# A Unique Approach for Sustainable Energy in Trinidad and Tobago

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Government of the Republic of Trinidad and Tobago
Ministry of Energy and Energy Affairs

IDB

CENTRO DE ALIANZAS PARA EL DESARROLLO

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The Government of the Republic of Trinidad and Tobago (GoRTT) is in the process of developing a Sustainable Energy Program (SEP), which aims to manage its natural resources in a more sustainable way, enhancing the use of Renewable Energy (RE) and Energy Efficiency (EE). As part of this process, the Inter-American Development Bank (IDB), who is supporting the SEP through a policy loan, has commissioned the consortium of the Centre of Partnerships for Development (CAD), Projekt Consult and LKS Ingenieria to develop consultancy services in order to support the implementation of the SEP. The following report is a summary of the major results of this project.

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## About CAD

CAD (Centre of Partnerships for Development) is a network of international experts specialized in international development, local economic development and public-private partnerships, with a focus on Green Economy and Sustainable Energy, SMEs in developing countries, entrepreneurship, Base of the Pyramid and Monitoring and Evaluation tools and methods.

## About Projekt Consult

Projekt Consult is engaged in the management and execution of projects in international cooperation programs. Prime emphasis is given to the promoting environmentally-sound work procedures and participatory approaches, as well as the application and transfer of needs-oriented technology acceptable to the community. Projekt-Consult GmbH, working in close cooperation with donor agencies and project partners, has developed comprehensive solutions which correspond to the particular socio-economic, cultural and ecological situation.

## About LKS Ingenieria

LKS is an international engineering and consultancy cooperative which provides strategic advice, project assessment and project development expertise in various areas including sustainable development in which it has experts in renewable energies, energy efficiency and climate change.

# Contents

# Abbreviations and Acronyms

| | |
|---|---|
| ADO | Automotive Diesel Oil |
| AE | Alternative Energy |
| AEP | Annual Energy Production |
| AOE | Annual Operating Expenses |
| BOE | Trinidad and Tobago Board of Engineers |
| BOOT | Build-Own-Operate-Transfer |
| BOT | Build-Operate-Transfer |
| CAD | Centro de Alianzas para el Desarrollo |
| CaO | Calcium Oxide |
| CCGT | Combined Cycle Gas Turbine |
| CEN | European Committee for Standardization |
| CFL | Compact fluorescent lamp |
| CHENACT | Caribbean Hotels Energy Efficiency Action Programme |
| CHP | Combined Heat and Power |
| $CO_2$ | Carbon Dioxide |
| CREC | Caribbean Renewable Energy Centre |
| CRF | Capital Recovery Factor |
| CSP | Concentrated Solar Power |
| DNI | Direct Normal Irradiance |
| ECC | ESCO Certification Committee |
| ECPA | Energy and Climate Partnership of the Americas |
| EE | Energy Efficiency |
| EEC | Energy Efficiency Committee |
| EPC | Energy Performance Contracting |
| ESCO | Energy Service Company |
| EU | European Union |
| EVO | Efficiency Valuation Organization |
| FCR | Fixed Charge Rate |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility |

| | |
|---|---|
| GHG | Greenhouse Gases |
| GoRTT | The Government of the Republic of Trinidad and Tobago |
| HDC | Trinidad and Tobago Housing Development Corporation |
| ICC | Installed Capital Cost |
| IDB | Inter-American Development Bank |
| IEA | International Energy Agency |
| IMF | International Monetary Fund |
| IPP | Independent Power Producer |
| IRENA | International Renewable Energy Agency |
| ISO | International Standards Organisation |
| LCOE | Levelized Cost of Energy |
| LED | Light emitting diode |
| LNG | Liquefied Natural Gas |
| LPG | Liquid Petroleum Gas |

## UNITS

| | |
|---|---|
| bcf | billion cubic feet |
| GJ | Gigajoule, $10^9$ Joule (energy) |
| GWh | Gigawatt-hours |
| ha | Hectare |
| kW, kWh | kilowatt, kilowatt-hours (electrical power and work) |
| MMBTU | Million British Thermal Units |
| MMSCF/D | Millions of Standard Cubic Feet per day |
| MW, MWh | Megawatt, Megawatt-hours (electrical power and work) |
| $Nm^3$, $m^3$ | Norm cubic meter, cubic meter |
| t, kt | ton, $10^3$ tons |
| t/a | tons per year |
| t/d | tons per day |
| tcf | trillion cubic feet |
| TWh | Terawatt-hours |

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# Executive Summary

The Government of the Republic of Trinidad and Tobago (GORTT) has received a Policy-Based Loan (PBL) (TT-L1023) from the Inter-American Development Bank (IDB). This PBL for the Sustainable Energy Program consists of three different operations, each with specific institutional and policy goals. The IDB hired the consortium of Centre of Partnerships for Development (CAD), Projekt-Consult and LKS in 2012 to support the Ministry of Energy and Energy Affairs (MEEA) with technical assistance in the development of policies and activities that will promote the deployment of Renewable Energy (RE) and the implementation of Energy Efficiency (EE) measures.

The following is the Final Report of the consultancy services undertaken. It defines the baseline for electricity generation and carbon dioxide emissions, provides recommendations on policies for a Sustainable Energy future, assesses the potential for EE in T&T and analyses the options for different RE technologies and their possible uptake in T&T.

## Baseline for Electricity Generation and Carbon Dioxide Emissions

In 2010, Trinidad and Tobago generated **8.5 TWh of electricity** with **$CO_2$ emissions of 700 g for every kWh generated**. When compared to international benchmarks for 2010, these figures demonstrate a high electricity consumption and $CO_2$ emissions per capita from energy-related activities at nearly 2.5 times the world average.[1] Plans are identified to improve the efficiency of the existing electricity generating plants as well as an intention to incorporate a small percentage of RE-based generation over the coming years.

The electricity generation is to almost **100% based on natural gas**. The contribution of RE generation is negligible with only a few residential and commercial micro-scale systems connected to the grid or operating as stand-alone systems.

[1] International Energy Agency: $CO_2$ Emissions from fuel combustion, 2012.

T&T has large natural gas reserves and gas extraction has increased significantly over the past 22 years from **177 bcf in 1990 to 811 bcf in 2011**. There has been no shortage of gas for local consumption and due to a substantial increase in the industrial natural gas use, power generation only accounts for **8% of the annual gas production,** with 56% being exported as LNG (liquefied natural gas). This abundance accompanied by low prices has made gas the obvious choice of energy for electricity generation up to now and for the medium-term future.

However, **a rapidly increasing demand for electricity** in all sectors in line with GDP growth and reduced exportation of Crude Oil will result in a larger proportion of gas being designated to power generation, with the consequent increase in local $CO_2$ emissions. It is therefore essential that concerted efforts are made to **introduce a higher percentage of RE** into the power generation equation along with parallel **EE implementation at** both the generation and end-use level.

Based on the growth rates seen over the past 20 years (average 4.4% per annum) it is expected that by **2020, T&T's gross power generation output will be 13.0 TWh**, equivalent to around 10,000 kWh per capita, far higher than in many industrialized countries, unless demand-curbing measures are being introduced.[2] The projected increase in consumption needs to be tackled accordingly. When extrapolating this further to **2032, T&T's gross power generation output could reach almost 16.8 TWh**, equivalent to around 12,000 kWh per capita, under a business-as-usual scenario. However, industrialized nations experience a saturation of electricity consumption at some point.

An elevated electricity demand will need to be more **efficiently generated** in order to avoid augmenting carbon emissions from increased fuel consumption. The thermal efficiency of the existing eight power plants is low. The proposed measures, which consist mainly in substituting simple-cycle gas turbines with combined-cycle plants could achieve a 45% efficiency improvement by 2020, a significant step forward against current efficiency rates of an average of about 27%. Moreover, looking as far as 2032, such energy saving measures will enable the natural gas production sector to increase its share of exports, generating increased revenue compared to the cost-inefficient and subsidized domestic market.

**EE measures** implemented in buildings and industrial processes could significantly lower **the demand for electricity** and related gas consumption, which in turn would lead to reduced $CO_2$ emissions.

[2] E.g. 7,081 kWh/cap. In Germany and 5,516 kWh/cap. in the United Kingdom in 2011. See: ttp://wdi.worldbank.org/table/5.11

However, there are currently various barriers, which do not incentivize the implementation of EE measures and technologies; one of these are the existing low tariffs for electricity. Due to the reduced rates for local gas consumption, electricity customers in T&T enjoy very low tariffs in comparison to other countries in the region, with prices seven times lower than the Caribbean average. Negative consequences include potential discouragement of both supply-side and demand-side efficiency improvements, the promotion of non-economic consumption of energy. Finally and importantly in the context of this assignment, fossil fuel energy subsidies hinder the development of RE technologies by making them economically uncompetitive (WB, 2010).

**Increasing the percentage of RE** in T&T's electricity generation mix will be vital in reducing overall $CO_2$ emissions. There are a number of zero carbon technologies available, which could potentially be applied both at a national and local scale to generate emission-free electricity and reduce the country's carbon footprint. GoRTT has expressed its plan to increase the share of RE-based power generation and has envisaged a respective target of 60 MW RE capacity by 2020 as part of its Green Paper. Although small (around 2.5% of overall power generation capacity) it will be a step forward in reducing overall emissions and is a foundation, on which further RE projects can be built on.

## Legal and Regulatory Framework and Supporting Policies

The most important policy is the Green Paper on Sustainable Energy that is currently under development and will be fed into a national consultation process for further discussion. The Green Paper will provide the overall guidelines for implementation of EE and RE measures in the future. While the draft Green Paper envisages to increase the share of RE to about 2.5% of overall power generation by 2020, the consultants recommend raising this target to at least 4% to create sufficient market size that could then lead to lower specific costs and a strengthened business sector. As under this scenario sufficient market size to make RE more attractive would have been reached, it is expected that a 0.5% increase per year in the first 8 years up to 2020, followed by a 1% increase thereafter, yielding a 16% share of RE electricity by 2032.

In order to create the legal and regulatory requirements for RE in T&T it will be necessary to amend the Trinidad and Tobago Electricity Commission Act that currently does not allow for wheeling or the feeding of electricity from independent operators into the grid without consent of the state-owned utility. Once the legal framework is in place, it is suggested to concentrate on the development of feed-in tariffs for grid-connected smaller-scale RE facilities, namely solar PV and small, as sources of RE with the largest potential. The introduction of a net-metering or net-billing schemes are not advisable under the current conditions with highly subsidized consumer tariff rates, as PV investments would need significant additional financial and fiscal incentives to be competitive. For utility-scale wind and solar plants, competitive bidding is recommended, which will allow site and capacity planning that fits generation expansion plans and uses existing resources adequately. To stimulate the initial uptake of household PV systems, it is recommended that a 100 roofs program be developed.

Low electricity tariffs are one major reason for low energy efficiency in T&T. In order to exploit the potential of EE and RE in the country, electricity tariffs need to be further increased. Other policy recommendations that could have a visible impact on energy efficiency include the enactment of an Energy Efficiency Law, as well as demand-side-management programs, a market ban of inefficient consumer products, such as incandescent light bulbs, the development of minimum efficiency standards and labelling programs, as well as the introduction of energy-related building standards, including the mandatory use of solar water heaters at least in specific cases. It is also recommended to expand the infrastructure in a way that SMEs can benefit from direct supply of natural gas and to install smart meters.

## Energy Efficiency (EE)

It is widely accepted that EE is one of the least-cost ways of satisfying growing demand for energy services. No comprehensive study has previously been made of the EE potential in Trinidad and Tobago, but our review indicates a unique case in the Caribbean: very low retail energy prices; a per-capita energy consumption exceeding North American and most European levels; and a low appetite for EE technologies and practices across the board.

The most important barriers to EE uptake are the country's low retail energy prices (which are largely a consequence of price subsidies employed by the Government) and low levels of public energy awareness and literacy. Unlike elsewhere in the Caribbean, limited access to financing is not a factor of significance.

In relation to policy-setting, the uptake of EE technologies will be influenced by the specific mix of and interaction between: information provided, incentives set and regulations imposed by the authorities. Policy in turn must translate into specific programs in each sector as proposed below.

The **residential sector** is almost fully electrified and consumes 29% of total electricity. Average household consumption is the highest in the CARICOM region, and it is considered that there is a large potential for energy savings through efficiency in the sector. Four main residential energy efficiency interventions are recommended, aimed at:

- Reducing the use of electricity for water heating;
- Encouraging the use of energy-efficient appliances and lighting;

- Reducing energy consumption in the social housing sector;
- Engaging and motivating consumers to adopt no-cost, durable energy savings behaviours.

Over the first five years, estimated savings from the recommended residential EE measures, would amount to 930 GWh of electricity worth US$ 46.5 million at current electricity rates; and avoided emissions of some 651 kt of carbon dioxide ($CO_2$).

Trinidad and Tobago has over 6,300 hotel rooms, with a total annual electricity consumption estimated at 76 GWh. It is recommended that **the hotel sector** invests in EE interventions as part of a holistic sustainability strategy, aimed at increasing overall sector performance. In this context, we propose four general program interventions, to:

- Improve air-conditioning efficiency;
- Use more efficient lighting and controls;
- Use more efficient equipment and appliances;
- Encourage green hotel certification.

Based on an assessment, implementation of these measures can allow the hotel sector to achieve aggregate savings of 10.3 GWh of electricity over a five-year period.

Overall, **the commercial and industrial sector** consumed some 5,600 GWh of electricity in 2011, which was two-thirds of the country's total electricity consumption. In the absence of specific industrial sector end-use consumption data, it can reasonably be assumed, that electric motors, process heating, cooling, ventilation and lighting are significant end-users. The relevant EE investments that processing and manufacturing firms should make include:

- Retrofit of motors with Variable-Frequency Drive (VFD) systems;[3]
- Process heating retrofits;
- Installation of high-efficiency, chilled beam air-conditioning systems;
- Lighting replacements/retrofits and implementation of lighting control systems.

It is estimated that over the first five years, a modest total of 224 commercial and industrial customers will take advantage of the proposed **Energy Service Company (ESCO) 150% Tax Allowance Program**, resulting in a cumulative savings over the period of approximately 33 GWh of electricity.

[3] A Variable-Frequency Drive (VFD) or Variable-Speed Drive (VSD), is an electronic control device used in electro-mechanical drive systems to control the speed and turning force of alternating current motors, by varying the motor input frequency and voltage. VFDs are used in applications ranging from small appliances to the largest motors and compressors, and allow significant energy savings compared to operation in fixed-speed mode.

The uptake of viable EE technologies will be influenced by the specific mix of information, incentives and regulations, delivered under the umbrella of Government policy. GoRTT has already commenced education and awareness programs, as well as incentives for promoting EE. Continued government action in four areas is recommended:

- Delivery of information;
- Design and implementation of incentives;
- Enacting and enforcement of regulations;
- Design and implementation of specific projects (such as energy audits and interventions on high-profile government buildings).

In relation to institutional arrangements, the establishment of a **Trinidad and Tobago Energy Agency (TTEA)** is recommended; with responsibility for ensuring the promotion of RE and EE, supporting the MEEA by outsourcing activities that are not part of the core functions of the Ministry.

Given GoRTT's maintenance of a system of significant price subsidies, the market situation does not encourage private investment in EE and it is recommended that GoRTT must lead by example with specific initiatives.

As part of this intervention, GoRTT, with support from external energy experts, has undertaken **energy audits in public buildings**. Results indicate that energy saving potentials are high in all the selected buildings. Energy savings of over 22% can be achieved through the implementation of energy conservation and/or renewable energy measures with a payback time of less than five years. Beside these promising saving potentials, the audits also resulted in a number of interesting lessons for the MEEA and the ESCO Certification Committee (ECC). These included the need for capacity building of auditors, and the need for an increased focus on passive solutions with regard to building envelope improvements.

The proposed **five-year budget** plan for the implementation of all EE measures estimates an expenditure of US$ 23.3 million, resulting in cumulative energy savings of 972.9 GWh, cost savings of US$ 48.6 million and avoided emissions of 681kt of $CO_2$ over the period.

To promote EE in the housing sector, a full **Global Environment Facility (GEF)** proposal has been developed. The Project Information Form (PIF) was approved as of early 2014. The GEF project intents to focus on promoting EE in the social housing sector, assisting their low-income users to save as much energy and expenditures as possible. It is expected that the experiences gained in this project will also have considerable effect on the housing market and domestic sector in general.

## The potential of different RE technologies in T&T

All possible technologies for RE in T&T that could theoretically be applied, have been assessed. PV, SWH and onshore wind energy are the most promising technologies. To support a generous uptake of these technologies, detailed technical studies are necessary, such as a detailed wind measurement to assess the potential electricity yield at concrete sites.

### Wind Power

While wind power is not used in T&T at present, the GoRTT plans to install a wind capacity equivalent of 5% of the total generation capacity by 2020. T&T lies in an area with strong winds all year round and the GoRTT is currently undertaking a wind assessment to define the exact potential locations for wind farms. Based on experiences in other Caribbean islands it seems likely that a capacity factor of at least 35% can be achieved.

It is relevant to note that when it comes to the cost of installing wind turbines in T&T, it is more expensive than in most other countries, due to the lack of road infrastructure to cope with oversized trucks, etc. Another major constraint is the likely unavailability of large cranes near the site and the lack of trained assembly crews. As more wind turbines are installed in the Caribbean as well as in T&T those costs will reduce very quickly; however, it is a cost factor that needs to be taken into account.

To be able to capitalize on the existing potential for wind farms, legislation that allows wind farms to be operated by independent power producers needs to be established and a subsidy scheme for the promotion of wind farms would need to be established.

Offshore wind power will be a significant source of electricity in the future, but before Trinidad can start to explore this resource, the onshore market should be developed, as experience gained with wind turbines on land is essential. At the same time, as offshore wind power is still in its early development, it requires strong and long lasting technology support schemes by governments, as well as very strong engineering skills to overcome technical challenges. It is therefore not advisable for T&T to use its resources on venturing into offshore development at the current stage.

### Solar PV

In the case of Trinidad and Tobago, it is relevant to note that hardware costs are no longer the determining factor for the overall installed costs. Particularly for small residential systems, the so-called *soft costs* for sales taxes, permission fees, labour, transaction, etc. by far outnumber those for the combined costs of modules, inverter and cabling, as the analysis of the U.S. market demonstrates. This means that a high percentage of the total value chain is raised, and remains within the local economy, despite the fact that most hardware needs to be imported.

The example of Germany with a very mature photovoltaic (PV) market shows that soft costs can be further lowered with increased experience and market penetration. This is the main reason for an early start into PV application at a broader scale, even if generation costs may not be fully competitive with other supply options at the moment.

With price levels experienced in Germany today, it would be possible to achieve levelized costs in Trinidad and Tobago of between US$ct 8.8 to 13.5 per kilowatt-hour (kWh), depending on the size of the system. Based on more conservative parameters, taking into account the practically non-existing PV market in Trinidad and Tobago, levelized costs have been calculated to be between US$ct 14.0 and 28.8 per kWh at 2012 prices.

Various examples from the Dominican Republic, St. Kitts, Cayman Islands, Puerto Rico and Jamaica show that solar electricity is now becoming a common feature in the electricity supply sector. This ranges from small residential rooftop systems to large ground-mounted solar farms with 20 MW or more. This also demonstrates that integration of such large solar plants with fluctuating electricity generation into relatively small generation systems is technically possible. Those PV plants can therefore compete with traditional fossil fuel power generation, if electricity is rated at full costs, excluding all direct and indirect subsidies.

## Solar Water Heating

In comparison to other islands in the Caribbean, the deployment of SWH in T&T is very limited. It is estimated that there are only a few hundred SWH systems in the entire country. All SWH systems in T&T are imported models as there are currently no local manufacturers. However, besides its limited application, the potential for SWH is extremely favourable, as solar insolation levels are high and DNI values are close to the global irradiance values on an inclined surface, which guarantees optimal performance of solar energy systems.

To encourage uptake of SWH, the GoRTT has developed a number of fiscal incentives, such as a 25% tax credit, 0% VAT on SWH, a 150% wear and tear allowance, as well as conditional duty exemptions for manufacturers. While these incentives have stimulated some growth, general uptake has been slow from a commercial, as well as from a domestic user perspective.

The major barrier for the uptake of SWH remains to be financing. The low cost of electricity, coupled with insufficient incentives make the cost of SWH prohibitive, especially for poorer households. At the same time, there is only very limited public awareness about SWH and their advantages and quality of service with regards to design, installation and maintenance is still poor.

In order to reach significant impact a penetration of about 10,000 SWH systems would need to be realized. Using an adequate incentive scheme, as adopted by Barbados, T&T could see a similar growth as Barbados did in the 1980's. To achieve this objective, the development of a specific government program combining incentives, capacity building, awareness raising, standards and testing would be necessary.

## Waste-to-Energy

Like most island countries, T&T faces increasing problems with its disposal of Municipal Solid Waste (MSW). The existing disposal facilities are simple dump sites without proper environmental protection, leading to increasing pollution of surrounding surface and ground water. At the same time, the establishment of new landfills is a major challenge due to limited land availability.

An ideal solution to solve the MSW problem while providing T&T with an additional source of RE or alternative energy would be the conversion of the MSW into energy. A first feasibility analysis shows that a moving grate incinerator combined with steam turbines for electricity generation might be the optimal solution for T&T, as it is a long established and well understood technology.

The MSW in T&T is dry waste that does not require specific technologies for pre-treatment and there are a large number of industrial engineers in the country that could easily be trained to operate the incinerator. Under the current estimations, a WtE project is not economically feasible. Further investigation to develop an appropriate economic model would be necessary and the possible utilization of steam for productive purposes should be investigated.

Major existing obstacles are the low price for electricity generation, as well as very low waste disposal fees. The existing informal sector would need to be integrated, as a WtE plant would eliminate their source of income. However, WtE projects cannot only be assessed on their economic feasibility, but need to take the overall waste management situation in a country into account.

It is recommended to undertake a comprehensive waste characterization study, as well as a study of the composition and status of the waste at the existing landfills. It has also to be analysed, in how far an incinerator plant could be built locally and how much of the equipment would need to be imported.

## Bioenergy

The potential for bioenergy sources in T&T is limited. There is also limited scope for manufacturing capacity in the segment of solid biomass energy. At maximum one plant would be required, however all components would need to be imported. Large biogas plants face the same problem, as the potential for replication would be very limited. A total of four demonstration project could be possible, being located at the local distillery, as well as the three existing large pig farms.

## Other technologies

Most ocean power technologies are still in their infancy and none of the existing technologies is perfectly suited for application in T&T. Due to maturity of technology and location, only tidal power stream plants may present a sensible opportunity. Ocean Thermal Energy Conversion (OTEC) has great potential and an international or at least a regional approach in the Caribbean should be sought. However, with no larger projects globally in existence, OTEC still needs a significant R&D push before it can provide a sizable contribution.

2

# Introduction

Trinidad and Tobago (T&T) is a twin-island state covering an area of 5,128 km² with a total population of 1.3 million, mostly located in Trinidad, the larger of the twin isles, with 4,820 km², and about 95% of the total number of inhabitants.

T&T has a long history in the exploitation of fossil energy resources. Its oil industry has one of the longest historic records in the world, and the country has more recently become a supplier of gas to its national industry and power sector, and is now also a major exporter of Liquefied Natural Gas (LNG).

According to BP's 2013 Statistical Review, total primary energy consumption (TPEC) in T&T was about 842 trillion Btu in 2012.[1] Natural gas consumption accounted for approximately 92% and consumption of petroleum products was just under 8% of TPEC. The use of renewable fuels was negligible.

Due to a highly energy-intensive industry, low energetic efficiency in almost all sectors and the exclusive use of fossil fuels, T&T has very high Carbon Dioxide ($CO_2$) emissions from energy use in the range of 52 million metric tonnes per year (2011). With 40 tonnes $CO_2$ per capita those emissions are among the highest in the world.

GoRTT is in the process of developing a Sustainable Energy Program (SEP), which will maximize the use of its natural resources, and develop the use of renewable and sustainable energy, including Energy Efficiency (EE).

