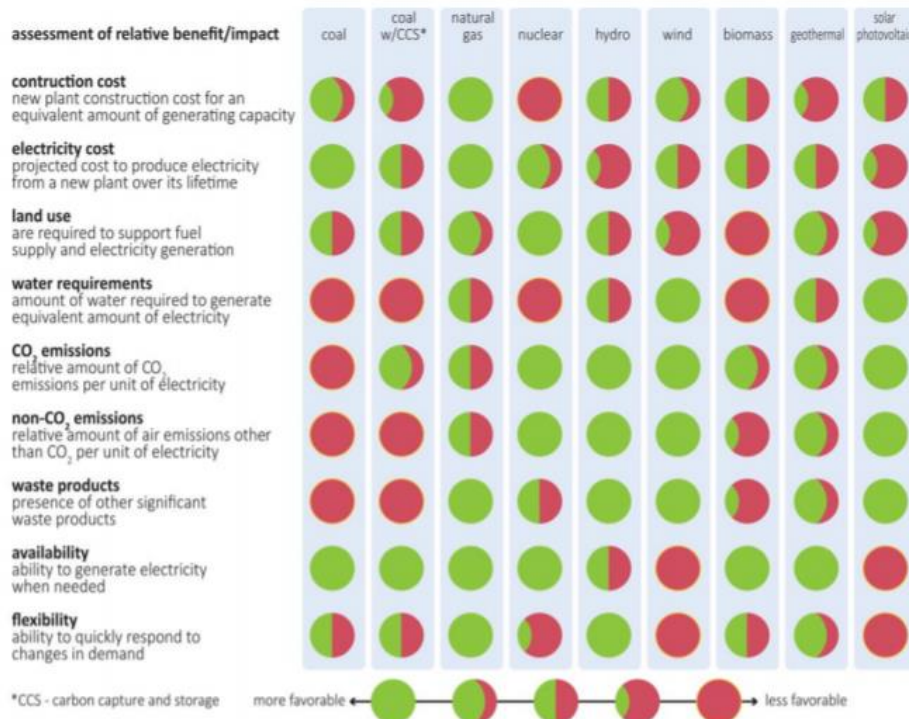


Figure 13: Assessment of relative benefits and impacts of electricity generation technologies

3. Output 4: Capacity Building of National and Local Officials on Monitoring and Assessment of Environmental and Energy Related Performance

Capacity Building Objectives and Target Audience

The target audience for the training

- I. Government Officials - who are responsible for energy management, national/regional GHGs mitigation programs, and have responsibilities in implementing national/regional energy policies, energy efficiency strategies as well as working to guide and support industry in transitioning to a low carbon economy.
- II. Industry Personnel – who are responsible for implementing or managing the company’s environmental sustainability programs; personnel responsible for ensuring plant’s operational reliability; and in general, all personnel who impacts energy performance of the organisation.
- III. Other – individuals who may focus on energy management projects; individuals who also play a role in educating communities or society at large on the importance of energy management and energy efficiency, climate change and renewable energy.

3.1 Training Material Content Design and Development

The CSIR through the National Cleaner Production Centre South Africa (NCPC-SA) has since 2002 collaborated with the United Nations Industrial Development Organisation (UNIDO) to design capacity building training material on climate change mitigation and environmental management. The training content developed was based on common challenges prevalent in developing countries in creating a systematic and integrated framework for managing energy, water, and the environment in a cost effective and sustainable manner. To this end, NCPC-SA is a custodian of over 15 tailor made programs for industry and government. In responding to the capacity building requirement of the project (i.e Output 4), the CSIR engaged the Mauritian Ministry of Environment to first understand and map out the training needs for the different stakeholders. The conclusion drawn from those discussions was the need for the capacity building program to address the needs of two distinct stakeholder groups - government officials and power plant IPP personnel. The stakeholder needs and expectations are tabled below.