[1] According to U.S. Energy Information Administration statistics it was 930 billion btu in 2013 (EIA, 2013).

The Program will focus on:

i. Developing a sustainable energy framework;
ii. Institutional strengthening of Government entities for the formulation and implementation of policies oriented towards Sustainable Energy, supporting the widespread use of Alternative Energy;
iii. Promoting small energy businesses, which will forge links with other sectors, such as services and manufacturing.

Specific provisions will be made to determine national Renewable Energy (RE) potentials, encourage renewable electricity technologies, such as wind, solar, hydro, biomass and geothermal, and to support EE and conservation initiatives.

To implement and develop the Sustainable Energy Program (SEP), GoRTT has received a Policy-Based Loan (PBL) (TT-L1023) from the Inter-American Development Bank (IDB). This PBL for the SEP consists of three different operations, each with specific institutional and policy goals.

The IDB hired the consortium of Centre of Partnerships for Development (CAD), Projekt-Consult, and LKS to support the Ministry of Energy and Energy Affairs (MEEA) in the development of policies and activities that will promote the deployment of RE and the implementation of EE measures.

As stated in the Terms of Reference, the general objective of this assignment is the promotion of RE and EE programs, to ensure sustainable development in T&T, and to provide alternatives to minimize the dependency on fossil fuels.

This includes the:

i. Support to the preparation and development of the programmatic PBL for the SEP;
ii. Provision of technical assistance to GoRTT, i.e. the Central Government of Trinidad and Tobago, and the Tobago House of Assembly, in the area of EE; and
iii. Exploration of options for RE, together with the funding of specific RE pilot projects. Particular focus will be given to Tobago in order to promote sustainable energy use.[2]

## 2.1 Limitations of the Report

One of the major limitations of this report is the availability of data. While the Consultants, as well as the local CAD representation and the MEEA have made every effort to receive all

[2] Terms of Reference, Support to the Sustainable Energy Program.

the necessary data to analyze the situation in T&T in as much detail as possible, a number of challenges have been encountered throughout the process:

1) Existence of data:
   Due to the low energy costs, in T&T a number of sectors such as the tourism sector, do not record the average energy consumption, as energy is not a relevant cost factor.

2) Access to data:
   It has proven to be a long and complicated process to receive the necessary data from the relevant organizations, such as the Trinidad and Tobago Electricity Commission (T&TEC). The Consultants, as well as the MEEA, have tried to source the necessary energy data. Although various intents, such as written and formal requests, direct visits and follow-up by phone were undertaken, it was not possible to retrieve all existing data.

In order to treat with the above limitations the Consultants have made assumptions wherever possible. In each of the Chapters and Appendixes, the method for developing and calculating the assumptions has been explained.

For some of the data, it has not been possible to develop assumptions, as no comparable data were available.

3

# Baseline for Electricity Generation and Consumption

## 3.1 Objective and Scope of the Baseline

The following chapter establishes a baseline (business-as-usual), in terms of electricity generation and consumption, as well as associated carbon dioxide emissions in order to document the effectiveness of any significant future RE contribution and EE measures and establish energy forecast scenarios. The baseline focuses on the electricity sector and includes the following factors:

1. Amount of natural gas and diesel oil (final use) applied for electricity generation (chapter 3.3);
2. Type and generation efficiencies of existing and future power plants(chapter 3.4);
3. Longer-term development of power generation capacity (fossil fuel baseline without RE), including reserve capacity (chapter 3.5);
4. Past and projected final electricity demand (residential, industrial etc., including information about electricity consumption in public buildings and hotels) and peak loads; prospective baseline scenarios without EE measures will be based on adequate and reasonable assumptions (chapter 3.6);
5. Past and future development of $CO_2$ emissions in the power sector (chapter 3.7);
6. Typical daily load curves (chapter 3.8);
7. Transmission and distribution grid and plans for reinforcement or extension in T&T (chapter 3.9);
8. Electricity generation costs, cost coverage and subsidies in the power sector (chapter 3.10).

## 3.2 The Trinidad and Tobago Energy Matrix

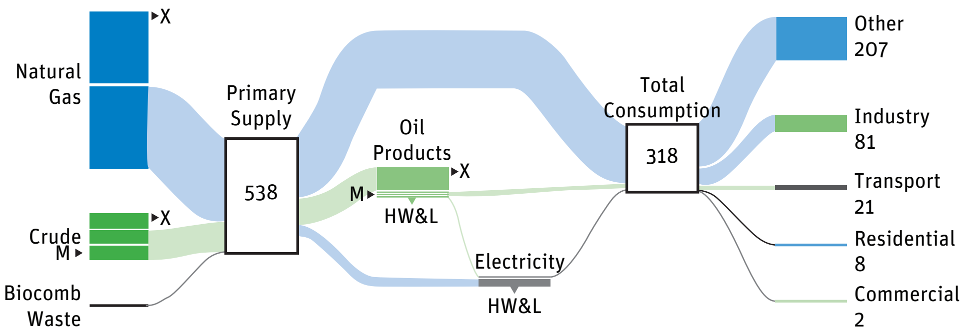
The energy sector is one of the most important sectors in T&T. It amounts to 45.3% of national GDP (2011), provides almost 60% of government revenue and is the most important export commodity with 83% of merchandise exports, mainly refined oil products, liquefied natural gas (LNG), and natural gas liquids (IDB, 2013). T&T is the main exporter of oil in the Caribbean, as well as the main producer of LNG in Latin America and the Caribbean.

While the following chapter mostly focuses on the baseline for electricity, **Figure 1** provides an overview of the primary energy matrix and energy flows in T&T.

**FIGURE 1**

Energy Flow Trinidad and Tobago[a]

All figures in kBOE/day




Energy Matrix › Trinidad & Tobago › 2010

*Source*: Own calculations based on IEA World Energy Balances.
[a] CR&W = Combustibles, Renewables and Waste.

T&T exports the majority (58%) of its natural gas in the form of LNG. In 2012, T&T was the 6th largest LNG exporter in the world (IEA, 2012c). The rest is used domestically in the petrochemical industry (28%), the electricity sector (8%) and other (7%), (IDB 2013).

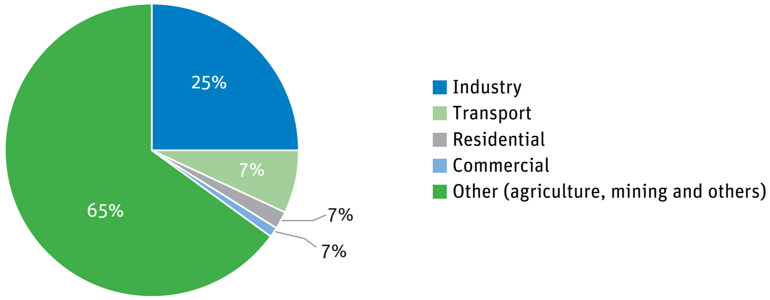
T&T also produces around 80,000 barrels of oil per day (2012). 20% of total production are consumed locally, mainly by the transport sector (IDB, 2013)

Final consumption is dominated by gas and petroleum extraction industry and others (which includes non-energy consumption and the production of derivates, 65%), followed by industry (25%), transport (7%) and the residential and commercial sector with 3%.[1]

[1] Own elaboration based on Energy Flow Trinidad and Tobago.

**FIGURE 2**

Distribution of final consumption by sector




*Source*: Own elaboration based on data from IDB.

T&T with its hydrocarbon based economy, while only contributing to 0.1% of global $CO_2$ emissions, has one of the highest per capita $CO_2$ emissions in the world. It currently ranks 2nd with regards to per capita emissions and produces an estimated amount of 52 million metric tons of $CO_2$ annually (UNEP, 2011; IEA 2011).

Based on data from the University of Trinidad and Tobago (UTT), the contribution of the energy sector and petrochemical operations to $CO_2$ emissions is around 80%, and the transport sector accounts for 6% (Trinidad Express, 2013).

While the report focuses on the potential for $CO_2$ emissions reductions in the power sector, as well as through energy efficiency and the use of renewable energy, it also needs to be noted that the GoRTT is starting to focus on the use of CNG in the transport sector, as another strategy to reduce $CO_2$ emissions in the country.

## 3.3 Natural Gas and Diesel Oil (Final Use) applied for Electricity Generation

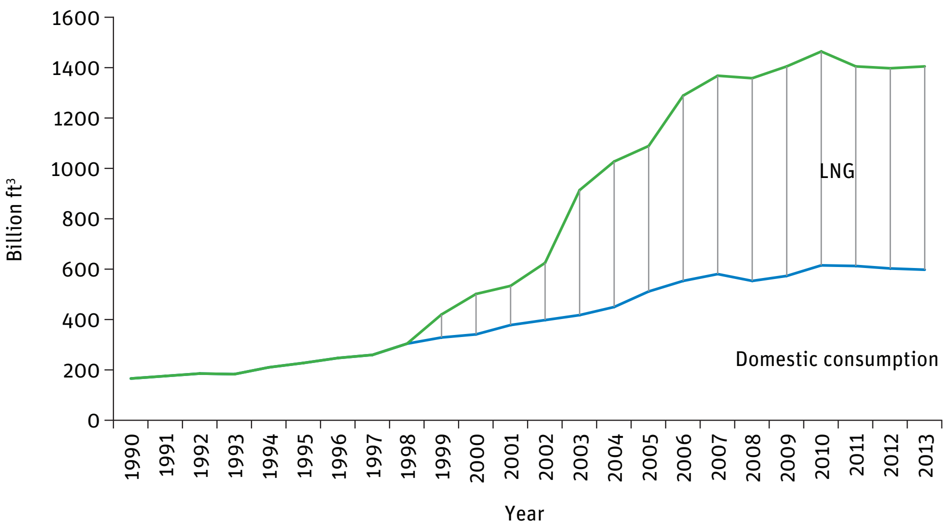
### Annual Domestic Consumption of Natural Gas and LNG Export

As illustrated in **Figure 3**, the annual domestic consumption of natural gas in T&T has risen between the years 1990 and 2013, from 167 bcf to 599 bcf—an increase of 359% over the timeframe of 23 years.[2]

[2] In 2010 domestic consumption peaked at 616 bcf and thereafter decreased.

**FIGURE 3**

Natural Gas Utilisation in T&T 1990–2013




*Source*: MEEA.

The underlying reasons of this growth in natural gas consumption include the following factors:

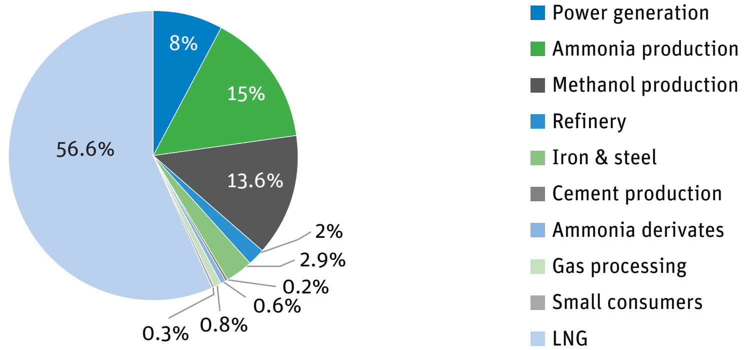
- *Availability of natural gas for local market*: significant increase of local extraction of natural gas over the last 22 years: from 235 bcf in 1990 to 1,514 bcf in 2013[3]—an increase of 644%. The gas to oil production ratio also confirms the importance of natural gas for the local market, given that it increased from 1:1 (energy equivalent) in 1998 to 5:1 in 2007 (GASCO, 2011). Furthermore, the increased availability of local natural gas at least until 2010 is also due to investments in local gas infrastructure, which was in turn facilitated by a significant increase in energy revenues due to, for instance, oil price increases in the early 1980s (GASCO, 2011).
- *Price of natural gas for local market*: the price is much lower than elsewhere, which, in turn, has been the main contributing factor (along with suitable infrastructure developed by the Government) to the development of industries that are intensive users of gas.[4] Gas is sold at varying prices to different domestic companies and foreign buyers based on a number of criteria (T&TEC, 2013).

[3] Production has peaked in 2010 at 1580 bcf.

[4] With 11 ammonia plants and seven methanol plants, T&T is the world's largest exporter of ammonia and the second largest exporter of methanol, according to IHS Global Insight.

**FIGURE 4**

Overview of Natural Gas Consumers in T&T, including LNG export, 2012




Own graph; Source: MEEA, 2012b.

- *Increase in industrial natural gas consumer base*: connection of local manufacturing businesses (including small ones) to the natural gas grid (GASCO, 2011). In this context, **Figure 4** above provides an overview of the different types of natural gas consumers:
- *Increase in GDP and industrial activity*: T&T's GDP per capita has increased by 400% between 1990 (4,170 current US$) and 2011 (16,699 current US$) (WB, 2013); at the same time the value added of the industry has increased from 47% of GDP in 1990 to 60% of GDP in 2011 (WB, 2013).
- *Increase in electricity production from natural gas*: The gross electricity generation (in turn almost exclusively from natural gas, with electricity from oil or RE-based electricity being negligible, i.e. accounting for less than 1%) has gone up from 3.6 TWh in 1990, to 8.5 TWh in 2010—an increase of 137% over 20 years (IEA, 2012a).

As for the share of natural gas used to generate electricity, this figure has decreased from 13.6% in 2000 (MEEA, 2011a) to 8.0% in 2012 and 7.9% in 2013. The main reason for this development is the increased importance of LNG exports (which have gone up from 31.7% of the total use of natural gas in 2000, to almost 57% in 2012[5]). T&T has been the world's sixth largest LNG exporter in 2012.

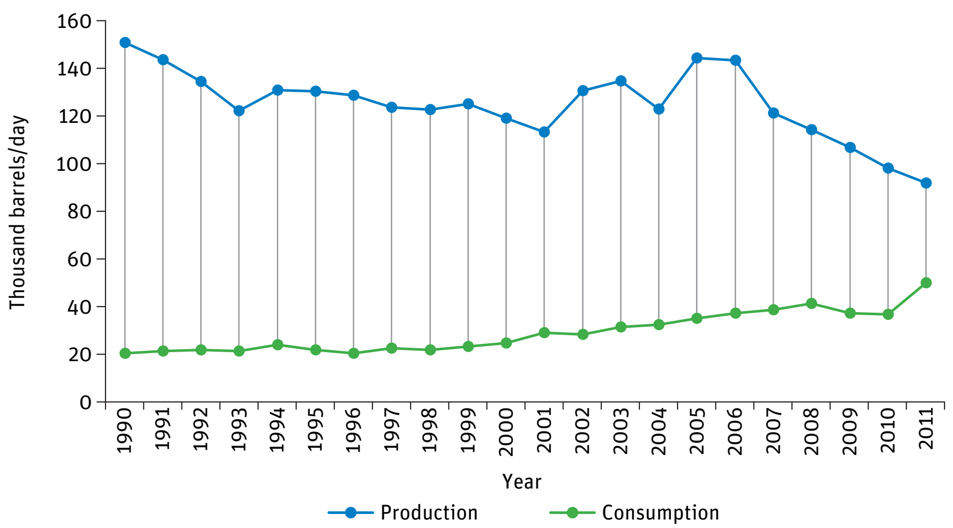
## Annual Consumption of Oil

Between the year 1990 and 2011, and as illustrated in Figure 5 below, the annual consumption of oil in T&T has increased from 20,400 barrels per day (bpd) to 50,000

[5] 57.4% in 2013.

**FIGURE 5**

Total Oil Production and Consumption in T&T, 2000–2011




Own graph; Source: MEEA, 2014.

bpd[6]—an increase of 145% over a period of 22 years. As for the production data in Figure 5, this covers total oil production, which—as per the relevant IEA definition—includes "*production of crude oil—including lease condensate-, natural gas plant liquids and other liquids and refinery processing gain (loss)*". Oil production peaked at 179,000 bpd in 2006, however it has declined year-over-year since 2008. The declines have been attributed to maturing oilfields and operational challenges. According to (EIA, 2013), total oil production has fallen to 119,315 bpd in 2012, while consumption stood at 43,686 bpd.

In this context, **Figure 5** above also shows crude oil production, which has been below 100,000 barrels per day since 2010. In 2012, the production had fallen to 81,735 barrels per day (EIA, 2013; MEEA, Consolidated Monthly Bulletin 2012); in 2013, the daily average was 81,157 bpd (MEEA, Consolidated Monthly Bulletin2013). T&T had 728 million barrels of proven crude oil reserves as of January 2013 (EIA, 2013).

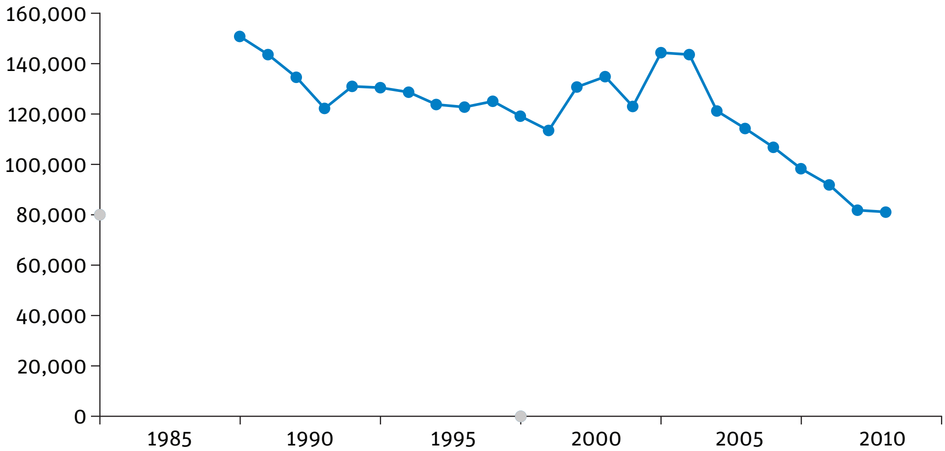
The underlying reasons of the **growth in oil consumption** include the following factors:

- *Increase in GDP and industrial activity*: as already mentioned in the previous section, T&T's GDP per capita has increased by 400% between 1990 (4,170 current US$) and 2011

[6] According to EIA, 2013, it was only about 40,000 bpd in 2011.

**FIGURE 6**

Crude Oil Production in T&T, 1990–2013




Own graph, Source: MEEA, 2014.

(16,699 current US$); at the same time the value added of the industry has increased from 47% of GDP in 1990 to 60% of GDP in 2011 (WB, 2013).

- *Increase in energy intensity per unit of GDP*: as already mentioned in the previous section, the total primary energy intensity in T&T has risen by 38.2% between 1990 (16,663 Btu per 2005 US$) and 2012 (25,496 Btu per 2005 US$) (EIA, 2013).
- *Growth of high oil consumption industry sectors*: two relevant factors in this context are: i) growth of industrial sectors as a percentage of GDP, which has increased from 47% in 1990 to 60% in 2011 (WB, 2013) with manufacturing being the only economic sector, that despite the global financial crisis, has at no point since 2007 experienced negative growth rates (CBTT, 2012); and ii) increase in consumption and conversion (refinery) of the locally extracted petroleum: increase in oil and natural gas refining by almost 500% between 1995 and 2009 (CSO, 2013).
- *Increase in residential oil consumption*: as a result of the 10.7% population growth in T&T over the last 22 years, the transportation sector is considered to have grown accordingly, as well.

The percentage of the total consumption of diesel oil used to generate electricity is negligible, given that in the past diesel has only been utilized for electricity generation for the two power plants in Tobago, with a combined installed capacity of 86 MW, accounting for 3.5% of the total power generation capacity, and for the start-up phase of gas powered plants. Diesel oil use therefore accounted for less than 1% of the primary fuel used for electricity generation in T&T (as of 2012). Furthermore, the Cove diesel/gas power plant in Tobago switched

**Ultra-Low-Sulphur Diesel Unit (ULSD)**

As part of the SEP, the GoRTT is implementing a ULSD. In July 2013, the construction progress of the ULSD project was negatively affected by financial constraints and poor planning and out-of-sequence work, which led to significant amount of rework. Nevertheless, as at July 2013, total EPC project progress was 96.6%, while engineering was 98.9%, and construction was 96.7% complete. The new ULSD Plant will enable Petrotrin to meet stringent new diesel quality specifications (sulphur and aromatics) in the local, regional and international market and is part of Petrotrin´s clean energy program. The ULSD is designed to process 40,000 BPSD (barrels per stream day) of diesel boiling range feed-stocks to produce a diesel product that will reduce: sulphur content from >1000 ppm to 8 ppm; aromatics from >45% to <25%; and the Cetane Number from 41 to 50. This is consistent with the most stringent current and forecasted future on-road fuel specifications.

to operate on natural gas in November 2013. Due to those recent changes, this report approximates diesel generation to zero.

## Projections of Natural Gas for Electricity Generation

In terms of projecting the electricity generation into the future, and therefore, the amount of natural gas to be used for it, the following factors need to be taken into account:

a. Factors determining the demand for electricity, i.e. projected development of electricity demand in the commercial and industrial sector, development of Gross Domestic Product (GDP) and the residential sector (development of population size and households);
b. Projected power generation mix, i.e. types of plants, fuel types and thermal efficiencies;
c. Availability of the underlying primary fuel, i.e. natural gas reserves.

### *Electricity Demand*

Factors determining the **demand for electricity** are the following:

- ***Projected GDP growth***: the International Monetary Fund's (IMF's) most recent projections for the development of the GDP in T&T are positive—with real GDP growth rates projected to be around +2.2% in 2013, and +3.0% in 2017 (IMF, 2012b).
- ***Increase of residential energy consumer base***: T&T's population has grown 10.8% over the last 22 years, i.e. from 1.21 million in 1990 to 1.35 million in 2011 (WB, 2013); The crude birth rate for T&T has been relatively constant for almost two decades (since 1995: between 14–16 per 1,000 as per WB, 2013), and there are no negative indicators in terms of a potential lower immigration or higher emigration rate. However, UNDESA, as well as UNDP Population Figures expect a stabilization in population by around 2025, at approximately 1.4 Million people. Another factor to be taken into account in this context is that the number of households may increase at a higher rate due to the tendency for less occupancy per household.

**Table 1: Customer Forecast by Rate Category[a]**

| | Rate A | B* | D1 | D2 | D3 | D4 | D5 | E1 | E2 | E3 | E4 | E5 | S | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 375,569 | 38,336 | 2,320 | 772 | 14 | 19 | 1 | 3 | 0 | 0 | 0 | 1 | 38 | 417,108 |
| 2016 | 428,231 | 43,359 | 2,913 | 1,020 | 14 | 22 | 1 | 3 | 0 | 1 | 0 | 1 | 63 | 475,628 |
| % change | 14% | 13% | 26% | 32% | 0% | 16% | 0% | 0% | 0% | 100% | 0% | 0% | 66% | 14% |

Own table; Source: T&TEC, 2010.

[a] For rate category description see Table 5. At 30th April 2013, T&TEC had 433,733 customers in total (PRTT, 2014). Of those, 3,392 were industrial customers.

*B1 customers are not included in the forecast.

- ***Increase of non-residential energy consumer base***: according to the forecast by T&TEC (2011), the number of non-residential electricity customers until 2016 is expected to increase in every rate class with the exception of most of the large and very large industry customers (whose number is expected to remain stable)—as illustrated in **Table 1.**
- ***Increase in electricity consumption across most rate categories***: according to forecast in T&TEC (2011), the electricity consumption is expected to increase in most rate categories until 2016—as illustrated in **Table 2**.

In line with T&T's average electricity output growth between 1990 and 2010 (IEA, 2012a), it is assumed that T&T's annual **power generation output** will keep increasing at a similar rate until 2020, i.e. around 4.4% per annum. As a result, gross output is expected to **increase to nearly 13.0 TWh in 2020**—equivalent to around 10,000 kWh per capita. This per capita value, in turn, is far higher than in many industrialized countries[7]. *An increase in end-use efficiency of 10%, for instance, would already have a significant impact*.

### *Projected Power Generation Mix*

In terms of **projected power generation mix**, i.e. types of plants, fuel types and thermal efficiencies, the following factors need to be considered:

- ***Current power generation mix***: In 2012, T&T's power generation mix consisted of eight power plants with a total installed nameplate capacity of 2,417 MW—99% of which natural gas-fired (1% is diesel).
- ***Projected power generation mix***: As presented in **Table 3** in section 3.4, the average overall thermal efficiency was around 26.6%[8] in 2012. In order to improve this low value, a replacement of around 50% of all Simple Cycle Gas Turbine (SCGT) (i.e. equivalent to around 975 MW) by Combined Cycle Gas Turbine (CCGT) by 2020 is expected, based on T&TEC's

[7] E.g. about 7,845 kWh/cap. in Germany and about 5,620 kWh/cap. in the United Kingdom in 2013.

[8] Weighted average from thermal efficiencies of current mix of 930 MW SCGT and 465 MW CCGT. It has increased to about 30% in 2013 with the partial operation of the combined-cycle turbines of TGU.

**Table 2 Electricity Sales to Each Rate Category**[a]

| Year | Rate A | Rate B | Rate B1 | Rate D1 | Rate D2 | Rate D3 | Rate D4 | Rate D5 | Rate E1 | Rate E2 | Rate E3 | Rate E4 | Rate E5 | Rate S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | 2,071 | 740 | 3 | 530 | 1,422 | 428 | 865 | 5 | 375 | n.a. | n.a. | n.a. | 679 | 150 |
| 2010 | 2,271 | 765 | 2 | 564 | 1,435 | 429 | 912 | 1 | 543 | n.a. | n.a. | n.a. | 904 | 111 |
| 2011 | 2,412 | 773 | 2 | 512 | 1,368 | 460 | 892 | 1 | 321 | 401 | 0 | 0 | 870 | 109 |
| 2012 | 2,652 | 784 | 2 | 530 | 1,414 | 461 | 977 | 1 | 322 | 577 | 0 | 0 | 872 | 116 |
| 2013 | 2,853 | 784 | 2 | 549 | 1,461 | 460 | 985 | 1 | 484 | 0 | 653 | 0 | 870 | 116 |
| 2014 | 3,051 | 790 | 2 | 569 | 1,509 | 460 | 1,009 | 1 | 564 | 0 | 653 | 0 | 870 | 121 |
| 2015 | 3,256 | 809 | 2 | 589 | 1,559 | 460 | 1,009 | 1 | 571 | 0 | 653 | 0 | 870 | 121 |
| 2016 | 3,480 | 843 | 2 | 610 | 1,612 | 461 | 1,035 | 1 | 575 | 0 | 653 | 0 | 872 | 126 |

Own table; Source: T&TEC, 2010.
[a] For rate category description see Table 5.

confirmation that "*combined cycle plants should replace all gas turbine plants*" (T&TEC, 2011). This would result in a projected improvement of the overall thermal efficiency to an estimated 38.5% by 2020[9].Furthermore, natural gas is expected to remain the only significant (fossil) fuel used for electricity generation.

## *Development of Natural Gas Reserves*

Regarding **availability of the underlying primary fuel**, i.e. natural gas reserves, the following factors need to be considered:

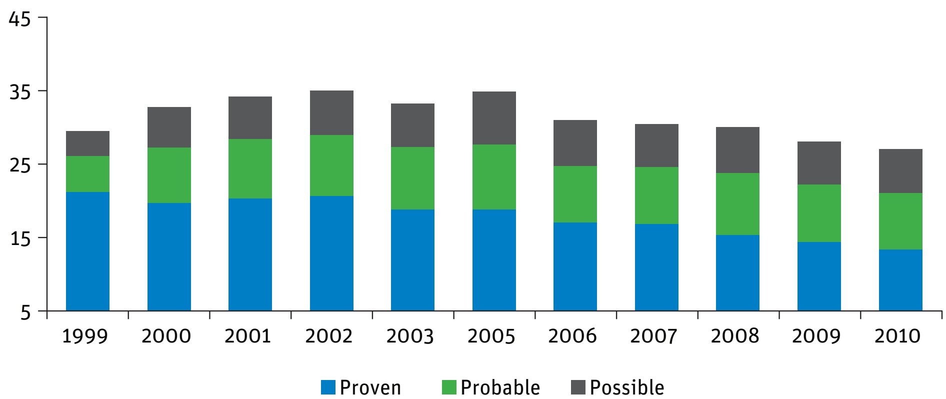
- *Natural gas reserves* (IMF, 2012a; Guardian, 2012). There are two main reasons for the decline in natural gas reserves since 2005 (see **Figure 7**): i) no new areas for exploration and production had been awarded between 2006 and 2012, presumably in part due to the global economic crisis and the collapse in energy prices in mid-2008; and ii) an increase in natural gas production until 2010. As a result, the total natural gas reserves have declined from 34.9 tcf in 2005 to 25.5 tcf in 2011.

  The decline in **proven reserves** in 2011 has slowed down in comparison to the years before, and was estimated to be around 1.5%, compared to an annual slowdown rate of between 6–9% in the years prior. The underlying reasons for this trend reversal were increased development drilling activities in 2011, better than expected reservoir performance, and a decrease in natural gas extraction (further continued in 2012). As at end of 2011, the proven natural gas reserves equate to an equivalent of around nine years of

[9] Midway between current thermal efficiency weighted average of 26.6% and projected future upgrade of all SCGT by CCGT (49.9% thermal efficiency).

**FIGURE 7**

Natural Gas Reserves in T&T, 1999–2010




*Source*: IMF, 2012a.
*Note*: There was no audit in 2004.

natural gas production, based on the country's current commitments, which result in an annual production rate of about 1.5 tcf.[10]

- In 2012, the MEEA launched a bid round for 6 deep-water blocks. Four blocks have since been awarded to the Australian company BHP Billiton, for which production sharing contracts with the MEEA were signed in June 2013. BHP Billiton has plans for investments of approximately US$ 565 million for the first exploration phase, and a further US$ 459 million over the next optional phases. The exploration programme involves seismic surveys of approximately 5,330 km² to be started at the second quarter of 2014, and the drilling of six exploration wells. The first well is expected to be drilled in 2016. Preliminary estimates of the combined natural gas resource potential of these blocks are in the range of 2.4–23.6 trillion cubic feet (tcf), and crude oil resources are in the range of 428–4,200 million barrels of oil.

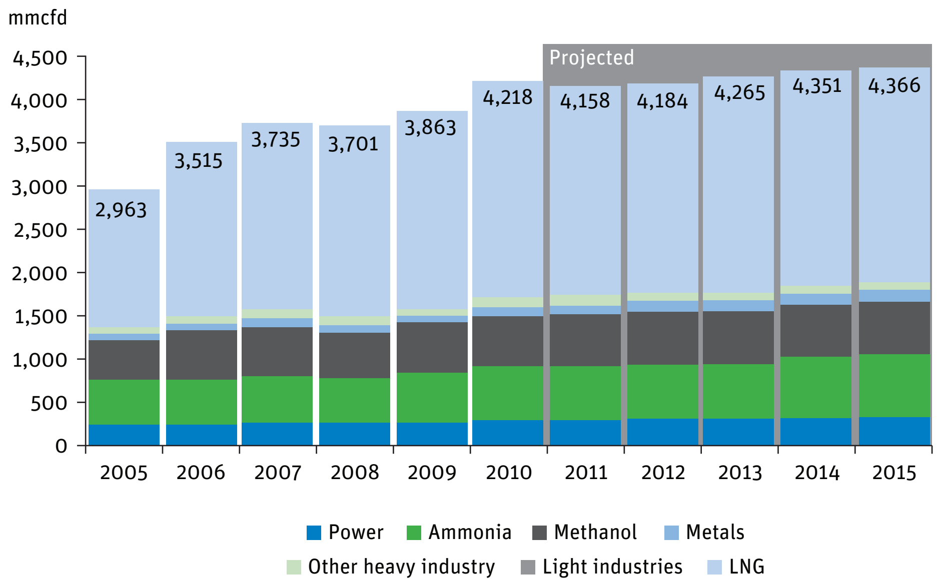
  In addition, another Deep Water Competitive Bid Round was launched in August 2013, which closed in March 2014. Blocks will be awarded at the end of the evaluation process which is near completion. Furthermore, a Trinidad Onshore Bid Round was launched in April 2013; three blocks in the prolific oil and gas province of the southern basin of Trinidad were awarded to: Lease Operators Ltd., Range Resources Trinidad Ltd. and Touchstone Exploration Inc.

Given this overall context, the following factors relevant to the projections of the amount of natural gas to be used for electricity generation (2012–2020) are presented:

[10] As of January 2012, T&T had 13.3 tcf of proven natural gas reserves (EIA, 2013). As of end of 2012, T&T had 13.11 tcf of proven natural gas reserves (2012 Ryder Scott Gas Reserve Audit).

**FIGURE 8**

Natural Gas Demand in T&T, 2005–2015




*Source*: MEEA, 2012b.

As illustrated in **Figure 8**, no substantial increase of natural gas demand is expected for the near future; i.e. it is expected domestic consumption will increase, and LNG export will decrease.

### *Projected Natural Gas Consumption for Electricity Generation until 2020*

- The fuel consumption of all power plants in 2010 was equivalent to almost 118,600 TJ or 112.4 bcf of natural gas (T&TEC, 2013).
- Generating the projected 13.0 TWh in 2020 would therefore result in a fuel consumption of around 182,000 TJ at the current low thermal efficiency; applying the projected improved average thermal efficiency of 38.5% by 2020 would result in a 45% efficiency improvement, resulting in a reduction of the same magnitude of the fuel consumption, which would decline to only 81,400 TJ—*equivalent to a value of around US$ 386 million.*[11]

## 3.4 Type and Generation Efficiencies of Existing and Future Power Plants

In 2012, T&T's power generation capacity consisted of eight power plants operated by T&TEC and different Independent Power Producers (IPPs) with a total installed nameplate capacity of 2,417 MW. **Table 3** summarizes the relevant data in this context.

[11] Using US$ 5.0/MMBTU as a reference price; 1 TJ = 947.82 MMBTU.

**Table 3 Power generation plants in T&T (2012)[a]**

| Name of company | Type of plant (generators) | Location | Installed capacity, MW | Fuel type | Heat rate (kj/kWh)* | Thermal efficiency (%)* | Modes of operation |
|---|---|---|---|---|---|---|---|
| Trinity Power Ltd. | Gas (3 turbines/ total of 225 MW) | Couva | 225 | NG | 13,316 | 27.0 | SC |
| PowerGen | Gas (2 turbines/ 48 MW) and steam (4 turbines/ 260 MW) | Port of Spain | 308 | NG | 15,182 | 23.8 | SC |
| | Gas (10 turbines/634 MW) | Point Lisas | 634 | NG | 17,222 | 20.9 | SC |
| | Gas (2 turbines/ 208 MW) | Point Lisas | 208 | NG | 12,918 | 27.9 | SC |
| | Gas (2 turbines/ 40 MW) and combined cycle (3 turbines/ 196 MW) | Penal | 236 | NG | 9,974 | 36.2 | SC/CC |
| TGU | Gas (6 turbines/ 450 MW) and combined cycle (2 turbines/ 270 MW) | La Brea | 720 | NG | 13,040 | 27.6 | SC/CC |
| T&TEC | Dual fired diesel/ gas (4 turbines/ 64 MW) | Tobago (Cove) | 64 | NG** | 8,566 | 42.0 | SC |
| | Diesel (8 turbines/ 21.7 MW) | Tobago (Scarborough) | 21.7 | ADO | 9,792 | 36.8 | SC |
| Total/ Average | | | 2,416.7 | | | 26.6 | |

*Source*: Calculations made, based on data extracted from (T&TEC, 2013), (IDB, 2011).
*Note*: *2012 figures - with exception of Scarborough (2011 figures); **this plant was running on diesel oil, but was switched to use NG in 2011; NG = Natural gas; ADO = Automotive Diesel Oil; SC = Simple Cycle; CC = Combined Cycle; Average = Weighted average.
Please note that this table reflects the situation in 2012 with the TGU plant only operating with simple-cycle turbines. At the end of 2013 this plant had a thermal efficiency of 38%, while the average for all plants reached 30% (PRTT, 2014).

At the end of 2013, the total installed capacity had decreased to 2,155 MW, with one of the plants at Point Lisas with 208 MW having been shut down in the meantime and somewhat differentiating capacity figures for the remaining plants (…).

As for the **Trinidad Generation Unlimited (TGU) plant**, the commissioning schedule of March 2011 confirmed excess power over the course of the initial years of operation of the plant, with operation established as part of a phased approach. The commissioning schedule was as follows (T&TEC, 2013):

- Phase 1A (225 MW of simple cycle gas turbines): 1 August 2011
- Phase 1B (another 225 MW of simple cycle gas turbines, i.e. total of 450 MW): 20 December 2011
- Phase 2 (two 135 MW steam turbines for combined cycle, i.e. full operation of 720 MW): 18 December 2012

Due to transmission capacity restrictions, currently (first half of 2014) only about 350 MW of the installed capacity of 720 MW are available to the national electricity grid.

It has been already noted, that thermal efficiencies of SCGT, as well as CCGT in T&T are below global industry-wide standards, which are typically around 35–42% (SCGT) and 50–59% (CCGT)[12].

## Projected Type and Generation Efficiencies of Power Plants

Projections (2012–2030) of type and generation efficiencies of power plants (per turbine, mode of operation) depend on three main aspects:

i. Retirement plans of existing power plants:
A total of up to 691 MW is expected to be retired between 2013–2015 at three of PowerGen's existing power plants, which have extraordinarily low efficiencies of between 20.9% and 27.9% (T&TEC, 2013).

ii. Anticipated commissioning of new power plants:
There are plans for the establishment of a new power plant in Barataria by 2018. Furthermore, plans have advanced for an onshore wind energy pilot project at the East coast of Trinidad (Toco) with a capacity of 1.4 MW.

[12] Based on Lower Heating Value and Gross Output.

iii. Anticipated upgrades of existing power plants: Powergen has a plan to potentially re-power the Port-of-Spain Power Station—provided that a new power station in Barataria were not commissioned by 2018 (T&TEC, 2011).

More details on these three main factors are provided in section 3.5.

Overall, the average efficiency of power plants in T&T can at least be increased to the level of the new TGU plant (in combined cycle mode).

## 3.5 Longer-term Development of Power Generation Capacity

Longer-term development of power generation capacity depends on three main factors, i.e. (i) retirement[13] plans of existing power plants, (ii) adding new generation capacity, i.e. either commissioning plans of new power plants or repowering of existing capacity, as well as (iii) anticipated upgrade plans of existing power plants.

Regarding the retirement plans for existing power plants, the following turbines are expected to be retired over the course of the next years[14]:

- 77 MW of PowerGen's existing capacity at Point Lisas (given that all of TGU's new units are operational);
- As soon as the revised 1994 Power Purchase Agreement (PPA) comes into effect[15], the following capacity will be retired:
  - 168.5 MW at Point Lisas plant[16];
  - 20 MW at Penal plant[17];
  - 308 MW at Port of Spain (POS) station after December 2015;
  - A further 118 MW of PowerGen's existing capacity (2014).

According to T&TEC, there are no further retirement plans for existing power plants at this stage.

With respect to additional generation capacity, there are plans for the establishment of a new power plant in Barataria by 2018 and T&TEC has already allocated TT$ 16.1 million for the acquisition of the construction site between 2014 and 2016 (T&TEC, 2011). Furthermore,

[13] Power stations that will be retired, but that are not owned by T&TEC are subject to internal management decisions when or if to decommission and possibly demolish.
[14] As confirmed by (T&TEC, 2013) and based on PowerGen's submission of 2010–11–17.
[15] Point in time is unknown, but for the purpose of this Report, it is assumed to take place in 2014.
[16] Ptls #3 (20 MW) + Ptls #5 (86 MW) + Ptls #8 (62.5 MW) = 168.5 MW; even more has already been retired in 2013 (PRTT, 2014).
[17] Penal #6 (20 MW).

several upgrades of relevant infrastructure across the country have either already been completed, or are still on-going or planned with the objective to improve the transmission network (for instance upgrade or replacement of overhead lines, underground cables, transformers, circuit breakers and isolators). Another option would be to repower existing generation sites, such as the POS plant.

As for reserve capacity, it is assumed for T&TEC to maintain a reserve capacity of 25% in the future. Taking into account a continued peak demand growth rate of 4% (T&TEC 2013), **Table 4** provides an overview of the development of power generation capacity (fossil baseline without RE), peak demand and reserve capacity.

**Table 4 Future Plans of Power Generation Capacity in T&T (including retirement of POS Plant in 2015)**

| | Generation capacity (MW) | Peak demand (MW) | Reserve margin | Target reserve margin T&TEC | Reserve margin – target margin |
|---|---|---|---|---|---|
| 2011 | 1,855 | 1,287 | 44% | 25% | 19% |
| 2012 | 2,211 | 1,338 | 65% | 25% | 40% |
| 2013 | 2,404 | 1,392 | 73% | 25% | 48% |
| 2014 | 2,098 | 1,448 | 45% | 25% | 20% |
| 2015 | 1,944 | 1,506 | 29% | 25% | 4% |
| 2016 | 1,790 | 1,566 | 14% | 25% | –11% |
| 2017 | 1,790 | 1,628 | 10% | 25% | –15% |
| 2018 | 1,790 | 1,694 | 6% | 25% | –19% |
| 2019 | 1,790 | 1,761 | 2% | 25% | –23% |
| 2020 | 1,790 | 1,832 | –2% | 25% | –27% |
| 2021 | 1,790 | 1,905 | –6% | 25% | –31% |
| 2022 | 1,790 | 1,981 | –10% | 25% | –35% |
| 2023 | 1,790 | 2,061 | –13% | 25% | –38% |
| 2024 | 1,790 | 2,143 | –16% | 25% | –41% |
| 2025 | 1,790 | 2,229 | –20% | 25% | –45% |
| 2026 | 1,790 | 2,318 | –23% | 25% | –48% |
| 2027 | 1,790 | 2,411 | –26% | 25% | –51% |
| 2028 | 1,790 | 2,507 | –29% | 25% | –54% |
| 2029 | 1,790 | 2,607 | –31% | 25% | –56% |
| 2030 | 1,790 | 2,712 | –34% | 25% | –59% |

Own table; Sources: T&TEC, 2010; T&TEC, 2013 and IDB, 2011.

Based on the available information, the POS plant is expected to be decommissioned in 2016, which—if no additional power plant capacity was to come online (i.e. new power plant or re-powering of existing power plant)—would result in the reserve margin decreasing from 45% in 2014 to –2% in 2020 and to –34% by 2030. In this case, if the reserve margin of 25% is to be maintained, new additional generation power of:

- About 500 MW would be sufficient (no later than by 2016) to maintain the reserve margin at or above the 25% target reserve margin until 2020, and
- Another about 1,100 MW (as from 2020 onwards) to keep it at or above the target reserve margin until 2030.

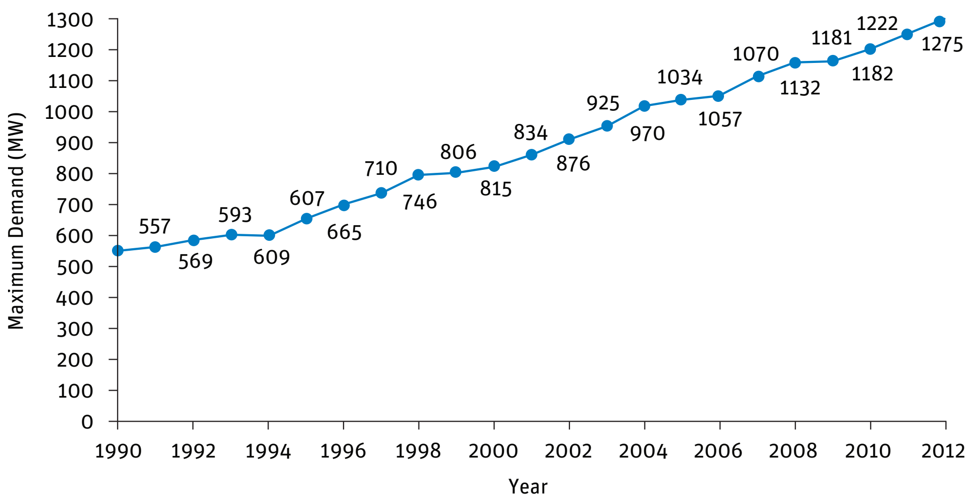
## 3.6 Peak Loads and Peak Demand

As illustrated in **Figure 9**, the peak demand of the public electricity service in T&T has grown from 557 MW in 1990 to 1,322 MW in 2012—equivalent to an average annual growth rate of about 4%.

As for projecting peak demand into the future (2013–2020), peak demand is assumed to develop without major measures for EE increase. The past average peak load growth rate of 4%

**FIGURE 9**

Peak Demand in T&T 1990–2012




*Source*: T&TEC, 2013.

per annum (between 1990 and 2012) is assumed to continue until 2020. T&TEC undertook a system peak demand forecast analysis with the following results: 1,541 MW in 2015 and 1,817 MW in 2020 (T&TEC 2011). These projected T&TEC figures are based on an assumed continued average peak load growth rate of roughly 4% per annum. Newer forecasts indicate a demand of 1,596 MW at the end of 2017, while the installed capacity would be 1,905 MW at that time, leaving a generation reserve margin of 19.4%, which is less than the desired 25% (PRTT, 2014). Those forecasts now assume an increase in electrical demand of 3 to 3.5% per annum.

Given that generation capacity is the most capital intensive infrastructure aspect for T&TEC, system peak demand forecasting needs to be an accurate input into the generation planning process (T&TEC, 2010). Given the importance of accuracy in this process (T&TEC continues to use econometric models to generate their peak demand forecasts) in combination with the aforementioned positive economic outlook for the years to come (see section 1.3), the above mentioned T&TEC peak demand forecast is considered reasonable by the Consultants as baseline not considering any EE intervention.

Another scenario in this context includes curbing the growth of peak demand to an annual rate of 2% in the future, which would result in a projected peak demand of 1,403 MW in 2015 and 1,549 MW in 2020.

## 3.7 Past and future Development of $CO_2$ Emissions in the Power Sector

### Development of past $CO_2$ Emissions in the Power Sector

This section presents the past development of $CO_2$ emissions in T&T's power sector.

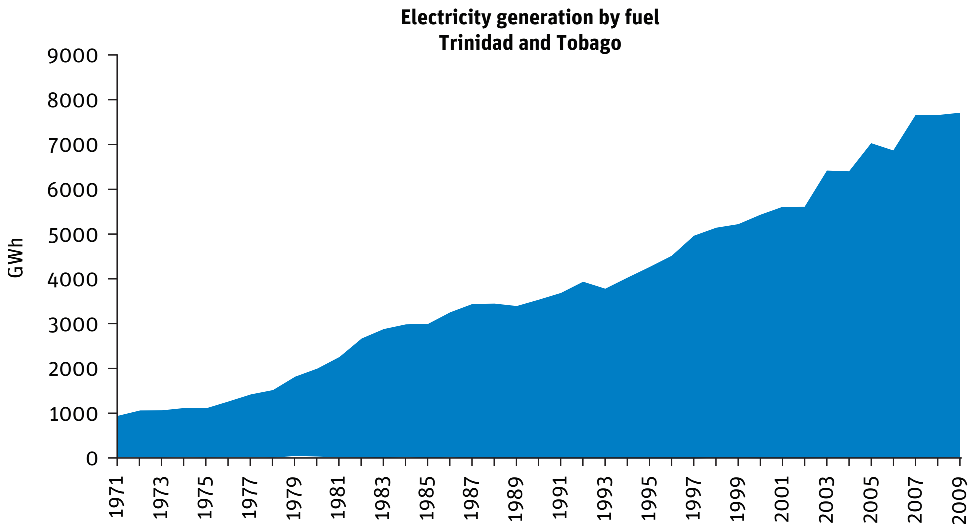
The underlying data are as follows:

- **Carbon factor "$CO_2$ emissions from electricity generation in T&T"**: As confirmed by T&TEC (2013), the applicable carbon factor is 0.69 kg $CO_2$/kWh. This carbon factor is in line with the 0.70 kg $CO_2$/kWh (2010 figure) given by the International Energy Agency (IEA). For the purpose of this report, and in view of data availability of the relevant annual carbon factors since 1990, the IEA figures are utilized. The carbon factors between 1990 and 2010 were in a range between 678 g $CO_2$/kWh[18] and 767 g $CO_2$/kWh, with the most recent value being the aforementioned 700 g $CO_2$/kWh.