Table 4: Capacity Building Needs Identification

Capacity Building Needs Identified	Stakeholder 1 – Government Officials	Stakeholder 2 – Thermal Power Plants Personnel
<ul style="list-style-type: none"> Knowledge on the latest technology trends and international best practices applicable to thermal power plants 		✓
<ul style="list-style-type: none"> Knowledge and tools on how to best improve plant efficiencies through the optimisation of various energy consuming systems found in thermal power plants 		✓
<ul style="list-style-type: none"> Effective methodology and tools for monitoring energy and environmental performance of current thermal power plants operations. 	✓	✓
<ul style="list-style-type: none"> Effective methodology and tools that can be applied to establish approval frameworks in evaluating new applications for thermal power plants build programs to support the country's set targets to improve energy and environmental performance of the thermal power plant sector. 	✓	

<ul style="list-style-type: none"> Insights on relevant comprehensive list of environmental performance parameters that should be monitored for thermal power plants as well as suitable control limits to establish for each parameter within the context of Mauritian power sector 	✓	
<ul style="list-style-type: none"> Insights on low carbon and/or renewable energy feedstock energy that can be used to replace coal based fuels for power generation 		✓
<ul style="list-style-type: none"> Technical insights for government officials to partner with and assist in thermal power plants in taking corrective actions to address any energy and environmental performance deviations 	✓	

Based on these needs, two training modules were selected from NCPC-SA existing offerings. The training content for the two modules was adapted to suit local conditions in Mauritius and expanded to address the specific stakeholder needs. Changes made to the training material included incorporating case studies discussions and exercises relevant to thermal power plants as well as changing all financial calculation to Mauritian Rupees. The existing steam system optimisation scoping tool was also expanded to include scoping and performance evaluation for environmental performance.

The final training content following all consultations with the Mauritian Environmental Ministry was drafted as follows:

- Mission 1 – Training conducted at Omnicane St Aubin Plant for a small group of delegates from government and Omnicane St Aubin plant personnel. The training was conducted over three days. The training agenda and modules covered were as follows:

Table 5: Training Schedule and Content for Second Mission

	DAY 1: 11 July 2019
	STEAM SYSTEMS OPTIMIZATION & LATEST TECHNOLOGIES FOR OPTIMAL THERMAL POWER PLANTS ENERGY AND ENVIRONMENTAL PERFORMANCE
Time	Course Outline
08:00	Registrations
08:30	Introductions & Welcome
	Introduction to Systems Approach

	Review of Steam System fundamentals - Thermodynamics
	Review of the US DOE Steam System Scoping Tool (SSMT)
	Student Exercise – Evaluation of an industrial plant system using SSMT and identifying energy saving areas
Tea Break (10:00 – 10:15)	
	Utility Costs – Power, Fuel, Water
	Identification of Impact Boiler – example from industrial plant
	Steam Cost Indicator
	Calculation of Boiler Efficiency using Field Measurements
	Boiler Losses – Shell loss, Blowdown loss and Stack loss
	Developing a 1-Header Steam model in SSMT
	Understanding marginal steam costs
Lunch Break (12:00 – 13:00)	
	Blowdown and flash steam
	Steam generation conditions
	Letdowns/PRVs
	Deaerators
	Heat Recovery Components
	Condensate Recovery
	Distribution Losses
	Interactive Exercise – Marginal Steam Cost Discussion and Comparisons
Tea Break (15:00 – 15:15)	
	Fundamentals of Turbines
	Backpressure Turbines
	Modelling Backpressure Turbines in SSAT

	Condensing Turbines
	Student Exercise
16:30	END of DAY 1
	DAY 2: 12 July 2019 STEAM SYSTEMS OPTIMIZATION & LATEST TECHNOLOGIES FOR OPTIMAL THERMAL POWER PLANTS ENERGY AND ENVIRONMENTAL PERFORMANCE
08:30	Day 1 Review and Q&A
	Steam System Optimisation – Generation Area
	Boiler Efficiency Improvement
	Blowdown Management
	Blowdown Energy Recovery
	Feedwater Economizers / Combustion Air Preheaters
	Excess Air Control
	Fuel Switching
	Student Exercise
Tea Break (10:00 – 10:15)	
	Steam System Optimisation – Distribution Area
	Steam Leaks
	Heat Transfer through Insulation
	Student Exercise
	3E Insulation Evaluation Software
	Steam System Optimisation – End-Use Area
	Steam Generation Condition Impacts
	Steam Demand Savings Projects
Lunch Break (12:00 – 13:00)	

	Steam System Optimisation – Condensate Recovery Area
	Steam Trap Management Program
	Evaluation of Condensate Recovery Systems
	Condensate Flash Tanks and Vents
	Student Exercise
	Steam System Optimisation – Cogeneration Area
	Backpressure Turbine – PRV Operations
	SSMT Turbine Projects Economics
	Condensing Turbine Impacts
	SSMT Condensing Turbine Projects
Tea Break (15:00 – 15:15)	
	Industrial Steam System Energy Assessment & Reporting Environmental Performance and Monitoring for Steam Systems Conclusions Tools and Resources
16:30	END of DAY 2
	DAY 4: 15 July 2019 ENERGY PERFORMANCE MEASUREMENT AND INDICATORS (EnPMI)
Time	Course Outline
08:00	Registrations
08:30	Introductions & Welcome
	Why are we here
	Delusions and Challenges
Tea Break (10:00 – 10:15)	