[18] Given that there are carbon factors in the past that were lower than todays, this suggests that plants were more efficient in the past.

**FIGURE 10**

Gross electricity generation T&T




*Source*: IEA, 2012b.

- **Electricity output**: The gross electricity generation has gone up from 3.6 TWh in 1990 to 8.5 TWh in 2010 (**Figure 10**)—an increase of 137% over 20 years (IEA, 2012a).
- **Electricity generation by fuel**: T&T produces all of its primary fuel required for power generation. Electricity production has almost exclusively been from natural gas since well before 1990, with only a very small percentage (up to 1%) of the electricity being generated from oil.[19] Generation from RE technologies is negligible as well, as it is limited to only a few residential and commercial micro-scale systems, such as solar PV and wind.

Regarding the development of past $CO_2$ emissions from electricity generation in T&T, **Figure 11** illustrates a constant rise from 2.5 Megaton (Mt) $CO_2$ in 1990 to 5.9 Mt $CO_2$ in 2010—an increase of 134% over that timeframe.

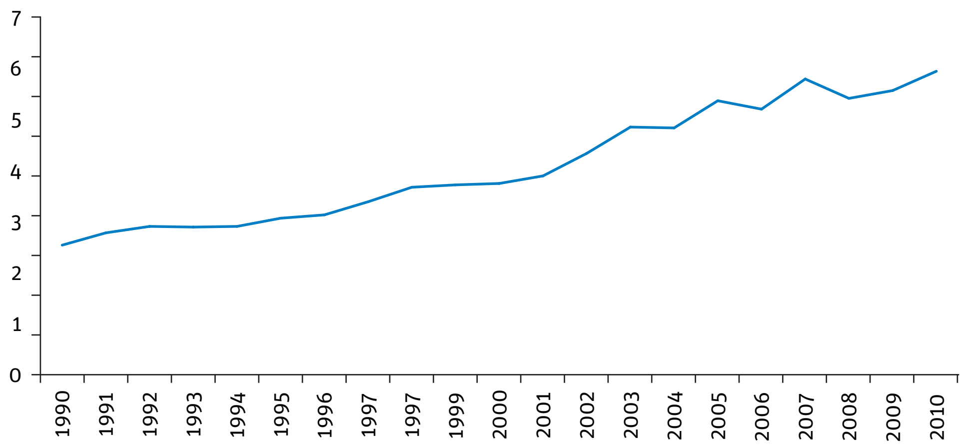
## Estimated near-term Development of $CO_2$ Emissions (Baseline Scenario)

The baseline development of power generation-related $CO_2$ emissions predominantly depends on two main factors: i) the future carbon intensity of the power plants and ii) the expected electricity output.

[19] Since April 2013, all public electricity is produced exclusively from gas, when the Cover power station on Tobago started to operate on gas instead of oil.

**FIGURE 11**

Development of past CO2 emissions (in Mt) from electricity generation in T&T




Own graph; Source: data extracted from IEA, 2012a.

### *Carbon Intensity of Power Generation*

It is expected that the future carbon factors for electricity generation in T&T will decrease (in comparison to the current ones)—for three main reasons:

- As already stated in earlier, 50% of all simple-cycle turbines will eventually be replaced by combined-cycle plants by 2020, thereby significantly improving the thermal efficiency.
- GoRTT has expressed its plan to increase the share of RE-based power generation and has envisaged a target of 60 MW RE capacity (mainly wind power) by 2020. Even then, the share of RE-based generation will remain very small with around 2.5% of overall power generation capacity; yet, the emission-free RE generation (in turn equivalent to around 1.5% of overall gross electricity generation) will still contribute to a further decrease in overall emissions.
- A third factor in this context is the fuel type used for power generation. Apart from the small decrease in carbon intensity stemming from an increase in RE generation, natural gas is expected to remain the main or only (fossil) fuel used for electricity generation, in turn not causing any increase in carbon intensity resulting from a potential change to a fuel source with a potentially higher carbon factor.

### *Expected Electricity Output*

In line with the average electricity output growth between 1990 and 2010 (IEA, 2012a), it is assumed that the output will keep increasing at a similar rate, i.e. around *4.4% per annum*. This development also depends on two other factors: expected GDP/industrial output growth, as well as the development of population and household figures in T&T. As for the former, the IMF's most recent projections for the development of the GDP in T&T are positive—with real GDP growth rates projected to be around +2.2% in 2013 and +3.0% in 2017 (IMF, 2012b). Regarding the latter, T&T's population has grown at a rate of 10.7% over the last 22 years, and although it is expected to continue to increase as far as 2025, T&T´s population is expected to stabilize at around 1.407 million people according to UNDESA´s latest population figures, while the number of households may further increase due to reduced occupancy per household.

### *Summary of assumptions and estimated $CO_2$ development until 2020*

Estimated **future electricity output** in T&T:

- Annual power generation output rate will keep increasing at a similar rate as in the past, i.e. *4.4% per annum*, thus from 8.5 TWh in 2010 to 13.0 TWh in 2020.

Expected development of **future carbon factors for electricity generation** in T&T:

- Assumed replacement of around 50% of all existing SCGT by CCGT by 2020 (i.e. equivalent to around 460 MW SCGT being replaced), thereby improving the overall thermal efficiency from an average of currently 26.6%[20] to an estimated *38.5% by 2020*[21]. This in turn, equates to a thermal efficiency improvement of 44.7%, which when applied to the carbon factor of 700 g $CO_2$/kWh in 2010 would result in an annually decreasing carbon factor, with 387 g $CO_2$/kWh in 2020. Applying the respective carbon factor to the power generation output as identified above results in carbon emissions of 5.0 Mt $CO_2$ in 2020.

Influence of **RE generation** on $CO_2$ emission (Government scenario):

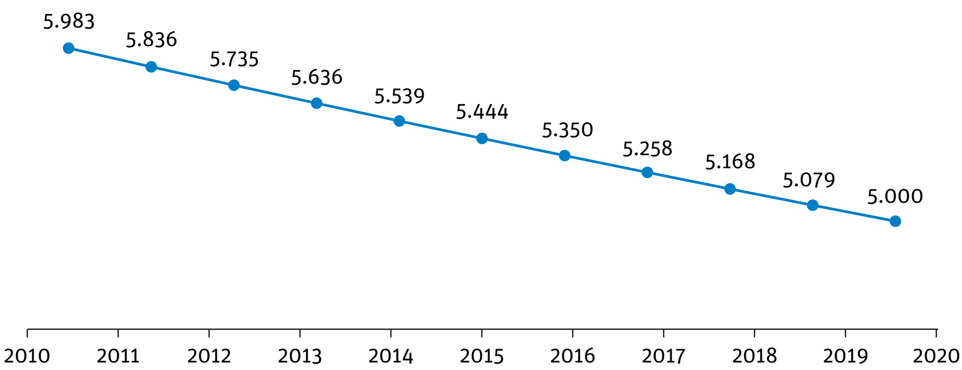
- Increasing the share of RE-based power generation to a target of 60 MW RE (wind) capacity by 2020. This would result in close to 1.5% of RE contribution to total electricity generation[22], in turn resulting in a *further decrease in overall emissions by the aforementioned 1.5%*. Applying this percentage reduction to the figure calculated above (i.e. 5.0 Mt $CO_2$) results in carbon emissions of 4.93 Mt $CO_2$ in the year 2020.

As a result, and as illustrated in **Figure 12**, the development of future $CO_2$ emissions in T&T until 2020 is estimated to be as follows:

[20] Weighted average from thermal efficiencies of current mix of 930 MW SCGT and 465 MW CCGT.
[21] I.e. 50% between current thermal efficiency weighted average of 26.6% and projected future upgrade of all SCGT by CCGT (49.9% thermal efficiency).
[22] The share can be higher, if energy saving measures will lower electricity consumption considerably.

**FIGURE 12**

Possible development of future $CO_2$ emissions from electricity generation in T&T (in Mt), Baseline Scenario




*Source*: Own calculations.

## 3.8 Typical Daily Load Curves

The purpose of this load curve analysis is to determine T&T's daily load profile behaviour and generation capacity requirements (i.e. the amount of power that needs to be made available at any point in time).

This section presents the daily load curves provided by T&TEC for each day of the week 28 December 2012. For the purpose of the analysis of this section, two daily load curves of that particular week have been selected (i.e. Monday and Sunday—as illustrated in **Figure 13** and **Figure 14**) given that these were the two days with the most extreme high and low points in terms of weekday and weekend loads. The remaining five daily load curves (Tue–Sat) are provided in **Appendix A**: Load Curves of T&TEC.

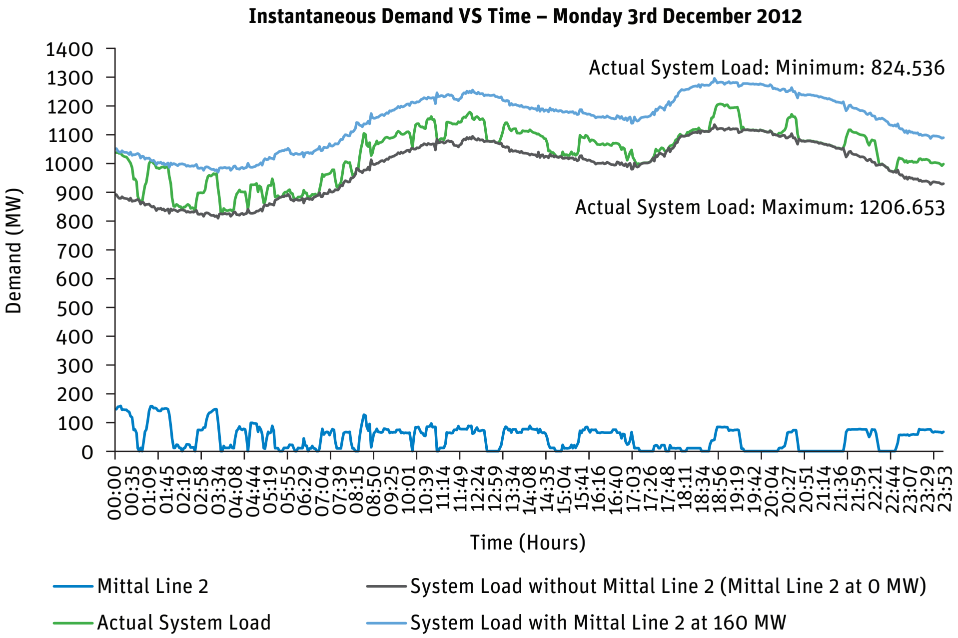
**Table 5** summarizes the respective minimum, maximum and average 'actual system load' values throughout that week. The data shows that the system load ranges between the weekly minimum (824.5 MW) and maximum value (1,320.5 MW), with the average value being 1,057.8 MW. These values provide an indication in terms of base load and peak load requirements.

The data indicate a number of further relevant factors:

- The demand profiles are characterized by two peaks: a day time peak (roughly between 8.30am and 5pm) and a higher night time peak (roughly between 6.30pm and 10.30pm).

**FIGURE 13**

Exemplary daily load curve in T&T: weekday




*Source*: T&TEC, 2013.

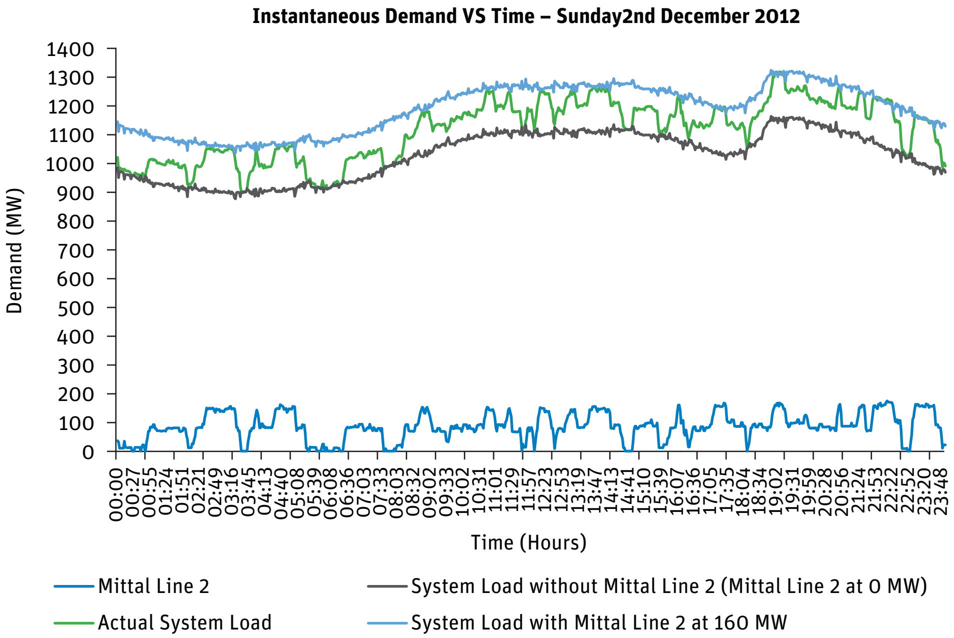
- There is an early morning demand profile trough (which ends around 6.30am) with only minimal commercial or residential consumption.
- The base load is relatively high.
- The maximum demand on weekend days is similar to that on days during the week.

The relevance of this data for T&TEC, for instance, includes:

- In the context of generation planning, potential increased load demand (e.g. new desalination plant, other industrial plants, new housing developments, etc.) would require an analysis to evaluate a need for improved infrastructure (e.g. new substations, feeders, etc.);
- At the same time, acceptable levels of reliability need to be maintained; in this context, T&TEC has a reliability criterion of loss of load expectation (LOLE) of <= 12 hours per year, meaning that the expected time the available generation capacity will fall short or be unable to supply the total system load cannot exceed a yearly maximum of 12 hours (T&TEC, 2010);

**FIGURE 14**

Exemplary daily load curve in T&T: weekend




*Source*: T&TEC, 2013.

- Improved analysis of potential demand side management measures, such as load shifting through time-of-use tariffs, which maximize the efficient use of generation capacity, by shifting demand from peak to off-peak periods.

## 3.9 Transmission and Distribution Grid and Plans for Reinforcement or Extension

Based on the findings of Longer-term Development of Power Generation Capacity, the key areas for reinforcement or extension over the next years are as follows (see also **Appendix B**: Maps of Transmission and Distribution Grids):

- **Barataria** (between San Juan and Port of Spain):
  - Is a location for a potential new power plant (no details known regarding anticipated capacity);
  - Sits at a strategic location from an infrastructure-related point of view, i.e. benefits from a nearby substation, as well as 33 kV and 132 kV overhead lines and proximity to gas supply;

**Table 5 Minimum and maximum ‘actual system load’ values in the week 2–8 Dec 2012**

| | Minimum (MW) | Maximum (MW) | Average (MW) | Daily Energy Estimate (MWh) |
|---|---|---|---|---|
| Monday, 2 Dec 2012 | 824.5 | 1,206.7 | 1,036.1 | 24,865.5 |
| Tuesday, 3 Dec | 857.2 | 1,200.6 | 1,025.6 | 24,614.9 |
| Wednesday, 4 Dec | 832.0 | 1,283.7 | 1,046.0 | 25,105.0 |
| Thursday, 5 Dec | 850.3 | 1,183.3 | 1,036.4 | 24,874.6 |
| Friday, 6 Dec | 855.1 | 1,255.5 | 1,069.2 | 25,661.8 |
| Saturday, 7 Dec | 873.8 | 1,278.3 | 1,072.9 | 25,750.7 |
| Sunday, 8 Dec | 901.4 | 1,320.5 | 1,118.7 | 26,849.6 |

| | |
|---|---|
| Min (MW)/Week | 824.5 |
| Max (MW)/Week | 1,320.5 |
| Average (MW)/Week | 1,057.8 |
| Min (MWh)/Energy Estimate | 24,614.9 |
| Max (MWh)/Energy Estimate | 26,849.6 |
| Average (MWh)/Energy Estimate | 25,648.3 |
| Weekly total (MWh)/Energy Estimate | 103,136.7 |

Own table; Source: data extracted from (T&TEC, 2013).

  - At first glance it seems that the current infrastructure would be sufficient to accommodate the commissioning of a new power plant in the Barataria area, however, more detailed analysis (including access to more data) would be required to make a sound statement on that issue.
- **Port of Spain**, Wrightson Road:
  - Is the current location of a PowerGen gas-steam power plant (original installed capacity: 300 MW);
  - Might be subject to either decommissioning (anticipated timescales: year 2015) or repowering; final decision on these issues is still pending;
  - Sits at a central location in Port of Spain and also benefits from a connection to a substation, as well as 33 kV and 132 kV overhead lines;
  - Between 2011 and 2016, almost the entire underground transmission network (i.e. 24 km out of a total of 25 km of underground transmission cables) is scheduled to be replaced—mostly in the city of Port of Spain;
  - Six transformers (out of a total of 31 interbus transformers) are scheduled to be replaced by 2016 (at Westmoorings, Wrightson Road, Rio Claro, and at St. Mary’s substations);

    - At first glance it seems that the current infrastructure (especially once the ongoing works have been completed) would be sufficient to accommodate a potential repowering of the existing PowerGen plant or even the construction of a new power plant in the area, however, more detailed analysis (including access to more data) would be required to make a sound statement on that issue.
- **Toco** (North-East Trinidad):
    - Designated **wind energy pilot project site** with a capacity of 2 x 1.4 MW turbines;
    - Benefits from two nearby substations, three 33 kV overhead lines, a communication tower, as well as the connection cable with Tobago.
- **La Brea** (South-West Trinidad):
    - Location of TGU plant (combined cycle; total capacity: 720 MW);
    - Benefits from two nearby substations and a connection to the 33 kV overhead line;
    - The main load (480 MW) of the recently constructed TGU power station was expected to be the Alutrint Smelter Plant. However, GoRTT has made the decision not to proceed with the construction of Alutrint (T&TEC, 2011). As a result, new transmission lines will need to be constructed to reinforce the connection of the TGU plant with the load centres.

Relevant transmission and distribution-related works recently completed or planned include the following (T&TEC, 2011):

- Felicity area and Charlieville: installation of two transformers and of switchgear, respectively;
- Pinto Road: replacement of transformers to improve the reliability of the 66 kV supply;
- Orange Grove: establishment of new 66/12 kV substation to reinforce and improve reliability of electricity supply in Mt. Hope, St. Augustine, San Juan, Barataria, Tacarigua and the surrounding areas (completed);
- Couva: upgrade of 12 kV line conductors in the Calcutta area for greater current carrying capacity for distribution (completed);
- St. Joseph/Maracas: provision of an alternative supply to meet increasing load demands and improve reliability (completed)
- New HV transmission lines constructed (total of over 63 km):
    - Bamboo/Mt Hope 132 kV tower line
    - Mt Pleasant/Diamondvale 66 kV Overhead line
    - Carenage/Mt Pleasant 66 kV Overhead line
    - San Raphael 132 kV Tower line
    - Pinto Road/Wallerfield 66 kV Tower line
    - Reform/Debe 220 kV Tower line
    - Debe/Union 220kV Tower line
    - Debe/Penal 132 kV Tower line
    - Bamboo/East Dry River 132 kV Tower line
    - Brechin Castle/Reform #3,#4 132 kV circuits;

- Tobago voltage increased to 66 kV for new lines.
- Isolators work (i.e. replacements) between 2011 and 2016: Bamboo 132 kV, Bamboo 66 kV, San Rafael, Fyzabad, Pt. Fortin, North Oropouche and Harmony substations.
- Works to be carried out at various substations by 2016 also include the replacement of 48 oil and faulty gas and vacuum circuit breakers (out of a total of 154 circuit breakers).
- Current distribution-related projects include Geographic Information System (GIS) mapping of infrastructure, Computerized Maintenance Management System (CMMS), as well as distribution automation.

**Electricity infrastructure-related challenges** in T&T (requiring investment in the infrastructure to improve quality and reliability of electricity supply) also include:

- Voltage fluctuations (potentially resulting from obsolete infrastructure and poor power factor of customer electrical loads);
- Vulnerability to wide area blackouts (due to a mainly centralized electricity generation system) in cases where generation infrastructure was to fail;
- Vandalism and theft of assets;

A number of difficulties are expected in relation to the ongoing and upcoming transmission- and distribution-related works (T&TEC, 2011), including:

- Availability and capacity of relevant local expertise to ensure timely completion of the projects;
- Potential project management-related issues at T&TEC due to various ongoing mega projects;
- Ensuring continued operations during the refurbishment of the existing infrastructure;
- Potential cost increase.

## 3.10 Electricity Generation Costs

This section presents an overview of electricity generation cost, including conversion and fuel costs. Overall, fuel purchases and conversion to energy account for more than 60% of T&TEC's total operational costs (T&TEC, 2011). In terms of recent trends in this context, the addition of the TGU plant to the grid was assumed to result in a 60% increase in average conversion costs, in turn being the main contributor to the proposed revised electricity tariffs up to 2016, which as outlined in chapter 4 would result in a rate increase across all classes, with some of them moving up by more than 30% by 2016.

As can be seen from Table 6 the conversion costs vary significantly depending mainly on the age of the plant, while the specific fuel costs depend primarily on the efficiency of the plant. It is evident that the new TGU plant is not operating cost-covering with the current tariffs being in place.

**Table 6  Conversion costs and Specific Fuel costs of T&T power plants in 2013**

| Power Station | Capacity (MW) | Conversion Cost (TT$-ct/kWh and US-ct/kWh) | Specific Fuel Cost (TT$-ct/kWh and US-ct/kWh) |
|---|---|---|---|
| PowerGen Total | 1,135 | 16.0/2.5 | 11.4/1.8 |
| Trinity Power | 225 | 10.0/1.5 | 10.0/1.5 |
| TGU La Brea | 720[a] | 35.0/5.4 | 7.2/1.1 |
| Tobago (Cove & Scarborough) | 75 | N/A | 39.0/6–0 |
| **Total** | **2,155** | **18.3 /2.8** | **10.0/1.5** |

*Source*: PRTT, 2014.
[a] Until mid 2014, only 350 MW were available to the grid.

Highlights of the **electricity generation costs** include:

- Overall T&TEC expenditure for generation was expected to increase from TT$ 1.43 billion in 2010 to TT$ 2.51 billion in 2012[23];
- The percentage of conversion costs out of total generation costs was supposed to increase from 42% in 2010 to 63% in 2012; as a result, the proportion of fuel costs would have decreased from 52% in 2010 to 37% in 2012;

**Table 7  Electricity generation costs**

| | | 2010 | | 2012 (projected) | |
|---|---|---|---|---|---|
| | Sales (in thousands of MWh): | 7,908.6 | | 8,708.0 | |
| | | TT$ | US$ | TT$ | US$ |
| Total generation cost (in millions): | | 1,432.3 | 223.9 | 2,510.4 | 392.4 |
| of which conversion cost (in millions): | | 598.9 | 93.6 | 1,581.5 | 247.2 |
| | per kWh: | 0.08 | 0.01 | 0.18 | 0.03 |
| of which fuel cost (in millions): | | 748.0 | 116.9 | 928.9 | 145.2 |
| | per kWh: | 0.09 | 0.01 | 0.11 | 0.02 |
| Cost per kWh sold: | | 0.18 | 0.03 | 0.29 | 0.05 |
| Sales of electricity (in millions): | | 2,665.2 | 416.6 | 3,578.1 | 559.3 |
| Revenue per kWh sold: | | 0.34 | 0.05 | 0.41 | 0.06 |

Own table; Source: T&TEC, 2011.
*Note*: Exchange rate TT$–US$ (www.xe.com): 0.156301.
2012 total conversion cost = conversion cost PowerGen, Trinity Power (TT$889.9 million) + TGU (TT$691.6 million).

[23] All 2012 figures in this context are projected figures. During time of reporting no newer figures were available.

- Costs per kWh sold were expected to go up from TT$ 0.18 (US$ 0.03) in 2010 to TT$ 0.29 (US$ 0.045) in 2012;
- At the same time, revenue per kWh sold was projected to increase by TT$ 0.07 (US$ 0.01) to TT$ 0.41 (US$ 0.06) in 2012 assuming the rate increase was implemented;
- Electricity sales and total revenues over these two years were assumed to increase from 7.9 TWh/TT$ 2.67 billion (2010) to 8.7 TWh/TT$ 3.58 billion (2012);
- Overall, due to interest, finance and pension costs, T&TEC is making a financial loss.

A table with the detailed electricity generation costs is presented above.

## 3.11 Conclusions of baseline study

The baseline study establishes the key factors impacting the energy sector and the related $CO_2$ emissions:

i. High electricity consumption per capita with high $CO_2$ emissions[24] given the nature of Energy Production based economy and lack of considerable EE and RE measures and incentives; dependent on population growth and GDP increase.

ii. The whole energy sector currently contributes over 43% of the GDP (2013) and estimates anticipate an exponential increase in per capita GDP in the future.

iii. The existing fuel mix for electricity generation is **99% natural gas** with the other 1% coming from diesel oil;

iv. There is currently no expected shortage of gas to meet the future demand. The oil demand is likely to overtake the domestic production capacity within the 2032 period.

v. Based on the analysis, this report assumes that the projected GDP increases cannot be maintained until 2032 with the depleting oil reserves including the combined current reserves and the best estimate for deep sea gas reserves being currently awarded.

vi. It therefore demonstrates the need to diversify the energy matrix, to reduce national demand which could be used for increased energy exports.

[24] International Energy Agency: $CO_2$ Emissions from fuel combustion, 2012.

4

# Energy Policy

## 4.1 Main actors

The following chapter provides an overview of the main actors relevant for the energy sectors and subsequently promoting RE and EE in Trinidad and Tobago. Table 8 shows the primary entities operating within the country's energy sector.

### Ministry of Energy and Energy Affairs (MEEA)

The MEEA as the major counterpart of this consultancy organizes EE and RE in its operations under two different areas: The Energy, Research and Planning Department is responsible for Renewable Energy and Energy Efficiency, as well as a number of other activities such as international relations, trend analysis and research, Public Sector Investment Programme (PSIP), etc.

The department is led by a director and divided into a number of teams, the RE and EE team being one of them. The RE and EE team is led by a Senior Energy Analyst.

Its main responsibilities include:

- Renewable Energy (RE) and Energy Efficiency (EE) Policy development and review.
- Preparing, drafting and reviewing legislation in relation to the incorporation of RE into the country's energy mix
- Developing and reviewing appropriate fiscal and other incentives for RE and EE
- Providing technical and other support to the Bureau of Standards in the preparation of standards and certification of RE and EE suppliers, equipment and products
- Implementation of and ensuring compliance with requirements of standards and certification procedures
- Spearheading RE and EE initiatives being pursued by the MEEA through dialogue with various stakeholders
- Organizing training workshops with other stakeholders in RE and EE
- Education, training and public awareness

- Preparing a register of RE and EE service providers and suppliers on the MEEA's website and servicing this register as needed
- Collaborating with the NEC in the evaluation of RE and EE project proposals
- Providing technical support to the Carbon Reduction Strategy Task Force
- Interfacing with all relevant internal and external stakeholders in the pursuit of RE and EE initiatives and ensuring timely and efficient submission of data for which requests have been made.

Apart from the Renewable Energy Group, there is a second team (outside the Energy, Research and Planning Department) that is supporting the implementation of RE and EE at the Ministry. It directly reports to the Minister and is headed by the Advisor to the Minister of RE. The team is responsible for the Energy Communication Campaign. The MEEA is currently undergoing a strategic change process, one of the major changes relevant for RE and EE, being the upgrade to its own division.

**Table 8 Responsibility for the Energy Sector in T&T**

| Entity | Type | Responsibility |
|---|---|---|
| Standing Committee on Energy | Ad-hoc cabinet committee chaired by the Prime Minister | Responsible for high-level oversight and decision-making in the energy sector. Comprised of cabinet ministers and supported by senior technocrats from the MEEA, Ministry of Finance and Ministry of Planning, and the top brass of the energy sector's state enterprises. |
| Ministry of Energy and Energy Affairs (MEEA) | Government ministry | The development of policies, strategic direction and plans for the national energy sector. |
| RE Committee (REC) | Working Committee of the MEEA and other stakeholders | To review and advise on the potential of RE technologies, to set realizable targets and timeframes for RE in the energy mix and to recommend incentives and legislation to facilitate the market shift. |
| Petroleum Company of Trinidad and Tobago Limited (Petrotrin) | State-owned, integrated oil & gas company | T&T's largest producer of crude oil and operator of the sole petroleum refinery in the country. |
| Oil & Gas companies | Privately-owned oil & gas producing companies | Responsible for the exploration and production of crude oil and natural gas under the terms of licences issued by GoRTT. |

(*continued on next page*)

**Table 8 Responsibility for the Energy Sector in T&T** *(continued)*

| Entity | Type | Responsibility |
|---|---|---|
| National Gas Company of Trinidad and Tobago (NGC) | State-owned diversified energy company | Purchases, transports, distributes and sells natural gas to industrial & commercial users. Owns, operates and maintains the country's offshore and onshore pipeline network; through its subsidiaries develops gas-related industrial sites, infrastructure & services and is involved in upstream gas, oil & LNG production. |
| National Energy Company (NEC) | A wholly-owned subsidiary of the NGC | To develop and manage suitable infrastructure so as to facilitate and promote the activities relevant and appropriate to all natural gas-related operations in T&T. |
| The Energy Chamber | Private-sector trade association | The trade association representing the collective interests of its membership, comprised of companies operating within the energy sector in T&T. |
| Regulated Industries Commission | Independent statutory body | To ensure high-quality, fair and equitable utility services, including matters related to licensing, rate-setting, customer care and quality standards, efficiency and competition. |
| Trinidad and Tobago Electricity Commission (T&TEC) | State-owned, vertically integrated utility | Generation, transmission and distribution of electricity |
| Independent Power Producers (PowerGen, Trinity Power and TGU) | Public/private Joint venture/privately owned IPPs | Responsible for providing power capacity and energy to the T&TEC grid, under the terms of a power purchase agreement (PPA). |
| Environmental Management Authority, Ministry of the Environment and Water Resources | Statutory agency | The EMA operates under the 1995 Environment Management Act and is mandated to develop and enforce criteria, standards and regulations for environmental management across all sectors of the economy, and to educate the public about the nation's environmental issues through awareness programmes. |
| National Petroleum Marketing Company Limited (NPMC) and United Independent Petroleum Marketing Company Limited (UNIPET). | Wholesale Marketing Companies | The NPMC and the UNIPET are engaged in the storage, marketing and distribution of fuel. |

*Source*: Own elaboration.

## T&TEC and Independent Power Producers

The second relevant actor that deserves attention is the utility T&TEC. T&TEC is a state-owned, vertically integrated electricity company, responsible for all levels of power generation and supply. T&TEC is also in charge of power system planning for both islands, as well as electricity generation and distribution in Tobago. T&TEC buys all energy generated by the Power Generation Company of Trinidad and Tobago (PowerGen), an independent power producer where it maintains a 51% share, as well as from Trinity Power Limited and from Trinidad Generation Unlimited (TGU). T&TEC has a monopoly for transmitting, distributing and sale of electricity in T&T.

The purchase of bulk power from the Independent Power Producers is governed by four separate Power Purchase Agreements (PPAs). Two of these PPAs are with PowerGen for a total contracted capacity of 819 MW. This PPA commenced in 1994 for a 15-year period, which ended in December 2009. Its renewal is still pending. The second PPA, referred to as PPA 2005, has contracted 210 MW from the Pt. Lisas power plant. This PPA covers a period of 30 years and will terminate in 2035. The Trinity agreement was signed in 1998, also for a term of 30 years. The most recent PPA was signed in 2009 with TGU for a contracted capacity of 729 MW, of which the first phase was commissioned in 2011 with 225 MW. The PPA is valid for a 35 year period. The GoRTT holds more than 90% of the shares in TGU, with the remaining shares owned by the AES Corporation.

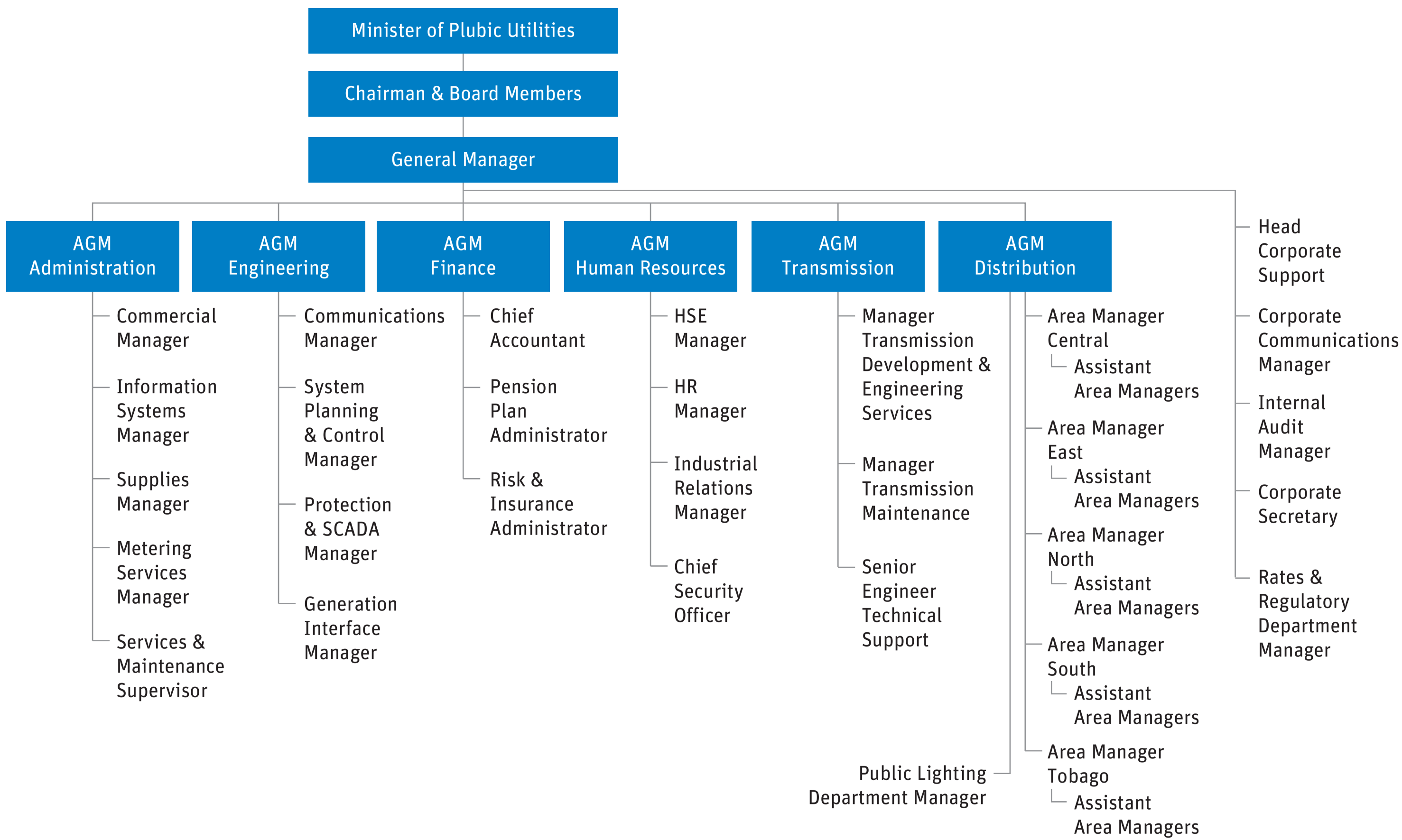
Currently, T&TEC purchases gas on behalf of the IPPs for a fixed price, while the PPAs only define the conversion costs, i.e. transforming gas energy into electricity.

All proposals for the expansion of the power system must be reviewed by the Regulated Industries Commission (RIC), the Ministry of Public Utilities and T&TEC in order to determine best options for covering future demand and analyze costs and possible tariffs adjustments. Section 53 of the Trinidad and Tobago Electricity Commission Act gives T&TEC the responsibility for proposing tariffs. In accordance with Section 6(1) of the RIC Act, the RIC is empowered to make the final determination on the proposed tariffs.

T&TEC's operational structure is depicted in **Figure 15** (see next page). The Engineering Division of T&TEC prepares the load forecast and performs the load flow and short-circuit studies for the transmission system. A project plan is developed, approved and forwarded to the Transmission Division. The Transmission Division and Engineering Services Department analyzes the proposed transmission development plan and determines the best strategies for implementation.

**FIGURE 15**

Operational structure of T&TEC




*Source*: T&TEC.

A Research Unit is currently conducting research on renewable energy options, with a view to developing a strategy for integration. T&TEC has a number of ongoing small-scale renewable energy projects at the University of Trinidad and Tobago, the Islamic Centre in Gasparillo and within T&TEC. With larger RE projects coming up, T&TEC's staff will certainly need to be strengthened with additional expertise.

## 4.2 Legal and Regulatory Framework and Supporting Policies

The following chapter provides a short overview on the Legal and Regulatory Framework and supporting policies and then analyses some aspects with regard to changes of the political and regulatory framework for the enhancement of RE and EE technologies. With respect to other and more detailed political actions that could support EE initiatives and the uptake of solar water heating, reference is made to the respective chapters and our recommendations to the draft Green Paper of October 2012 (see chapter 4.3). Attention is drawn to several suggestions for political initiatives and activities that have been made in the different chapters on RE technologies.

T&T has almost a 100% access to electricity and only remote areas in Tobago are not connected to the grid. The following report therefore focuses on grid-connected options for RE. It is not recommended to focus on stand-alone RE from the policy side, as the impact would be minimal. Information with regards to the application of Solar Home Systems can be provided to isolated households; however, it is recommended that GoRTT focuses its attention on other activities, as recommended in chapter 6.

### Status quo of the regulatory framework

Established under the Regulated Commission Act No. 26 of 1998, the Regulated Industry Commission (RIC) is responsible for regulating supply of electricity in T&T.

The RIC Act specifies that the RIC is to:

> *—Review the principles for determining rates and charges for services every five years or, where the license issued to the service provider prescribes otherwise, at such shorter interval as it may be determined. (IADB 2011)*

Also, under the current act, electricity generation is not possible without prior licensing through MEEA, unless an exemption is granted (RIC Act No. 26 of 1998, Part IV).

The latest revision of tariffs was due in 2011, however until now the proposed revision of the tariffs (a 21% increase as proposed by T&TEC) had not been approved by the end of 2013.

The Trinidad and Tobago Electricity and Commission Act (Chapter 54:70) was originally enacted in 1945 and was subsequently amended several time, with the current version being from June 2009. As the name suggests, the core intention of the Act has been the establishment of the state-owned utility enterprise T&TEC, which was created to combine the services of generation, transmission and supply of electricity for the whole country under one body. Until now, T&TEC is the sole buyer of all generated electricity and has a country-wide monopoly for the distribution of electric power.

The Act states in Part VI, section 31. (2) that the Commission[1] may "*with the consent of the Minister, purchase energy from an approved generator of electricity*". It further says in paragraph (3) of the same section that "*the right to generate energy in any part of Trinidad and Tobago for the public or any member thereof is vested in the Commission who may, subject to subsection (5) enter into a license agreement with an approved generator of electricity permitting the approved generator of electricity the non-exclusive right to generate electricity*."

It further outlines and clarifies in the same section 31:

(3A) *"Subject to this Act, the right to supply energy in any part of Trinidad of Tobago to the public or any member thereof, either directly or indirectly, is vested in the Commission."*

(3C) "*The Commission may, with the approval of the Minister, by Order declare a body corporate or firm to be an approved generator of electricity."*

(5) "*The right of an approved generator of electricity to generate energy is subject to such terms and conditions as the Minister may determine."*

The current policies and strategy documents that are promoting Sustainable Energy are the following:

- The Draft Green Paper on a National Energy & Minerals Policy
- Report on a Framework for Development of a Renewable Energy Policy
- Report on a Framework for Energy Efficiency Policy and Program

## Amending of the Trinidad and Tobago Electricity Commission Act and the RIC act

Based on the existing legislation, the so-called "*approved generator*" is the classical Independent Power Producer who delivers all its electricity to the sole buyer under a negotiated Power Purchase Agreement (PPA). Currently, the T&TEC Act neither allows for smaller op-

[1] T&TEC.

### Connection of *pilot projects* to the grid

An analysis of the current regulatory framework reveals that it is currently only possible to connect RE to the grid under two potential scenarios:

1. To facilitate operation without going through a lengthy licensing process and to avoid any conflicts with the single-buyer of electricity it is recommended that operation of potential RE energy systems is maintained in the hands of T&TEC. This could be done on the basis of a contractual agreement between the plant owner and grid operator, defining the exact role of each party. T&TEC would have full control and supervision of the system, but would need to guarantee that RE electricity is dispatched with priority to the grid.
2. A power reimbursement contract between T&TEC and the owner of a facility can be developed to organize implementation. In this case it needs to be made sure that instead of going through a lengthy licensing process, a rather simple request for registration should be sufficient.

If pilot projects take place, it is recommended that all electricity generated is exported to the grid and metered accordingly. Every kilowatt-hour produced should be reimbursed at the average electricity price the facility would pay for its energy consumption. This money should be used as a fund for maintenance and repair and therefore be kept in a separate account. It is further recommended that a maintenance contract will be signed with the supplying and installing company. If reimbursement is not possible, another option could be that T&TEC provides funding for maintenance as part of their research and funding budget. This funding source could also be used for monitoring.

erators to feed electricity into the grid nor is self-generation or wheeling of electricity between power source and demand sink permitted.[2] The same accounts for the RIC Act (IADB 2011).

It will therefore be necessary to amend both acts accordingly and allow access to the grid, although the extent and scope should be controlled by T&TEC in line with the Regulated Industries Commission (RIC) and made dependent on capacity demand and technical circumstances. In addition, it is recommended to simplify the permission process for operators of small distributed generation and minimize the licensing procedure. A simple request for registration and control by the electrical inspectorate should be sufficient.

## Targets for RE

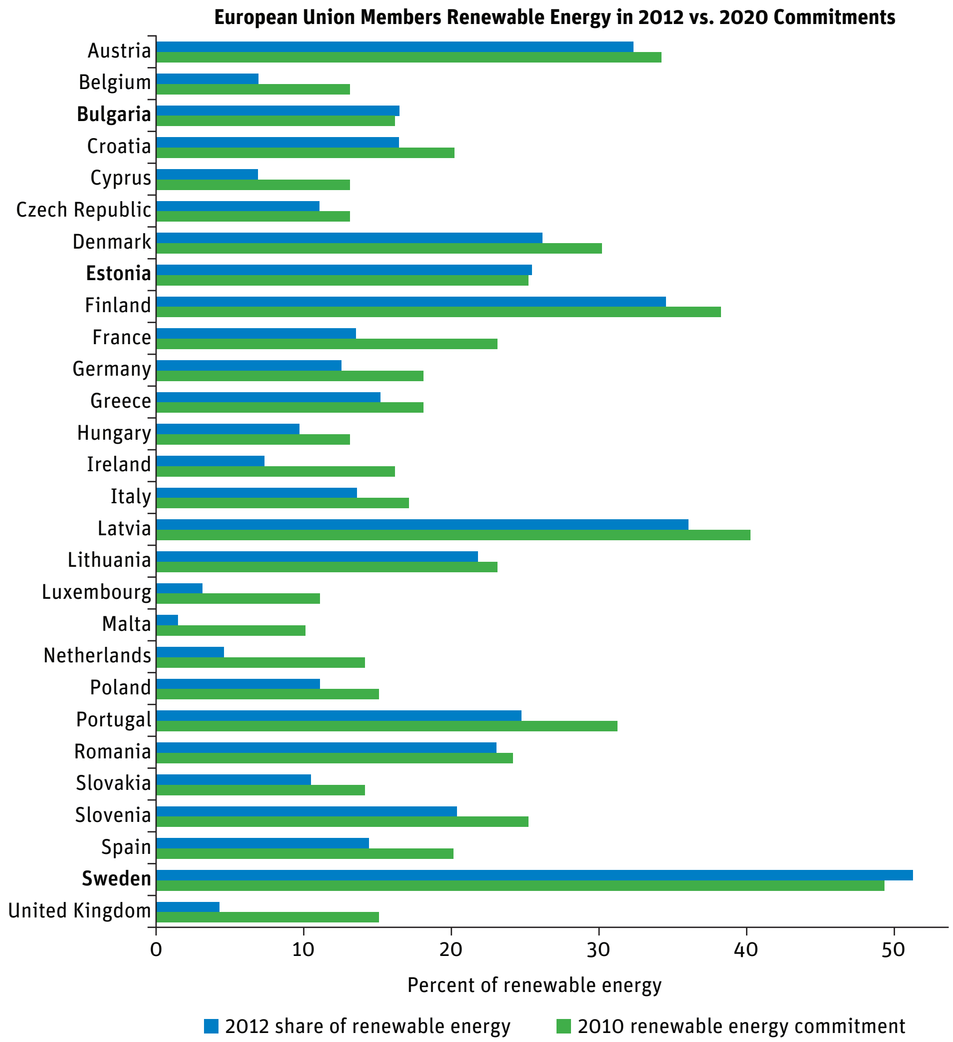
T&T has not yet established a politically approved and time-bound target (Renewable Portfolio Standard) for the contribution of renewable energies in the electricity generation and oth-

[2] Wheeling means the transport of electricity e.g. in case of industrial facilities which earn wind power at one site and use it at a different site by transporting electricity via the public grid on a payment basis.

er sectors, as has been done in other countries of the Caribbean and—in particular—in the member states of the European Union (see **Figure 16** for overall RE commitments). For instance, Grenada has officially declared that by 2020, 20% of all domestic energy usage for electricity and transport will originate from RE sources (GRENADA, 2011). Germany had already reached more than 25% of RE electricity contribution in 2013 and is bound to achieve at least 35% by 2020 and 80% by 2050, according to politically set binding targets.

**FIGURE 16**

Operational structure of T&TEC




*Source*: Renewable Solutions.

Renewables have accounted for an ever-growing share of electric capacity added worldwide each year. In 2012 they made up just over half of net additions to power generating capacity. By end of 2012, renewable electricity from non-hydro sources contributed 5.2% to global electricity generation, while 16.5% was provided from hydropower (REN21, 2013).

As in the field of renewable energies it would also be beneficial to express clear quantitative objectives for lowering energy intensity, either on a global scale (e.g. electricity consumption per GDP) or sector-wise. Setting RE targets alone will not assist in moving energy generation and consumption towards greater sustainability and security.

Setting clear and achievable RE and EE targets is an essential requirement for striving towards a less carbon-dependent economy. They will determine what policies are necessary to reach the objectives. A permanent observation and monitoring of the achievement level will point to adjustments required if goals may not be met in the remaining time period.

So far, the Government of Trinidad and Tobago in its draft Green Paper has only expressed a goal of generating 6% of the present peak electricity demand (i.e. 60 MW) from RE sources (mainly wind) by 2020. Underlying a capacity factor of about 35%, this would result in a contribution of about 1.5% to total projected gross electricity production in 2020, if wind is the prevailing energy source.[3] At the same time the CARICOM has published regional targets aiming for 20% of renewable power capacity in 2017, 28 percent by 2022, and 47 percent by 2027. (C-SERMS 2013) Under the current scenario, it is very challenging that T&T would be able to reach these targets and would be able to meaningfully contribute without developing more ambitious RE targets.