	Past and Present Energy Consumption
	Significant Energy Uses
	Data Collection and Measurement Plans
	Developing Models – Single Variable Regression Analysis
Lunch Break (12:00 – 13:00)	
	Importance of Weather
	Developing Models – Multivariate Regression Analysis
Tea Break (15:00 – 15:15)	
	Data Collection, Statistics and Uncertainty
16:30	END of DAY 4
	DAY 5: 16 July 2019 ENERGY PERFORMANCE MEASUREMENT AND INDICATORS (EnPMI)
08:30	Day 1 Review
	Energy Performance Indicators and Baselines
	Forecasting: Target Setting and Budgeting
Tea Break (10:00 – 10:15)	
	Monitoring Energy Performance
	Verification of Savings
Lunch Break (12:00 – 13:00)	
	Effective Reporting
	Benchmarking
Tea Break (15:00 – 15:15)	
	Q&A Session
	Summary and Next Steps

- Following the first mission at Omnicane St Aubin and the training feedback, the Ministry requested the training program to be expanded to four days to allow more time for the delegates to engage the training material. As a result, the second training session conducted during the mission to Terragen plant comprised of two days training on Steam system optimisation and two days training on Energy performance measurement and Indicators (EnPMI). The training content and agenda for the two day EnPMI remained the same as that offered in the first training session at Omnicane St Aubin.

3.2 Delivery of Training, Logistics and Facilitation Method(s)

The first session was conducted at Omnicane St Aubin Plant on 21 – 23 November 2018. The second training session was delivered at the Mauritian Ministry of Environment on 11-16 July 2019. Logistics for both training sessions were arranged by the host sites (i.e Omnicane St Aubin and the Mauritian Ministry of Environment and Sustainable Development). The training venues provided for both training sessions were adequate for training and they were equipped with overhead projector and WIFI internet connection required for the training sessions. Sitting arrangements were also adequate to accommodate all delegates and there was minimal disruptions and noise levels making the venues very conducive for learning. The training spaces, lunch areas as well as ablution facilities were in good hygienic condition.

The training was conducted in English and all training material was in English. Mauritius is primarily a French speaking country as such the CSIR team first consulted the Ministry of Environment and Sustainable Development for a discussion on the preferred medium of instruction for training. The Ministry confirmed that all delegates will be comfortable with training delivered in English. No delegate expressed any language discomfort during all training sessions.

Each delegate was given training manual booklet for each training course containing training slides used by the facilitators. There was also supplementary training material containing tools and student exercises, which were handed to each delegate in soft copies.

A projector was used to display the training slides.

Training delivery method(s) used were:

- Facilitator-led power point presentation of the training slides
- Group Work / Group Discussions
- Interactive PC based exercises and case study discussions
- Interactive web-based exercises and case study discussions
- Q&A sessions

Software Tools used:

The delegates were given access to three web-based energy optimisation software tools:

<https://insulationinstitute.org/tools-resources/free-3e-plus/>

https://www4.eere.energy.gov/manufacturing/tech_deployment/amo_steam_tool/overview

<https://www.degreedays.net/>

Assessment Methods used:

To test for comprehension and proficiency, delegates were given oral quizzes as well as individual and group exercises.

All delegates who successfully attended the training will be mailed course completion certificates.

3.3 Delegates Profile and Attendance

The selection and invitation of delegates for the training was to the discretion of the Ministry of Environment and Sustainable Development and the thermal plant management. The CSIR team only provided guidance on the target audience and background the delegate should possess to enable effective assimilation of the material covered.