The consultants therefore strongly suggest raising the target to at least a contribution of 4% in electricity consumption projected by 2020 in order to create sufficient market size that will reciprocally lead to lower specific costs and strengthen experience in new business sectors. By 2030, a target of 15% RE share in electricity consumption could be reasonably achieved, mainly based on a mix of wind and solar power. With a lower consumption increase between 2020 and 2030 of 3%/a, mainly due to enforced efficiency measures, annual electricity generation would result in 17.5 TWh by 2030, with 2.6 TWh coming from renewable energy sources. This in turn will lower the $CO_2$ emissions in the power sector from the baseline scenario by about 1 Mt, if the calculation is based on the emission factor as estimated for 2020, while total $CO_2$ emissions would be in the range of 6.8 Mt. It needs to be said that a policy of improved fossil fuel power plants is not sufficient in the longer run to keep $CO_2$ emission within acceptable levels. Only in combination with a substantial share of RE contribution, a significant increase of $CO_2$ emissions can be prevented in the future.

[3] Obviously the contribution would be higher if electricity consumption growth could be curbed.

One way of enforcing such a legally binding RE target is by mandating T&TEC to either generate (through its subsidiary PowerGen) sufficient RE or purchase the balance from external generators. Those external generators could be the established larger Independent Power Producers or small private, commercial and industrial operators selling (excess) renewable electricity to the grid. Giving T&TEC the main responsibility for implementation of the target provides the advantage that the most cost-efficient solutions could gain priority. It will certainly be larger wind farms that can generate electricity at competitive costs with new gas-based power plants, if natural gas would be sold to T&TEC at regular non-subsidized costs. Next in line would be larger solar power plants which are rapidly gaining economic ground against all other forms of electricity generation. In order to allow for private (and in particular small) operators to set up and run grid-connected RE systems, several amendments have to be made to the current regulatory framework.

## 4.3 Input to the Green Paper

Based on a specific request by the Ministry of Energy and Energy Affairs (MEEA), the Consultants prepared a review of chapter 6 “Efficient Use of Energy Resources” of the Draft of the Green Paper for Energy Policy. The Green Paper has been developed in a participatory process throughout the last year and is now ready to be presented to cabinet. The Consultants have analyzed the sub chapter on EE and provide a number of recommendations to strengthen EE as part of the Green Paper and to be able to use the existing potential for EE in the country.

The proposal made by the consultants has been integrated into the Green Paper Draft that is currently awaiting approval of the Honorable Minister.

## 4.4 Electricity Tariffs and Subsidy Schemes

### Tariff Schedule

As shown in **Table 9**, the current electricity tariff schedule in T&T is as follows:

The electricity rates are categorized into five classes of customers:

- **Residential** (A): Residential customers
- **Commercial** (B, B1): Non-residential customers with a maximum demand not exceeding 350 kVA
- **Industrial**:

**Table 9 Electricity Rates in T&T**

| Category | Tariff | Frequency of Billing | Customer charge (fixed) | Energy Charge (cents/kWh) | | | Demand charge ($/kVA) |
|---|---|---|---|---|---|---|---|
| | | | | 1–400kWh | 401–1,000kWh | Over 1,000kWh | |
| **Residential** | **A** | Bi-monthly | $6.00 | 26.00 | 32.00 | 37.00 | n/a |
| **Commercial** | **B** (General) | Bi-monthly | $25.00 | | 41.50 | | n/a |
| | **B1** (min. 5,000kWh/month) | Monthly | n/a | | 61.00 | | n/a |
| **Industrial** | **D1** (Small Industrial) | Monthly | n/a | | 19.90 | | 50.00 |
| | **D2** (Medium Industrial) | Monthly | n/a | | 21.80 | | 50.00 |
| | **D3** (Large Industrial) | Monthly | n/a | | 18.30 | | 42.50 |
| | **D4** (Large Industrial) | Monthly | n/a | | 16.70 | | 40.00 |
| | **D5** (Large Industrial - Standby) | Monthly | n/a | | 16.00 | | 37.00 |
| | **E1** (Very Large Load) | Monthly | n/a | | 14.50 | | 44.50 |
| | **E2** (Very Large Load) | Monthly | n/a | | 14.50 | | 44.00 |
| | **E3** (Very Large Industrial) | Monthly | n/a | | 14.50 | | 43.00 |
| | **E4** (Very Large Industrial) | Monthly | n/a | | 14.50 | | 42.00 |
| | **E5** (Very Large Industrial) | Monthly | n/a | | 14.50 | | 41.00 |
| **Street Lighting** | **S1-1** | Annually | n/a | | 848.72 | | n/a |
| | **S1-2** | Annually | n/a | | 565.81 | | n/a |
| | **S1-3** | Annually | n/a | | 411.5 | | n/a |
| | **S1-4** | Annually | n/a | | 372.92 | | n/a |
| | **S2-2** | Annually | n/a | | 450.08 | | n/a |
| | **S2-3** | Annually | n/a | | 347.2 | | n/a |
| | **S2-4** | Annually | n/a | | 282.91 | | n/a |

*Source*: data extracted from (T&TEC, 2009).
effective 1st September 2009.
figures are stated in TT$.
all charges are subject to 15% Value Added Tax.

  - Light Industrial (D1, D2): Small and medium industrial customers with a demand of up to 350kVA and 4,000kVA, respectively
  - Heavy Industrial (D3–E5): Large and very large industrial customers with load demands ranging from over 4,000 kVA (D3) to over 25,000kVA (E5)
- **Street Lighting**: for street, highway and safety lighting of thoroughfares, bridges, parks and other approved locations.

The tariffs are composed of three main components, not all of which, however, apply to all the above mentioned rate categories:

- **Customer charge**: this is a fixed charge for metering and administration only applicable to residential (tariff A) and small commercial customers (tariff B) and ranging from TT$ 6 (A) to TT$ 25 (B)
- **Energy rate**: this is a usage charge (per kWh) which applies across all tariffs; there is a three-tiered system for residential customers for different consumption levels (below 400 kWh, as well as below and above 1,000 kWh); overall, the tariff system is of a progressive nature, i.e. the average kWh cost increases in line with rising consumption.
- **Demand charge**: this is a maximum demand charge that only applies to light and heavy industry customers (tariffs D1–E5); it is a monthly charge per maximum kVA ranging from TT$ 37–TT$ 50.

As for projections related to the future of the electricity tariffs, the following factors are taken into account in this context:

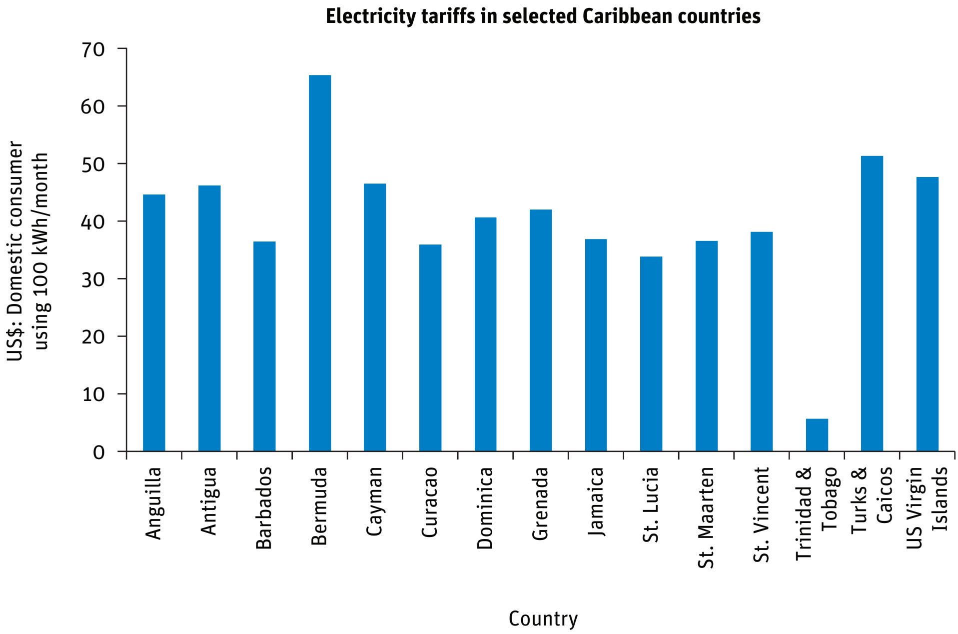
Firstly, electricity customers in T&T enjoy very low tariffs in comparison to other Caribbean countries—as shown in **Figure 17**.

Secondly, T&TEC is facing a difficult financial situation—for various reasons, including, but not limited, to the following ones (T&TEC, 2011):

- As a consequence of T&TEC not benefitting from a tariff adjustment between 1992 and 2006 (across all customer classes, with the exception of 18 of the largest industrial customers in T&T), T&TEC was operating with uneconomic electricity rates throughout the majority of these 14 years.
- There was at least one case where the actual implementation of new and RIC-approved tariffs was delayed in the past (e.g. November 2006 for commercial and industrial customers and May 2008 for residential customers). This in turn contributed to T&TEC revenue losses.
- T&TEC expenditures related to the Cove and TGU power plants were not included in the RIC approved 2006–2011 tariff adjustments, however, T&TEC is facing real costs from these expenditures.

**FIGURE 17**

Electricity Tariffs in Selected Caribbean Countries




Own graph; Source: CARILEC, 2012.

- T&TEC expenditures associated with operations/purchase of power from power stations, ageing infrastructure, future wage and salary increases, annual increases in fuel prices, as well as challenging return on rate base are considerable and need to be addressed.

Overall, there are three main possibilities to counteract T&TEC's upward cost pressures: rising electricity tariffs to an adequate level, reducing T&TEC investments in capital projects, or financing of any revenue shortfall by GoRTT.

Any projection related to potential future levels of electricity tariffs, therefore, largely depends on the political response to the challenging financial situation of T&TEC.

In this context, **Table 10** shows the T&TEC proposed electricity tariffs 2011–2016 which would result in a tariff increase across all classes, with some of them increasing by up to 30.8% by 2016.

## 4.5 Adaptation of criteria for using the Green Fund

In 2000, the GoRTT established the Green Fund as the national environmental fund.[4] The fund's grant facility is available to community groups and organizations engaged in activities focusing on remediation, reforestation or conservation of the environment. The fund is capitalized by a tax of 0.1% on the gross sales or receipts of companies carrying on business in T&T. Ten years on, the fund is very well endowed, but only a handful of projects have been financed and none with an EE focus. It is our recommendation that the GoRTT and the fund managers[5] review the aims, objectives and operating parameters of the fund to optimize it to include the ability to support viable EE and RE projects. Currently the Green Fund is only eligible for community groups, non-governmental organizations and non-profit companies or bodies engaged in activities related to the objectives of the Green Fund. Given the situation that the Fund has substantial problems in receiving acceptable proposals and has collected a large amount of funding capital it is advised that consideration be given to an extension of the scope of financing, in particular in such cases where private capital could be raised with additional public support.

## 4.6 Financing of SEP projects

Important for the financing of RE projects with relatively high initial capital costs and long payback periods is a stable and secure political framework with limited risks and clear market perspectives. Any potentially negative impact on the expected financial output of projects, such as uncalculated downward variations in tariffs for electricity supplied to the national grid or unannounced new taxes, will increase the risk level and raise interest rates on credit lines. High financing costs can create a substantial barrier for any RE project in developing countries with limited experiences of commercial banks.

Within specific programmes or based on bilateral agreements, international financing institutions[6] offer soft loans for specific purposes, which are usually channelled through national development banks (IRENA, 2012; UNEP, 2014). Other sources of financing could be attracted through sales of carbon credits within the Clean Development Mechanisms (CDM) in

[4] More information on the fund is available at http://www.mphe.gov.tt/agenciesdivisions/gf.html.
[5] The Green Fund Executing Unit, a division within the Ministry of Housing and the Environment.
[6] Such as KfW (Germany), European Investment Bank (EIB), World Bank Group, Inter-American Development Bank (IDB), Caribbean Development Bank. KfW alone made US$ 26 billion available for clean energy projects in 2012. In the same year, the 26 major development and export-import banks provided US$ 58.7 billion for renewable energy, with US$ 27.5 billion flowing into the wind energy sector and US$ 12.1 billion supporting the solar sector (BNEF, 2013).

**Table 10 Proposed Electricity Tariffs until 2016**

| | RIC Approved Rate 2009/10 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA |
| **Residential** | | | | | | | | | | | | | | |
| 0–400 kWh | 0.2600 | – | 0.2600 | – | 0.3302 | – | 0.3401 | – | 0.3401 | – | 0.3401 | – | 0.3401 | – |
| 401–1,000 kWh | 0.3200 | – | 0.3200 | – | 0.4064 | – | 0.4186 | – | 0.4186 | – | 0.4186 | – | 0.4186 | – |
| Over 1,000 kWh | 0.3700 | – | 0.3700 | – | 0.4699 | – | 0.4840 | – | 0.4840 | – | 0.4840 | – | 0.4840 | – |
| Customer Charge | 6.0000 | – | 6.0000 | – | 6.0000 | – | 6.0000 | – | 6.0000 | – | 6.0000 | – | 6.0000 | – |
| **Commercial** | | | | | | | | | | | | | | |
| B | 0.4150 | – | 0.4150 | – | 0.5271 | – | 0.5429 | – | 0.5429 | – | 0.5429 | – | 0.5429 | – |
| Customer Charge | 25.00 | – | 25.00 | – | 25.00 | – | 25.00 | – | 25.00 | – | 25.00 | – | 25.00 | – |
| **Industrial** | | | | | | | | | | | | | | |
| B1 | 0.61 | – | 0.6100 | – | 0.7747 | – | 0.7979 | – | 0.7979 | – | 0.7979 | – | 0.7979 | – |
| D1 | 0.20 | 50.00 | 0.1990 | 50.00 | 0.2527 | 53.00 | 0.2603 | 54.59 | 0.2603 | 54.59 | 0.2603 | 54.59 | 0.2603 | 54.59 |
| D2 | 0.22 | 50.00 | 0.2180 | 50.00 | 0.2769 | 53.00 | 0.2852 | 54.59 | 0.2852 | 54.59 | 0.2852 | 54.59 | 0.2852 | 54.59 |
| D3 | 0.18 | 42.50 | 0.1830 | 42.50 | 0.2324 | 53.98 | 0.2394 | 55.59 | 0.2394 | 55.59 | 0.2394 | 55.59 | 0.2394 | 55.59 |
| D4 | 0.17 | 40.00 | 0.1670 | 40.00 | 0.2121 | 50.80 | 0.2185 | 52.32 | 0.2185 | 52.32 | 0.2185 | 52.32 | 0.2185 | 52.32 |

(continued on next page)

**Table 10 Proposed Electricity Tariffs until 2016** *(continued)*

| | RIC Approved Rate 2009/10 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | | Proposed Rate 2011 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA | $/kWh | $/kWA |
| D5 | 0.16 | 37.00 | 0.1600 | 37.00 | 0.2032 | 46.99 | 0.2093 | 48.40 | 0.2093 | 48.40 | 0.2093 | 48.40 | 0.2093 | 48.40 |
| E1 | 0.15 | 44.50 | 0.1450 | 44.50 | 0.1842 | 56.52 | 0.1897 | 58.21 | 0.1897 | 58.21 | 0.1897 | 58.21 | 0.1897 | 58.21 |
| E2 | 0.15 | 44.00 | 0.1450 | 44.00 | 0.1842 | 55.88 | 0.1897 | 57.56 | 0.1897 | 57.56 | 0.1897 | 57.56 | 0.1897 | 57.56 |
| E3 | 0.15 | 43.00 | 0.1450 | 43.00 | 0.1842 | 54.61 | 0.1897 | 56.25 | 0.1897 | 56.25 | 0.1897 | 56.25 | 0.1897 | 56.25 |
| E4 | 0.15 | 42.00 | 0.1450 | 42.00 | 0.1842 | 53.34 | 0.1897 | 54.94 | 0.1897 | 54.94 | 0.1897 | 54.94 | 0.1897 | 54.94 |
| E5 | 0.15 | 41.00 | 0.1450 | 41.00 | 0.1842 | 52.07 | 0.1897 | 53.63 | 0.1897 | 53.63 | 0.1897 | 53.63 | 0.1897 | 53.63 |
| **Street Lighting (Annual Charge)** | | | | | | | | | | | | | | |
| S1-1 | 848.72 | – | 848.72 | – | 1,077.87 | – | 1,110.21 | – | 1,110.21 | – | 1,110.21 | – | 1,110.21 | – |
| S1-2 | 565.81 | – | 565.81 | – | 718.58 | – | 740.14 | – | 740.14 | – | 740.14 | – | 740.14 | – |
| S1-3 | 411.50 | – | 411.50 | – | 522.61 | – | 538.28 | – | 538.28 | – | 538.28 | – | 538.28 | – |
| S1-4 | 372.92 | – | 372.92 | – | 473.61 | – | 487.82 | – | 487.82 | – | 487.82 | – | 487.82 | – |
| S2-2 | 450.08 | – | 450.08 | – | 571.60 | – | 588.75 | – | 588.75 | – | 588.75 | – | 588.75 | – |
| S2-3 | 347.20 | – | 347.20 | – | 440.94 | – | 454.17 | – | 454.17 | – | 454.17 | – | 454.17 | – |
| S2-4 (all SL) | 282.91 | – | 282.91 | – | 359.30 | – | 370.07 | – | 370.07 | – | 370.07 | – | 370.07 | – |

*Source*: T&TEC, 2010.

large-scale RE projects, although the current low price level for such credits may not be sufficient to contribute significantly to project incomes.

Loans are never granted without security. Examples include the transfer of ownership of the plant, the transfer of rights from project contracts, pledging of the operator's account or pledging of shares in the business. Banks therefore often set requirements for the content of project contracts, or place stricter demand on the use of cash flow. In addition, they may require the quality of the installation to be inspected by external experts and will request at least two independent yield projections.

In order to keep costs as low as possible, clear guidelines and administrative procedures need to be established for all processes within the permission and preparation of projects. Unnecessary and overly bureaucratic requests should be avoided in order to minimize transaction costs and reduce the time for project realization. This concerns issues such as environmental impact assessments, application requirements for generation licensing and grid connections, construction permissions, technical requirements and inspections, contractual arrangements for payment schedules, etc. Experiences are widespread in other countries, so that replication of good examples can be easily done.

## 4.7 Needs for capacity building and institutional strengthening

It is considered that T&T has the human capital resources and the required base of educational and technical facilities (pre-college schools, technical colleges and universities) necessary for the development of a sustainable energy economy.[7] The requirement at this time is for the country's human and institutional resources to be organized into effective structures that allow the efficient utilization of the resources, as well as the provision of specific and relevant capacity building measures for further development.

The staff at the MEEA is and has been undertaking various capacity building measures (nationally and internationally) throughout the course of the last years. Some of the capacity building measures that stand out are:

- Sustainable Energy Policy and Technology—Training seminar for Latin America and the Caribbean (LAC)
- OLADE's Executive Development Programme on Energy Planning (EDPEP)

[7] For example, T&T is ranked 71st in higher education and training, out of 144 economies surveyed by the World Economic Forum in its *Global Competitiveness Report 2012–2013*.

- Training on Innovative fiscal and regulatory incentives for Energy Efficiency and Renewable Energy initiatives
- International Training Programme on Solar Energy Technologies and Applications at the Solar Energy Centre in India
- Seminar on Clean Energy Application and Climate Change for Developing Countries, China
- Regional Workshop of Capacity Building and Sharing Lessons in the development of Nationally Appropriate Mitigation Actions (NAMAs)
- Regional Designated National Authority (DNA) Training and Clean Development Mechanism (CDM)Workshop
- Regional Renewable Energy Financing Workshop and RETSCREEN Training

At the same time the consultants have prepared and implemented a range of training courses throughout the course of the consultancy. Training courses included:

- A workshop and training on the potential for biomass and bioenergy in T&T
- A workshop and training on the concepts, technical background and potential for Waste to Energy
- A workshop and training on Solar Water Heater, their technical specifications, as well as the potential in T&T
- A workshop for energy auditors on how to do energy audits in public buildings, as well as a one on one coaching of audit firms.

Capacity building and measures were dedicated to the MEEA, as well as other relevant stakeholders in T&T.

As can be seen, the MEEA is thriving towards continuous learning of its staff and provides them with the possibility to undertake renowned capacity building and training measures to be able to move towards more sustainable energy in T&T. However, the existing team is relatively small and has to fulfill an enormous amount of tasks. Further institutional strengthening, as well as a reorganization of activities, such as through outsourcing of a range of activities to a dedicated energy agency is therefore recommended.

5

# Energy Efficiency

## 5.1 Energy Efficiency Potential

It is widely accepted, based on international experience, that EE is one of the least-cost ways of satisfying growing demand for energy–related services (WB, 2011). In relation to T&T, a 2008 report by the Inter-American Development Bank's Sustainable Energy and Climate Change Initiative (IDB, 2008) provides an initial estimate of the overall EE opportunity, advising that

> "*If Trinidad and Tobago were to improve its Energy Efficiency by 10% over the next 10 years, it would save the equivalent of 980 GWh of electricity per year by 2018. The cost of achieving that level of efficiency by various measures would amount to around US 115 million over this period (in 2008 dollars)*". (MEEA, 2011)

The report advises that the alternative scenario—commissioning the equivalent of two gas-powered open cycle generation plants to produce the same 980 GWh of electricity per year—would, at 2008 prices, cost approximately US$ 365 million just to build, not counting operational and fuel costs. In short, it is suggested that EE is the quickest, cheapest and cleanest way to extend the country's energy supplies.

No detailed, comprehensive study has been made of the EE potential in T&T, but the MEEA (MEEA) is aware of the general opportunities. On the supply side, the Ministry cites aging power sector facilities which need to be upgraded and notes that the "*majority of existing power plants are simple-cycle with low conversion efficiency*" (see chapter 3.4).

On the demand side, several factors are noted by the MEEA, including the situation that "*current pricing of electricity is low for residential and commercial customers and this has led to inefficiency in the use of electricity*" (MEEA, 2011).

In principle, large firms that are highly energy-intensive tend to have a direct financial incentive (i.e.: continuous bottom line improvement) to improve EE and it is clear from our discussions with the stakeholders that the largest industrial operations in the country have recently become engaged in ensuring operational EE, for internal financial and international business reasons.

Part of the impetus for this was a 2011 EE study conducted on behalf of the National Energy Corporation (NEC) for the Point Lisa Industrial Estate (CBCL, 2011), which concluded that total energy use in the industrial sector could be reduced by 15% by 2023 if best practices were implemented. Based on walk-through audits in ammonia, methanol and iron & steel production facilities at Point Lisas, opportunities were identified for EE investments of over US$ 13 million, which would deliver annual savings of over US$ 2.8 million with a simple payback period of less than six years.

We consider that this study has adequately set the parameters for EE strategies and recommendations for the large industrial sector and therefore our review does not consider the technical issues, options or specific recommendations for this consumption sector.

## Which Technologies have Potential?

**Table 11** lists relevant EE technologies and provides an estimation of their sector of application, their technical EE potential, and their current rate of uptake (low, medium, high) in each sector.

The table shows that even though the potential for EE technologies to deliver energy savings (technical EE potential) is high, the actual uptake is non-existent or low in most cases and high in none. It additionally provides an overview on the availability of technologies in Trinidad and Tobago. The only technologies currently not imported to T&T are LED lamps and LED street lights.

## The Viability of Energy-saving Technologies

T&T presents the unique case in the Caribbean where energy consumption is high across the board but, because of energy price subsidies and low retail energy prices, the business case for EE investments is low. As indicated above, there are several established EE technologies that are relevant to the provision of the energy services: lighting, cooling, ventilation and mechanical work to end users. In the T&T market some are financially and economically viable, others are not. For example, the financial viability of a technology such as LED street lighting is poor at best, since the very high cost of the necessary investment will take too long to be recovered out of energy cost savings; even if the energy (kWh) savings are significant, the tariff rate per kWh is so low that the cost savings are marginal.[1]

[1] See Appendix 8.3.D, which summarizes the results of a comprehensive street lighting replacement study carried out in Portland Oregon.

**Table 11** EE Technologies and their uptake

| EE Type | Description | Potential sector of application | Technical EE Potential | Estimated uptake | Import status |
|---|---|---|---|---|---|
| CFL lamps | Small fluorescent lamps with electronic ballast in base, designed to replace regular incandescent lamps and provide the same light output for one-fifth to one-third the electricity consumption, with an average lifetime 8 times longer. | Residential<br>Commercial | High<br>High | Low/<br>Medium<br>Low | Already being imported |
| T8 fluorescent lamps with electronic ballast | Slim, 1” diameter efficient fluorescent tube that operates using electronic ballasts as well as the traditional magnetic ballast. | Residential<br>Commercial<br>Small Industrial<br>Public Sector | Med-High<br>Med-High<br>Med-High<br>Med-High | Low<br>Low-Medium<br>Low-Medium<br>Low | Already being imported |
| T5 fluorescent lamps (electronic ballast) | Slim, 5/8” dia. efficient fluorescent tube that operates with electronic ballast. More efficient but significantly higher investment cost than T8 tube. | Commercial<br>Small Industrial<br>Public Sector | High<br>High<br>High | Low<br>Low<br>Low | Already being imported |
| LED lamps | Highly efficient lighting based on light-emitting diode (LED) technology. Very high investment cost. | Residential<br>Commercial<br>Small Industrial<br>Public Sector | High<br>High<br>High<br>High | None<br>None<br>None<br>None | Not imported |
| LED street lamps | Street lighting that utilizes highly-efficient LED lamps for illumination. Very low energy usage, but very high cost of installation. | Public sector | High | None | Not imported |
| Variable-frequency drives | Electronic controller for AC motors that allow the speed and power (and hence the energy consumption) of the motor to be varied to suit the motor’s load. | Commercial<br>Small Industrial | Med-High<br>Med-High<br>High | Low<br>Low<br>Low-Medium | Already being imported |
| High-efficiency air-conditioning units | Room air-conditioning units with an EE ratio (EER) of 10 or more. The EER is the ratio of the cooling capacity (in Btu per hour) to the power input (in watts) | Residential<br>Commercial | High<br>High | Low<br>Low | Already being imported |

(*continued on next page*)

**Table 11 EE Technologies and their uptake** *(continued)*

| EE Type | Description | Potential sector of application | Technical EE Potential | Estimated uptake | Import status |
|---|---|---|---|---|---|
| High-efficiency commercial and industrial scale chiller units | High-capacity cooling units with efficient compressors employing variable-frequency drives, or absorption chillers utilizing waste heat. | Commercial<br>Industrial<br>Public Sector | High<br>High<br>High | Low<br>Low<br>Low | Already being imported |
| High-efficiency, domestic appliances and consumer electronic devices | Appliances and consumer electronic devices achieving Energy Star or similar rating for EE. | Residential<br>Commercial | Med | Low | Already being imported |

*Source*: Own elaboration.

The chart in **Figure 18**, from McKinsey & Company (MCKINSEY, 2009), provides a general starting point for assessment of viability. It shows an estimated EE supply curve for the US economy, depicting the range of EE measures from the lowest to highest cost to implement, per unit of energy saved, over the lifetime of the measure. Though the values in the chart are not specific to T&T, the relevant point is to identify the residential and commercial EE technologies in the low-cost range of the spectrum. From the chart we see that the "price for EE" of efficient refrigerators, electrical devices, electric motors, air-conditioners and lighting are all well below the forecasted weighted average price of energy across all fuel types in 2020 (the dotted horizontal line at US$ 13.80 per MMBTU, equal to US$ct 4.7 per kWh). In general, the chart indicates that these low-cost EE opportunities represent a viable way to provide for future energy requirements.

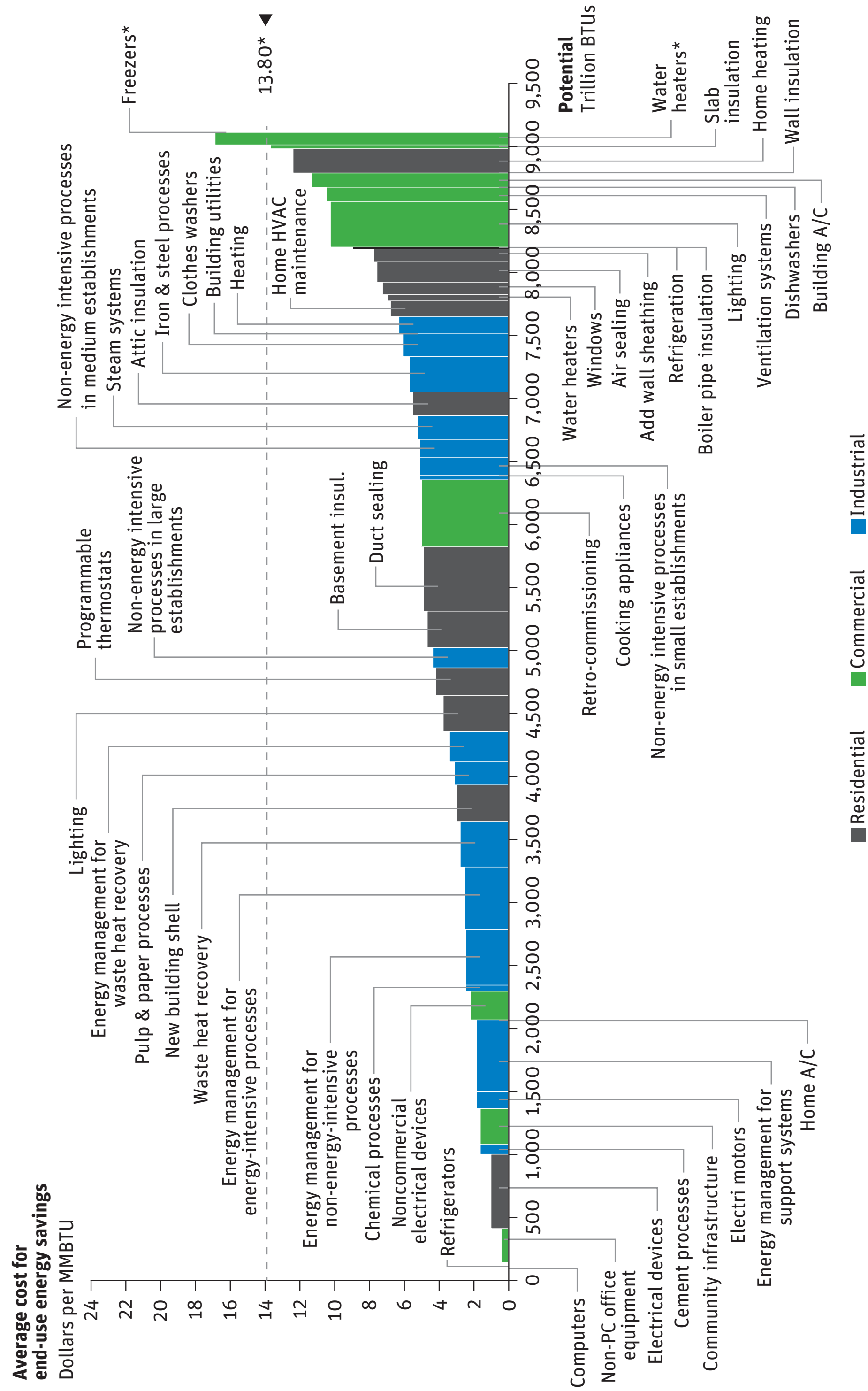
The chart also indicates something else to note: the x-axis of the chart shows the estimated total potential savings opportunity if all viable EE measures in the USA are implemented, with the width of each bar showing the amount of potential savings in that group of measures. So the complexity of the EE option is also demonstrated: no single group of measures accounts for more than about 12% of the total savings potential—there is no magic bullet for EE and a variety of measures need to be taken to generate meaningful impact.

To provide an interpretation of the chart allowing for local conditions: it is likely that in T&T the costs to implement the various measures will be at the high end of the ranges shown here, due to the addition of import-related transaction costs.[2] In relation to the forecast price of en-

[2] For example, the cost to save a kWh of electricity by installing CFL bulbs in T&T is estimated in Appendix C: Methodology. to be US$ct 1.2 per kWh, or US$ 3.56 per MMBTU, which is at the upper end of the range of the McKinsey estimated cost of energy savings for residential lighting.

**FIGURE 18**

US EE Supply Curve – 2020 (from McKinsey)




*Source*: MCKINSEY, 2009

ergy in 2020: although T&T's energy mix is dominated by natural gas compared to the costlier, predominantly coal-based mix in the USA, it is likely that the comparable local cost of energy in 2020 could be similar to the forecast shown here. T&TEC has proposed increases of 26% to 33% in its tariffs to 2016 (T&TEC, 2011). If (as is done in the chart), the average price of avoided energy consumption at the industrial price is considered, the proposed 2016 cost of electricity is TT$ct 26.9 per kWh (US$ct 4.2 per kWh or US$ 12.32 per MMBTU). If the T&TEC proposals are accepted by the regulator, and if Government progressively removes subsidies on the supply of natural gas to the power industry and on other fuel types through 2020, the reference price could be even higher.

## How is Uptake to be encouraged?

The appetite for EE technologies and practices in T&T is assessed to be low. The most important reason for this is the very low price of energy. For example, the hotel sector organizations (the *Tourism Development Company – TDC* and the *Trinidad Hotels, Restaurants & Tourism Association – THRTA*) acknowledge that, because energy costs relative to total operating costs are so low, they collect no data on their members' energy consumption. The same admission is made by the *Trinidad and Tobago Chamber of Commerce* and the *Trinidad and Tobago Manufacturers Association.*[3] Whereas energy costs in other Caribbean countries affect the regional and international competitiveness of their tourism and manufacturing sectors, this is not the case in T&T. Given this fact, we can conclude that the performance of energy audits, for example, is not a high priority for managers in the tourism and the (non-energy-intensive) manufacturing sectors.[4]

Another reason cited is low knowledge and awareness. An energy awareness survey (MEEA, 2012 c) carried out by the MEEA produced some interesting results that indicated low public awareness about energy. For example, according to the survey, only 43% of the respondents knew that their electricity was supplied by T&TEC.[5]

Limited access to financing is often listed as a barrier to the uptake of EE, but it is not likely to be a factor of major importance in this case. If there is low demand for implementing EE projects to begin with, there will be little demand for financing to do so. However, given that

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[3] Meetings held with these and other stakeholders, Sept 17th – 19th 2012 at the MEEA offices.

[4] Mr Andre Escalante, owner and CEO of Energy Dynamics Ltd, corroborates this view especially in relation to the performance of energy audits.

[5] The question asked was: *How does the energy that powers your electrical appliances get to you?* Answer choices were: a) *T&TEC/ Power lines from T&TEC*; b) *The Sun*; c) *Underground*. Only 43% of respondents chose the correct answer. Total number of respondents: 539. No age information was requested from respondents.

the GoRTT intends to increase the demand for EE investments, then mechanisms for financing these investments must be made available and these are considered below.

In terms of policy-setting, uptake of EE technologies will be influenced by the specific mix of and interaction between information provided, incentives set and regulations imposed by the authorities.

Information is a critical factor. If consumers do not have specific knowledge about the energy options available, they cannot make informed choices and decisions about energy use. Once information is available, incentives encourage desirable action and the case of residential light bulb replacement programmes is a classic example. Certainly from an EE perspective, it is desirable for all households to use CFLs instead of incandescent bulbs, as this will reduce national energy consumption, carbon emissions etc. Households who do so will save money over the lifetime of the CFL bulbs, with a quick return on their investment. However, the domestic sector in T&T enjoys very low energy prices and probably sees no pressing need to invest even small sums of money to take action to reduce energy costs that are already low. In such an event, specific incentives need to be applied, to encourage the desired result of reducing the use of incandescent bulbs. And in the event that incentives will not achieve the desired result, then regulations—the use of laws and rules—must be brought to bear. In this case, the GoRTT may choose to phase out the importation and sale of incandescent bulbs.

## A note on Behavior

An underrated factor in the EE equation is the aspect of consumer behaviour. Some studies of residential energy consumption have concluded that the energy consumer's behaviour is a "*potentially enormous source of energy savings*" (SHIPEE, 1980) yet it is hardly mentioned in analyses of EE potentials. As noted above, information is critical to the mission of reducing energy consumption, but it has been demonstrated (DARBY, 2006) that information, on its own, is not sufficient to change behaviour and must be accompanied by other motivating factors such as feedback, goal-setting and social proof (SAMUEL, 2009).

The conclusion is that standard education and public-awareness approaches will increase knowledge, but will not necessarily generate significant action towards the desired outcomes, and attempts must be made to engage and motivate consumers, by providing additional behavioural factors. In this regard, it is notable that T&TEC is already considering converting from bi-monthly to monthly billing for residential and commercial customers (T&TEC, 2011). We recommend that T&TEC should be encouraged to do so, as this will help consumers to get a better sense of the connection between personal behaviour and their household energy consumption and will go hand in hand with any national customer engagement programmes.

## 5.2 Proposed EE Programmes

### Residential Sector

*Overview and estimates of baseline consumption*

The residential sector in T&T is fully electrified and consumes approximately 29% of total electricity used. (T&TEC, 2010) Average daily consumption per household is high by Caribbean standards: 16.6 kWh per day (T&TEC, 2010), almost double the 8.5 kWh per day average in Barbados (LHP, 2011), though the average household size in T&T is only 19% greater than in Barbados.[6] Personal incomes are high in T&T, but similarly in Barbados, which also has a comparable per capita GDP and standard of living.

We make two estimates for baseline residential electricity consumption in T&T. The first is for the 'average' household, i.e.: the household with a consumption calculated simply by dividing total residential sales by the total number of residential customers; this estimate is shown in **Table 12**.

The second estimate is for households that use air-conditioning (which would be in a higher consumption range than the average). This estimate is shown in **Table 13**. Detailed information on these estimates is available in **Appendix C**: Methodology for Residential Baseline and Savings Estimates.

**Table 12 Average Household Electricity Consumption, 2010**

| Residential Electricity End Use | Bi-monthly Consumption, kWh | % |
|---|---|---|
| Lighting | 89 | 10 |
| Water Heating & Pumping | 164 | 18 |
| Cooking | 87 | 9 |
| Refrigeration | 175 | 19 |
| Laundry | 36 | 4 |
| Cooling & Ventilation | 141 | 15 |
| Appliances (entertainment & personal) | 225 | 24 |
| **Total** | **917** | **100** |

*Source*: Own elaboration.

[6] Data from year 2000 census reports for T&T, Barbados indicate average household sizes of 3.7 persons in T&T and 3.1 in Barbados.

**Table 13 Household Electricity Consumption with Air-conditioning, 2010**

| Residential Electricity End Use | Bi-monthly Consumption, kWh | % |
|---|---|---|
| Lighting | 120 | 4 |
| Water Heating & Pumping | 1,302 | 42 |
| Cooking | 87 | 3 |
| Refrigeration | 329 | 11 |
| Laundry | 254 | 8 |
| Cooling and Ventilation (A/C) | 727 | 24 |
| Appliances (entertainment & personal) | 267 | 9 |
| **Total** | **3,086** | **100** |

*Source*: Own elaboration.

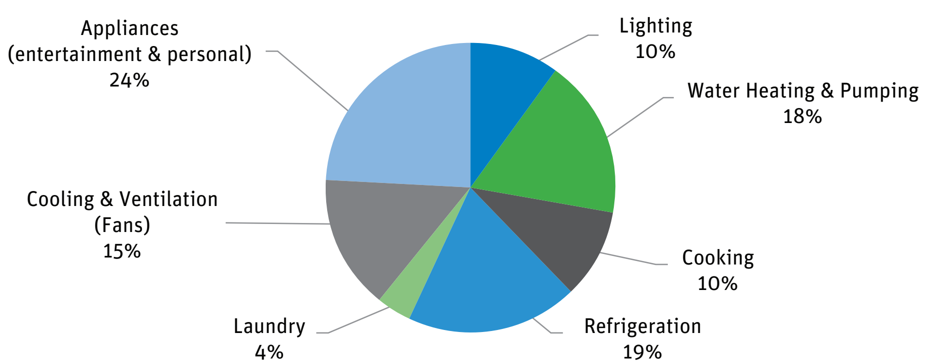
These estimates are illustrated in **Figure 19** and **Figure 20**.

### *Proposed EE Interventions*

The fundamental reason for T&T's high household electricity consumption is the low cost of electricity, but surveys conducted by the MEEA also indicate that public understanding of energy, where it comes from and how it translates into the provision of daily energy services is low. The above suggests that there are significant opportunities for reducing personal energy consumption, without adverse effects on lifestyle. Or to put it another way: low energy

**FIGURE 19**

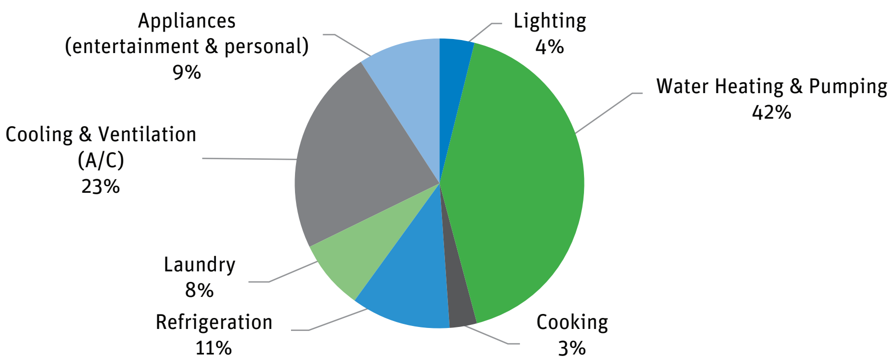
Average Household Electricity Consumption, 2010




*Source*: Own elaboration for Average Household Electricity Consumption, 2010.

**FIGURE 20**

Household Electricity Consumption with air-conditioning, 2010




*Source*: Own elaboration for Average Household Electricity Consumption, 2010.

cost and low public energy literacy are likely to result in high levels of energy wastage. With this in mind, the MEEA has already began a specific awareness, education and communications programme directed at the general public, marked by the launch of its RE/EE Campaign in September 2012. It is proposed below to extend these activities.

The government's social housing unit, the Housing Development Corporation (HDC) is mandated to make 6,500 housing starts per year for sale to eligible, low-income citizens. Information[7] supplied by the HDC shows that the HDC delivered 53% of that target in 2012, with plans for the delivery of approximately 3,200 new units per year through 2015.

HDC homes are supplied without appliances or light bulbs and it is likely that the eventual occupants simply buy the least expensive incandescent bulbs.[8]

To support the GoRTT in using social housing as an entry point for the provision of more energy efficient housing in T&T, the Consultants have developed a GEF Project Information Form (PIF) that is currently being reviewed by the GEF. This could potentially become a GEF supported project, enhancing the sustainability of the social housing sector in T&T.

[7] HDC: Responses to the request for support to the application for funds under the GEF-5 Trust Fund. HDC, 30 July, 2013

[8] An average of prices from three retailers in Port of Spain reveals that a 15-watt CFL costs almost six times as much as a 60-watt incandescent bulb.

**Table 14 Proposed EE programmes in the residential sector**

| Programme of measures | Type of Policy Intervention | | |
|---|---|---|---|
| | **Information** | **Incentive** | **Regulation** |
| To reduce the use of tank- and other types of electric water heaters (note this is related to increasing use of SWH covered elsewhere). | Implement an information programme on the benefits of solar water heating, energy-efficient lighting and appliances. | Progressively increase import duties on tank water heaters over the next 3 years. | |
| To encourage the use of efficient appliances. | Implement an information programme on the benefits of energy-efficient lighting and appliances (already started with the Awareness Campaign).<br>Develop and implement an appliance energy labelling programme. | Tax deduction of up to US$500 for performance of residential energy audits.<br>Tax deduction of up to US$5,000 for the purchase of approved 'environmentally friendly' products (such as solar water heaters, energy-efficient air-conditioners and appliances, etc.)<br>Provide incentives to appliance retailers to encourage trade-ins of old, inefficient appliances for more efficient models. This incentive could initially be targeted at lower-income households. | Certification of energy auditors.<br>Adoption of appropriate appliance & equipment standards.<br>Require energy labels to be displayed on all appliances offered for sale.<br>Progressively increase import duties and taxes on and phase out the use of inefficient appliances, particularly a/c units, over the next 5 years. |
| To encourage the use of efficient lighting. | Implement an information programme on the benefits of energy-efficient lighting and appliances (in progress). | Remove all import duties on all categories of energy efficient light bulbs, tubes and ballast fittings. | Adoption of appropriate standards.<br>Progressively increase import duties on and phase out the use of incandescent bulbs over the next 5 years. |
| To effect energy savings in social housing. | Implement an information programme to sensitize HDC owners of the benefits of energy-efficient lighting and appliances. | Pre-install 11 to 15W CFL bulbs in HDC housing units. | NR |

(*continued on next page*)

**Table 14 Proposed EE programmes in the residential sector** (*continued*)

| Programme of measures | Type of Policy Intervention | | |
|---|---|---|---|
| | Information | Incentive | Regulation |
| To engage & motivate consumers to adopt no-cost behaviours to reduce energy use. | Design and implement a programme to engage and motivate consumers to change their energy consumption behaviours. | T&TEC to be encouraged to move to monthly billing of residential and commercial customers. | NR |

*Source*: Own elaboration.
*Note*: NR = None Recommended.

The Trinidad and Tobago Bureau of Standards (TTBS) is already engaged with the exercise of determining the appropriate EE standards for lighting and appliances; though no national standards for these items have yet been published. No activities related to EE labelling of appliances are taking place in T&T, and there is no specific programme aimed at encouraging purchases of energy-efficient (*Energy Star* or equivalent) appliances. However, through the light bulb exchange program, Energy Efficient lighting and appliances are encouraged.

Based on the above, we recommend **four residential EE programmes** aimed at:

- Reducing the use of electricity for water heating;
- Encouraging the use of energy-efficient appliances and lighting;
- Reducing energy consumption in the social housing sector;
- Engaging and motivating consumers to adopt no-cost, durable energy savings behaviours.

### *Estimated Energy Savings Potential*

Our preliminary estimates of the annual savings potential in the residential sector are shown in **Table 15**.

The above estimate of potential savings amounts to 20% of total residential electricity consumption in 2010. These estimates are based on estimates and assumptions detailed in **Appendix C**: Methodology for Residential Baseline and Savings Estimates.

The nominal annual savings potential in the residential sector has been estimated, but it is recognized that the actual rate of uptake by the public, of new EE interventions, does not start at 100%; actual uptake (and therefore savings impact) in the first year will be small and will

**Table 15** **Estimated residential sector savings from replacement of baseline technologies with energy-efficient technologies**

| Residential | Estimated Annual Savings Potential | | | % Share of Total Savings |
|---|---|---|---|---|
| | MWh | '000 TT$ | '000 US$ | |
| Lighting | 151,960 | 46,682 | 7,294 | 35 |
| Water Heating & Pumping | 73,474 | 22,571 | 3,527 | 17 |
| Cooking | 0 | 0 | 0 | 0 |
| Refrigeration | 67,577 | 20,760 | 3,244 | 16 |
| Laundry | 11,248 | 3,455 | 540 | 3 |
| Cooling & Ventilation | 90,165 | 27,699 | 4,328 | 21 |
| Appliances (entertainment & personal) | 26,778 | 8,226 | 1,285 | 6 |
| Social Housing | 11,350 | 3,487 | 545 | 3 |
| Total Estimated Savings | 432,552 | 132,880 | 20,762 | 100 |

*Source*: Own elaboration.

grow in the next, and so on. Rogers (1962) proposed a model for the diffusion of innovations within cultures (EVERETT, 1962) that seems useful as a guide here and our estimates of up-take are based thereon. Most notably, we assume that 15% of the residential sector will not at any time adopt the EE interventions and that maximum uptake (i.e.: by 85% of the residential sector) will only occur sometime after year 5. These assumptions inform our savings targets set out in section 5.4 below.