The attendance for the training session were as follows:

Table 6: Delegates Profile and Attendance

Ref	1 Day Steam System Optimisation Training at Omnicane St Aubin Plant: 21 Nov 2018	2Days Energy performance measurement and Indicators (EnPMI) at Omnicane St Aubin Plant: 22-23 Nov 2018	2Days Steam System Optimisation Training at Ministry of Environment and Sustainable Development: 11-12 Jul 2019	2Days Energy performance measurement and Indicators (EnPMI) at Ministry of Environment and Sustainable Development: 15-16 Jul 2019
Total Number of Delegates	10	10	24	24

Ref	Title	Name	Surname	Institution	Position	1 Day Steam System Optimisation Training: xx Nov 2018	2Days Energy performance measurement and Indicators (EnPMI): xx-xx Nov 2018	2Days Steam System Optimisation Training: 11-12 Jul 2019	2Days Energy performance measurement and Indicators (EnPMI): 15-16 Jul 2019
1	Mr	Jeffrey	Bamboche	Terragen Thermal Power Plant	Chef de Quart			✓	✓
2	Mr	Ritish	Bhugowar	Terragen Thermal Power Plant	Chef de Quart			✓	✓
3	Mrs	Brinda	Chuckhorry	Ministry of Environment and Sustainable Development	Environment Officer			✓	✓
4	Mr	Rakesh	Dhununjoy	Central Energy Board (CEB)	Senior Engineer			✓	✓
5	Mrs	Varnabhye	Gunga	Ministry of Environment and Sustainable Development	Environment Officer			✓	✓
6	Mr	Ajayedutt	Juggurnath	Ministry of Environment and Sustainable Development	Environment Officer			✓	✓
7	Mrs	Vijayalaxmi	Jumnoodoo	Ministry of Energy & Public Utilities	Service to Mauritius Intern (STM)			✓	✓
8	Mrs	Parvatee	Kanhye	Ministry of Environment and Sustainable Development	Environment Officer			✓	✓
9	Mr	Jerome Pierre	Legallant	Terragen Thermal Power Plant	Chemist			✓	✓
10	Mr	Daniel Gerald	Mamotte	Terragen Thermal Power Plant	Process & Operational Manager			✓	✓
11	Mr	Yanovin	Moonosawmy	Omnican Thermal Operations (La Baraque) Ltd	Assistant Thermal Energy Operations Manager			✓	✓
12	Mr	Shersing	Nekitsing	Alteo Energy Ltd	Project Engineer			✓	✓
13	Mrs	Dina	Ramgobeen-Gukool	Alteo Milling Ltd	Sustainability Officer: Agriculture & Industrial Activities				✓
14	Mr	Akhilesh Krishna	Ramkalawon	Ministry of Environment and Sustainable Development	Environment Officer			✓	✓

15	Mr	Keeshav	Ramkurrun	Energy Efficiency Management Office	Senior Engineer			✓	✓
16	Mr	Suraj	Ramroop	Terragen Thermal Power Plant	Assistant Operations Manager			✓	✓
17	Mr	Muhumud Aly	Rawoo	Omnican Thermal Operations (La Baraque) Ltd	Assistant Operations Manager			✓	✓
18	Mr	Sanjay	Sookhraz	Central Energy Board (CEB)	Senior Environmental Affairs Officer			✓	✓
19	Mr	Nicheketa	Teckmun	Terragen Thermal Power Plant	Chef de Quart				
20	Mrs	Roufida	Teemul	Ministry of Environment and Sustainable Development	Environment Officer				
21	Mr	John Michael	Tsang Pun Yin	National Environmental Laboratory (NEL)	Scientific Officer				
22	Mr	NilshAd	Koussa	Terragen Thermal Power Plant	Mechanical Department Manager				
23	Ms	Joanna	Doorghen	Ministry of Environment and Sustainable Development	Environment Officer				
24	Ms	Nuhaa	Soobhany	Service to Mauritius Intern	Intern				
25				Omnican St Aubin		✓	✓		
26				Omnican St Aubin		✓	✓		
27				Omnican St Aubin		✓	✓		
28				Omnican St Aubin		✓	✓		
29				Omnican St Aubin		✓	✓		
30				Omnican St Aubin		✓	✓		
31				Omnican St Aubin		✓	✓		
32				Omnican St Aubin		✓	✓		

33				Omnicanne St Aubin		✓	✓		
34				Omnicanne St Aubin		✓	✓		

4. Conclusions

4.1 Baseline study

Technology: The thermal power plant technologies applied is nearing 20years of age in most of the IPPs plants with Omnicane St Aubin making use of recommissioned old boilers. Limited use is made of advanced boiler, turbine and condenser technologies. Technology changes (to newer more efficient technologies) will be costly and its implementation will be influenced by the lifespan of CEB IPP contracts.

Flue gas treatment measures essentially comprising of electrostatic precipitator are minimal and we suggest that a denitrification (deNox) unit and fluegas desulphurisation plant should be mandated in coal fired power plants.

IPPs produced 57% of Mauritian electricity in 2017. 41.6% of Mauritius electricity was generated using coal, 37.4% fuel oil and diesel and 14.7% Bagasse. Commercial electricity sales was 36% in 2017, domestic was 33% and industrial sales were 29%.

Boiler efficiencies at Omnicane were calculated using spot measurements to be 89.7% and at Terragen 87.6% (dual fuel - coal and bagasse firing). Boiler efficiency was 87.6% during periods of coal only firing and 68.9% during periods of bagasse only firing.

Performance baselines were developed for the Terragen site (for the three modes of operation, Coal and bagasse feeding, bagasse only and coal only) as data was readily available. These baselines can be used to determine the performance of the facility going forward – beyond 2019.

The Terragen and Omnicane plants were compared to other small scale (50-350MW) thermal power plants and it was found that the 5 Mauritian thermal power plants had good modular design and construction configurations. The Terragen plant reported a generation cost of 7.6 US cents per kWh compared to a global levelised cost of generation of 9.5-11.9US cents per kWh for traditional coal fired power plants. The operational capability of the Terragen plant to ramp up their generation with 2.7MWh/minute is very impressive and if the other plants have similar capabilities this compares well with global best practise. Thermal plant efficiencies range between 33-37% with best practise efficiencies exceeding 40%. The Terragen efficiency was 30.2% for the period June 2017 – June 2018 highlighting an area for improvement but is should however be qualified noting the rate and scale of Mauritian power grid fluctuations that influence this metric. Newer technologies would include: small scale fluidised bed coal plants, small scale coal gasification combined cycle (CGCC) plants and the ability to discard coal fines more effectively than large plants.

In summary, Mauritian thermal power plants compare well with global small scale power plants. There are technology improvements that can be applied but this should be viewed in the context of replacement timelines, available funding and the relatively stagnant national power demand.

4.2 Technical Process and Operational Related Recommendations

Omicane:

Boiler parameter data management, monitoring and controls can be upgraded. A broader dissemination of performance metrics with plant management will also help. Rapid response to boiler operation anomalies and significant deviations and the repair of some critical boiler equipment components. Boiler blowdown management can be improved by flashing the blowdown, using the flash steam and heat recovery on resultant blowdown liquid.

Procuring a basic set of measurement equipment such as thermal imaging camera, electrical data loggers and temperature gun will encourage spot measurements and improve trouble shooting.

At Omicane the load on the rebuilt boiler warrants monitoring and turbine generator efficiencies could be improved since these turbines were operating at lower than the design rated condition. Turbine impeller blade deposits removal should improve performance.

Upgrades such as boiler:turbine sliding pressure operation, VFDs for main cycle and auxiliary equipment, mill and burner control schemes a.w.a. a comprehensive control system could improve performance.

Cooling tower efficiency was less than best practise efficiency and installing VFDs and tuning to operate successfully in ambient conditions can be beneficial.

Establishing energy baselines to track and report generating unit performance would enable greater awareness and objective results.

A basic competency and awareness induction and plant operator level training to achieve greater plant wide appreciation of plant operating objectives.

Terragen:

Boiler blowdown controls can be improved together with a flash steam recovery from the boiler blowdown.

Improving the isentropic efficiency of the condensing part of the turbines through inspection of the blades for deposits, corrosion or erosion.

Implementation of VFDs at the cooling tower fans with controls and a proper tuning of the operation to suit ambient conditions.

Check the feasibility of a bagasse dryer that could significantly improve the efficiency during crop season.

Impact of upgrades:

Assuming all 5 thermal power plants in this study represent similar savings opportunities the cumulative energy and cost savings could conservatively be greater than **MUR 560M annually.**

4.3 Key Parameter Recommendations

Fuel and Energy Mix

Comparing the energy consumption of Mauritius and the rest of the world the writers of this report believes that that there should be an effort to increase renewable electricity generation. The use of bagasse and the use of cane field residue to generate power as piloted by the Terragen plant should be optimised. Mauritius has a few opportunities for increasing their renewables:

- Optimisation and maximising bagasse use.
- Offshore wind power generation.
- Pyrolysis of rubber tyres (latest technologies with low temperature pyrolysis).
- Waste to energy in the form of biogas can be investigated at waste water treatment facilities.

Fly and Bottom Ash

Unburnt carbon in both Omnicane and Terragen ash was found to be excessively high. The Omnicane ash reinjection system was not operational during the time of the CSIR team's visit causing their unburnt carbon in ash to range from 30-50%, compared to Terragen that was 16.6-38.7%.

The Carbon Burn-Out Unit (CBO) at Omnicane La Baraque enables the compliance of plants with the requirement of legislation. The final product obtained is mixed with bulk cement for the construction industry, with the advantage of additional steam and power generation at the CBO plant.

Our recommendations for correcting this problem are listed below, in order of execution:

- Improve boiler combustion efficiencies with more effective air:fuel ratio controls,
- Install, maintain and operate fly-ash refeeding systems to reduce the unburnt carbon levels in both fly- and bottom ash to levels below 10.0%, and ideally target 5.0% and
- Thereby obviate the need for a costly CBO unit and directly use final fly-ash residues in the building construction brick manufacturing process.

Coal ash was, until recently, buried in sugar cane field cavities and depressions, in what is also termed "de-rocking". Not only are such sites limited, but it also pose a potential environmental risk to ground water reserves and sugar cane quality. We were unable to obtain a copy of the environmental study conducted which allegedly confirms the safety of coal ash buried under sugar cane crops.

The American Coal-Ash Association's November 2018 report highlights the growing re-use of coal-ash in the following ways:

- Concrete production,
- Fly ash and bottom ash is used in the construction of new permanent disposal facilities,
- Use of fly ash and bottom ash in structural fills,
- Boiler slag is utilized in the production of blasting grit and roofing granules and
- Cenospheres are a very valuable form of ash harvested from wet disposal impoundments.

Working Conditions (Health and Safety)

The Mauritian government published the Occupational Health and Safety Act in 2005 with an update affected in 2013.

General adherence to the act was observed and the CSIR team as visitors to both the Omnicane as well as the Terragen plants were subjected to all the health and safety requirements. Clear signs as to risks and hazards and required PPE were posted at both plants and the team was accompanied by plant personnel throughout the plant walk-throughs.

Only one area of potential improvement was identified: the wearing of long sleeved shirts/overalls when working around the boilers themselves.

Business Risk

The reported delays and uncertainty around the renewal of power supply contracts by CEB for Mauritian IPP thermal power plants, especially in the case of the Terragen and Alteo plants, serves to delay critical decision making relating to plant upgrades and funding arrangements.

Electricity generation technologies all have their advantages and disadvantages. Renewable technologies such as solar and wind use ‘free’ resources and don’t produce greenhouse gas emissions, but are not always available when needed and require significant amounts of land. Figure 13 shows a table of the different electricity generation technologies with associated benefits and impacts. This table is aimed to aid the Mauritian Government in balancing its power needs, environmental needs, available technologies and cost to the fiscus in charting its way forward, knowing, that decisions taken today will have lasting impacts on the quality of life on the island.

4.4 Capacity Building of National and Local Officials on Monitoring and Assessment of Environmental and Energy Related Performance

The training component was aimed at government officials, plant personnel and other individuals that may focus on energy management projects.

Feedback was received on capacity building needs and based on these needs, two training modules were selected from NCP-C-SA existing offerings. The training content for the two modules was adapted to suit local conditions in Mauritius and expanded to address the specific stakeholder needs. Changes made to the training material included incorporating case studies discussions and exercises relevant to thermal power plants as well as changing all financial calculation to Mauritian Rupees.

The training offered were as follows:

- Mission 1 – Training conducted at Omnicane St Aubin Plant for a small group of delegates from government and Omnicane St Aubin plant personnel. The training was conducted over three days. Steam 1-day course followed by the Energy Performance Management Indicators course.

- Following the first mission at Omnicane St Aubin and the training feedback, the Ministry requested the training program to be expanded to four days to allow more time for the delegates to engage the training material. As a result, the second training session conducted during the mission to Terragen plant comprised of two days training on Steam system optimisation and two days training on Energy performance measurement and Indicators (EnPMI).

Logistics for both training sessions were arranged by the host sites (i.e Omnicane St Aubin and the Mauritian Ministry of Environment and Sustainable Development). The training venues provided for both training sessions were adequate for training and they were equipped with overhead projector and WIFI internet connection required for the training sessions.

Each delegate was given training manual booklet for each training course containing training slides used by the facilitators. There was also supplementary training material containing tools and student exercises, which were handed to each delegate in soft copies.

The attendance of delegates of the training is shown in Table 6. Delegates enjoyed the Steam and Energy Performance Measurement Indicators training and could see the value of implementing performance measurement in more areas than just energy.