Our estimates above and throughout this report are based on an assessment of technical savings and we make a note here about the potential impact of rebound effects. In relation to energy, the rebound effect is a behavioural response to the reduction in energy costs caused by an improvement in technical efficiency: as the cost of using energy is reduced due to efficiency improvements, people tend to use more energy, thereby offsetting the energy savings made possible by the efficiency improvements.[9] A 2007 study of the rebound effect published by the UK Energy Research Centre (SORRELL, 2007) concluded that "*rebound effects are of sufficient importance to merit explicit treatment. Failure to take account of rebound effects could contribute to shortfalls in the achievement of energy and climate policy goals*." We have however made no specific estimates of rebound effects, as the T&T case (very low energy prices and relatively high per capita consumption) presents a scenario, where rebound effects are likely to be small.

[9] See UK Energy Research Centre, The Rebound Effect (http://www.ukerc.ac.uk/Downloads/PDF/07/0710ReboundEffect/0710ReboundEffectReport.pdf).

## Hotel Sector

### *Overview and estimates of baseline consumption*

Tourism marketing in Trinidad has traditionally been based on targeting the business traveller, but this market has been declining and the target is now being focused for the first time on the leisure traveller and on ecotourism.[10] This signals the intention of the authorities to increase the size and fortunes of the hotel & tourism sector, which will nominally increase demand for energy services in the hotel sector. The aim is to be able to deliver new energy services through efficiency, rather than through additional energy production capacity.

The Ministry of Tourism reports a total of 6,307 hotel rooms in T&T in 2010 (MT, 2010). With 12.8% direct and indirect contribution to the GDP (2008), travel and tourism in T&T has far less importance than in other Caribbean countries (e.g. 26.5% in Grenada and 54.0% in Barbados; WTTC, 2009). A 2012 report on a CHENACT study[11] of the hotel sector in the region estimates that the hotels in T&T consume 76 GWh of electricity annually, i.e. about 1.0% of the total national electricity consumption (CHENACT, 2012).[12] Since electricity and LPG rates are significantly lower than in the rest of the Caribbean, the expenditure for energy and its share on the overall operational costs of hotels and guesthouses is also far lower. We assume that, in accordance with the findings of studies conducted elsewhere in the region (including CHENACT, **Figure 21**), the largest area of electricity use in hotels in T&T is for air-conditioning, followed by lighting, kitchen appliances and pumping equipment.[13]

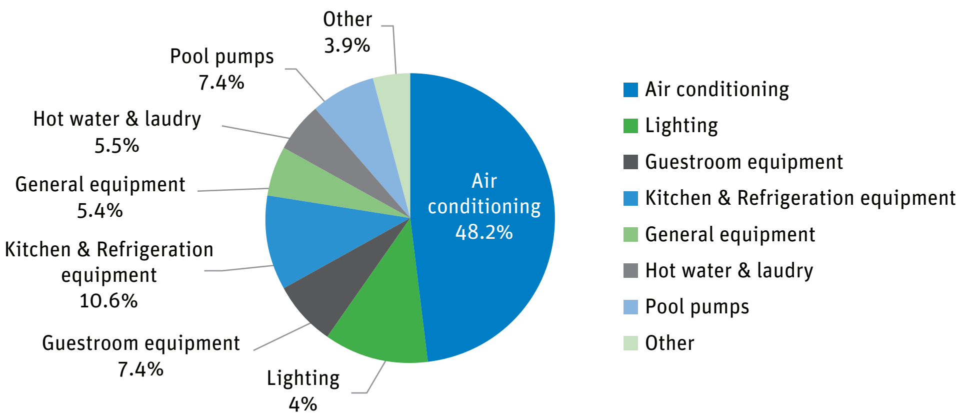
The hotel sector suffers from the constraint to invest in EE already identified above: low energy prices provide little financial incentive and payback periods are long. Hotel owners are more likely to make investments that increase their occupancy (and therefore increase direct revenues).

Based on the facts that (a) the tourism marketing approach is now focused towards the leisure traveller and (b) travellers appear to be becoming more environmentally conscious

[10] Interview with Ms Yolande Selman, Tourism Development Company, 17th September 2012 and interview with Ms Louanna Chai-Alves, Trinidad Hotels, Restaurants and Tourism Association, 18th September 2012.
[11] CHENACT is an EE project financed by the IDB, GIZ, CDE, UNEP, Barbados Light & Power and the Government of Barbados and implemented by the Caribbean Tourism Organisation. The Phase 1 report was presented in March 2012.
[12] If the estimation is correct, this share would be far lower than in other Caribbean island states.
[13] The CHENACT study finds that in Barbados, 48% of hotels' electricity is consumed by air-conditioning, 12% by lighting and 11% by kitchen and refrigeration equipment.

**FIGURE 21**

Electricity consumption by end-use in hotels of Barbados




*Source*: CHENACT, 2012.

(TRIPADVISOR, 2012), this suggests that hotels should be encouraged to invest in EE interventions as part of a suitable green certification programme. Consequently, we would recommend an approach that markets EE as part of a holistic sustainability strategy, which is meant to increase revenues, rather than an approach that focuses basically on reducing energy costs.

### *Proposed EE Interventions*

Based on the above we propose four general programme interventions that will:

- Improve air-conditioning efficiency;
- Use more efficient lighting and controls;
- Use more efficient equipment and appliances in rooms and back-of-house
- Encourage green hotel certification.

The recommended interventions to encourage uptake are shown in **Table 16**.

Hotels that benefit from energy audits will have specific recommendations made. In general, we recommend that the following measures be considered for implementation by hotels.

#### a) Air-conditioning

The specific investments in air-conditioning plant and equipment will depend on the hotel sizes and related factors, but the basic components will include, for *medium and large hotels*:

**Table 16 Recommended Programmes for EE in Hotels**

| Programme of Measures | Type of Policy Intervention | | |
|---|---|---|---|
| | Information | Incentive | Regulation |
| To increase the use of efficient air-conditioning systems | Design and implement a national sustainable tourism education & awareness programme, targeted at owners, operators and stake-holders in the hotel & tourism sector | 150% Tax Allowance programme | None Recommended |
| To use more efficient lighting & controls | As above | 150% Tax Allowance programme | |
| To use more efficient equipment & appliances back-of-house | As above | 150% Tax Allowance programme | |
| To encourage environmental & sustainability certification | As above | Provide support from the TDC's Hotel & Guesthouse Room Stock Upgrade Incentive Project for expenditures on approved environmental certification programmes (EarthCheck, Green Globe, etc). Properties will be reimbursed from the grant fund on completion and award of the certification. | |

- High-efficiency, chilled beam air-conditioning systems;
- Guest room occupancy controls;
- Retrofit of existing hotels to reduce cooling loads by passive cooling (e.g. by adding insulation, window tint, light-coloured roof treatments, etc.).

And for *small hotels*:

- High-efficiency chiller units;
- EER 10+ split units;
- Passive cooling retrofits to reduce cooling loads.

### b) Lighting & controls

For *all sizes of hotel*s, lighting and controls investments will include:

- Replacement of T12 fluorescent lamps and magnetic ballasts with T8 lamps/electronic ballasts;[14]
- Replacement of incandescent lamps with CFLs;
- Install photocell switches for outdoor lighting applications;
- Install occupancy and motion sensors for indoor public area lighting.

**c) Equipment & Appliances**

For *all sizes of hotels*, the recommended interventions regarding appliances and equipment are:

- Use appropriately sized and energy efficient (*Energy Star* or equivalent rating) guest room appliances (refrigerators, TVs);
- Retrofit walk-in freezers, refrigerators and cold rooms with defrost optimization (10% energy savings (SAMUEL, 2011) and compressor optimization systems (15% energy savings[15]).
- Retrofit pump motors with variable-frequency drives.

**d) Green Certification Programmes**

Various certification programmes exist; *EarthCheck* (see box) and *Green Globe* are two that are familiar to the T&T hotel sector and are applicable to large, medium and small hotels seeking to confirm that they are environmentally sustainable *bona fides*. These programmes include requirements for benchmarking and goal-setting to achieve annual energy and water use reductions, utilization of RE sources and specific awareness, education and communication efforts targeted at the owners, management and staff of the hotels being certified. This could also integrate activities that sensitize guests, such as through signage in guest rooms that encourage the conservation of energy and resources.

In consultation with the two Hotel associations TDC and THRTA, the GoRTT should establish a national sustainability certification process for all hotels in T&T. Such certification should be a component of the national EE policy and should be made obligatory for hotels after a certain time span.

[14] We do not recommend replacement of T8s with T5s, as the marginal energy and cost savings to be derived will not outweigh the significant additional replacement costs: a T5 lamp and adapter combination can cost up to 4 times as much as the equivalent T8/electronic ballast fitting and the T5 system does not outperform the T8 system by a similar margin, while both lamps are typically rated for the same lifetime.

[15] Estimate from supplier literature: http://www.smartcool.net/technology/how-smartcool-saves.

**Earth Check**

This certification has the objective to improve the carbon footprint of the participating hotels via six steps to sustainable tourism practices.

- Commitment: Addressing sustainability, prepare sustainable policy and complete corporate health check.
- Measure the carbon footprint: Measurement and benchmarking programs to assess environmental and social footprint.
- Sustainable Action Plan: Using the results available from Benchmarking determine the area where improvement is needed and prepare a Sustainable Action Plan.
- Implement Change: Engage with staff through capacity building programmes and suppliers through green purchasing to reduce and offset.
- Verification and offsetting: Achieve verification through a recognized and reputable programme.
- Evaluation, Monitoring and Marketing: Evaluate success and challenges, share best practice and celebrate achievements.

*Source*: www.earthcheck.org.

### *Estimated energy savings potential*

The report of the recently implemented CHENACT Phase 1 project estimates that the hotel sector in T&T could save up to 18 GWh of electricity over a 7-year period if EE interventions were carried out, primarily in relation to air-conditioning, lighting and control systems. Our 5-year targets are based on this savings estimate, with an expectation that the annual savings will not be linear; a slower rate of uptake and savings is assumed in the first year.

## Commercial & Small Industrial Sector

### *Overview and Proposed EE Interventions*

The industrial sector holds significant potential for energy savings, which is indicated by the 2011 Point Lisas EE study conducted by the NEC. Aside from the possible connection with the 150% Tax Allowance program, no further consideration is given here to EE options for the large industrial sector.[16]

Overall, the commercial and industrial sector consumed some 5,600 GWh of electricity in 2011, which was two-thirds of the country's total electricity consumption. This consumption is distributed across the sales categories as shown in **Table 17**:

[16] In 2010 there were 38 companies in T&TEC's Large Industrial (34) and Very large Industrial (4) customer classifications.

**Table 17 Electricity Sales to Commercial and Industrial Categories, 2011**

| Category | | Number of Customers | Sales, GWh | |
|---|---|---|---|---|
| | | | GWh | % |
| Commercial | B | 38,336 | 773 | 14 |
| Commercial | B1 | 35 | 2 | 0 |
| Small Industrial | D1 | 2,320 | 512 | 9 |
| Medium Industrial | D2 | 772 | 1,368 | 24 |
| Large Industrial | D3 | 14 | 460 | 8 |
| Large Industrial | D4 | 19 | 892 | 16 |
| Large Industrial - Standby | D5 | 1 | 1 | 0 |
| Very Large Load | E1 | 3 | 321 | 6 |
| Very Large Load | E2 | 1 | 401 | 7 |
| Very Large Industrial | E3 | 0 | 0 | 0 |
| Very Large Industrial | E4 | 0 | 0 | 0 |
| Very Large Industrial | E5 | 1 | 870 | 16 |
| **Total** | | **41,502** | **5,600** | **100** |

*Source*: T&TEC Business Plan 2011–2016.

Note that the consumption distribution is heavily skewed towards the large industrial customers: one very large industrial customer accounts for 16% of total consumption and only 39 customers (0.1% of the customer base) consumed 53% of the total.

### *Proposed EE Interventions*

The Efficiency Valuation Organization (EVO)[17] estimates that the following commercial and industrial technologies have the associated levels of performance risk and payback periods (**Table 18**).

In the absence of specific industrial sector consumption data, it can reasonably be assumed that electric motors, process heating, cooling, ventilation and lighting are significant end-users. The relevant EE investments that *processing and manufacturing firms* should make include:

- Retrofit of motors with variable-frequency drive systems;

[17] The Efficiency Valuation Organization (EVO) is a non-profit organization whose mission is "to develop and promote the use of standardized protocols, methods and tools to quantify and manage the performance risks and benefits associated with end-use EE, RE, and water efficiency business transactions." See www.evo-world.org.

**Table 18** **Performance risk and payback periods associated with EE technologies**

| EE Technology | Typical Associated Risk | Simple Payback, Years |
|---|---|---|
| High efficiency lighting | Low | 2–3 |
| High efficiency chillers | Low | 5–10 |
| High efficiency boilers | Low | 1–5 |
| Heat recovery & steam traps | Low | 2–4 |
| HVAC upgrades | Med – High | 2–8 |
| Variable frequency drives (VFDs) on motors (fans, pumps, etc.) | Med – High | 3–5 |
| New automated buildings & HVAC controls | High | 3–5 |

*Source*: Efficiency Valuation Organization 2009.

**Table 19** **Recommended Programmes for EE in Commercial & Small Industry Sector**

<table>
<tr><th rowspan="2">Programme of Measures</th><th colspan="2">Type of Policy Intervention</th></tr>
<tr><th>Incentive</th><th>Regulation</th></tr>
<tr><td>To utilize high-efficiency air-conditioning systems</td><td colspan="2">150% Tax Allowance programme</td></tr>
<tr><td>To retrofit motors with variable-frequency drive systems</td><td colspan="2">150% Tax Allowance programme</td></tr>
<tr><td>To implement light bulb and lighting fixture replacements / retrofits</td><td>150% Tax Allowance programme</td><td>Phase out of incandescent light bulbs</td></tr>
<tr><td>To encourage use of lighting control systems</td><td colspan="2">150% Tax Allowance programme</td></tr>
</table>

- Process heating retrofits;
- Installation of high-efficiency, chilled beam air-conditioning systems;
- Light bulb and lighting fixture replacements/retrofits;
- Implementation of lighting control systems.

The proposed programmes to encourage uptake of the above are shown in **Table 19**.

### *Estimated energy savings potential*

It is likely that, largely as a result of very low energy prices, energy consumption in T&T is attended by a significant component of energy wastage. Based on the findings of the NEC study and given that large companies in a competitive business environment are typically motivated to reduce costs in any case, it is reasonable to assume that a 15% energy savings is quickly attainable across the board for all categories of commercial and industrial consumers. In relation to the effect of the proposed ESCO 150% tax allowance, we estimate that over the first five years, a modest total of 224 commercial and industrial customers will take advantage of the programme, resulting in a cumulative savings over 5 years of approximately 33 GWh of electricity (which is a cumulative 25% reduction in consumption for those customers). This would result in savings of about 23.1 kt $CO_2$ emissions, certainly still not enough to attract the carbon market at current low prices for carbon emissions.

## Government

### *Overview and estimates of baseline energy consumption*

As noted above, the uptake of viable EE technologies will be influenced by the specific mix of *information*, *incentives* and *regulations* delivered under the umbrella of Government policy. However, the consistent comment heard from stakeholders during meetings and interviews is that government should not just set policy, install incentives and make regulations, but should actively lead by example in developing specific EE projects. We agree with this general proposition. The market situation, based on the Government's maintenance of a system of significant price subsidies, does not facilitate private investment in EE, at any level. Under existing market conditions, Government cannot expect the private sector to lead; it must take special initiatives to set an example.

In relation to information, GoRTT has already embarked (in September 2012) on a national energy awareness programme under the theme "My Energy, My Responsibility". The campaign is comprised of three phases and is designed to target school children throughout the country. Highlights of the programme are presented in **Appendix D**: Highlights of the "My Energy, My Responsibility" Campaign.

GoRTT has been active in developing incentives and regulations designed to encourage EE in the commercial and industrial sectors. The most important is the *150% Tax Allowance* incentive, designed to encourage companies to engage Energy Service Companies (ESCOs) to identify saving potentials and implement energy saving projects. The programme is targeted at commercial, light and heavy industrial companies.

The programme (which is enacted, but not yet operational) provides for approved companies to receive a 150% tax allowance[18] on their investment, once a minimum level energy reduction is achieved, as a result of their investment in the recommended EE activities. It is intended that certain types of companies (e.g.: power generators) will be excluded; there

[18] A tax allowance decreases the amount of the taxable income and can be rolled forward to future years.

will be a minimum expenditure that would be eligible for an allowance and a cap on the allowable investment value.

The implementation of the allowance is the responsibility of the ESCO Certification Committee (ECC), a multi-sectoral body chaired by the MEEA.[19] The ECC's stated terms of reference are to certify ESCOs, develop procedures and standards for the conduct of energy audits and to make recommendations on the applications for and award of the tax incentives. It is to be noted that no actual certification of ESCOs or energy auditors is actually being done at this time; the ECC is primarily establishing a register of firms. We make recommendations on this incentive below.

With regard to baseline energy consumption, we note that no estimates are available of the aggregate energy consumption of government-owned or operated buildings and facilities.

### *Proposed EE Interventions*

As has been outlined above, Government action is recommended in the following four areas:

- Delivery of information;
- Design and implementation of incentives;
- Enacting and enforcement of regulations;
- Design and implementation of specific projects.

**a) Delivery of information**

Government should design and implement a comprehensive, five-year programme to quantify, analyse and improve the general public's awareness of and engagement with energy issues. Such a programme will include some of the following activities:

- Competitions, promotions and giveaways;
- Exhibitions and energy fairs;
- Free workshops and demonstrations;
- Information campaigns;
- Lectures & presentations to the public and to schools;

Level 1 energy audits;

- Development of a data base with government energy usage data;
- Publication of government energy usage data;

[19] Other members are the Board of Engineering, the T&T Electrical Inspectorate Division, the Accreditation Council of T&T, the T&T Green Building Council (TTGBC), the T&T Bureau of Standards (TTBS), the Regulated Industries Commission (RIC), University of Trinidad and Tobago (UTT) and the University of The West Indies (UWI).

- Internal benchmarking of government energy use data;
- Radio and TV shows;
- Research, surveys and publication of results;
- Social media and mobile quizzes and games.

**b) Design and implementation of incentives**

Three general types of incentive are considered: incentives for individuals, for businesses and incentives that encourage the electricity distribution company to engage in programmes that reduce customer demand.[20]

**c) Incentives for households**

Households are already eligible for a *25% tax credit for solar water heating* installations of up to TT$ 10,000 (US$ 1,560) in value. In addition, we recommend the following for consideration by the GoRTT:

- Provide tax deductions for individuals for:
  - Performance of *household energy audits* by certified energy auditors (recommended deduction of up to US$ 500);
  - *Implementation of EE improvements* recommended by the audit and/or purchase of 'environmentally-friendly' products such as efficient split air-conditioning systems, Energy Star or equivalent rated appliances, etc. (up to US$ 5,000 per year). Note that eligibility for this incentive should not be affected by opting out of the energy audit;
- Provide incentives to encourage appliance retailers to offer *trade-in programmes*, for customers to replace inefficient appliances with energy-efficient ones;
- Provide support for *low-interest credit* through established financial organizations (banks, credit unions).

**d) Commercial incentives**

The GoRTT has recently legislated several interventions targeted at the commercial and industrial sectors, the most important of which are the *Green Fund* and the *ESCO Client 150% Tax Allowance*.

*The Green Fund (see also chapter 4.5)*

In 2000 the GoRTT established the Green Fund as the national environmental fund.[21] The fund's grant facility is available to community groups and organizations engaged in activities focusing on remediation, reforestation or conservation of the environment. The fund

[20] Such demand side management (DSM) programmes aim to reduce overall demand for electricity and/or to shift demand from peak times to off-peak times.
[21] More information on the fund is available at http://www.mphe.gov.tt/agenciesdivisions/gf.html.

is capitalized by a tax of 0.1% on the gross sales or receipts of companies carrying on business in T&T. Ten years on, the fund is very well endowed, but only a handful of projects have been financed and none with an EE focus.

It is our recommendation that the GoRTT and the fund managers[22] review the aims, objectives and operating parameters of the fund to optimize it to include the ability to support viable EE projects.

*ESCO Client 150% Tax Allowance*

A major initiative by the GoRTT is its *ESCO Client 150% Tax Allowance*, which was enacted in 2010.[23] We were provided with two restricted circulation documents regarding this allowance:

- ESCO Client 150% Tax Allowance – Guidelines, and
- Audit Requirements & Guidelines.

Based on discussions with the ESCO Certification Committee, we estimate that with modest uptake and success in achieving the target energy reductions, the 150% tax allowance scheme could facilitate savings of 33 GWh and US$1.6 million over 5 years, with an estimated payback period of approximately six years. Our estimates and assumptions are detailed in **Appendix E**: Estimate of Costs & Benefits of 150% Tax Allowance Program

We recommend that the Trinidad and Tobago Electricity Commission (T&TEC) should be the entity responsible for measurement and verification of energy savings achieved by participants. There are several advantages to this approach:

- T&TEC already possesses the necessary information (kVA demand data) to classify clients so there would be no privacy issues in relation to handling or use of such data;
- T&TEC already possesses the necessary measurement data (metered electricity consumption) for the prospective customers;
- They would only need to incorporate the verification aspects, which should not be difficult for them.

In such a case, T&TEC would be ruled as not eligible to apply for the incentive, but since tax allowances only apply to companies that make a profit in any given year and T&TEC does not, then this issue is moot, at least for the near future.[24]

[22] The Green Fund Executing Unit, a division within the Ministry of Housing and the Environment

[23] Under the Finance Act 2010 (section 10P of the Corporation Tax Act), which regulates proposed tax allowances for ESCOs.

[24] Also, it is considered that, in principle, government-owned entities should not need incentives—they can simply be mandated to take the desired action.

**e) Incentives for the electricity supplier to implement DSM and conservation programmes**

Interventions made by the electricity supplier, with the aim of reducing overall demand for electricity and/or shifting demand from peak to off-peak times, generally referred to as demand-side management (DSM) programs, are another option for reducing consumption. A key factor in the success of such programs in advanced economies has been the implementation of policies and incentives designed to make EE investments attractive to utilities, even as the ultimate aim of the investments is to reduce end user consumption of electricity (and therefore revenue to the utilities). An obvious constraint in the T&T context is that the utility, T&TEC, is already operating at a financial loss. A key question therefore is if the RIC will allow T&TEC to recover, in future tariffs, the additional costs it would incur to implement DSM programs.

**f) Regulations**

It is recommended that GoRTT should enact an **Energy Efficiency Act** that will, among other things:

- Provide *financial and economic incentives* for EE in all sectors: residential, commercial, industrial, transport and agriculture.
- Establish an *EE Information Centre* that will advise all types of customers on best ways to conserve energy.
- Mandate the application of appropriate *EE standards*, through a national *building code*, for cooling, ventilation, lighting, hot water systems and appliances in institutional, commercial and industrial buildings. Development of the code can refer to existing American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) standards[25] and US Green Building Council (USGBC) guidelines, among others. Specific clauses in the code will be needed to cover:
  - Lighting efficiency, so that spaces are lit by natural means during the daytime and not under- or over-illuminated otherwise;
  - Insulation efficiency for air-conditioned spaces, so that cooling is confined to the building envelopes;
  - Passive design for reducing building heat loads, so that less energy needs to be used for cooling in the first place, e.g.: through installation of shading devices outside windows.
- Provide a path for the *phasing-out of inefficient technologies* such as incandescent lighting;
- Provide the legal framework for registration, training and certification of energy auditors and ESCOs;
- Provide business incentives for the utility companies to consider efficiency and *demand-side-management (DSM) activities* in their least-cost planning models for provision of additional energy services;

[25] Such as 2010 ASHRAE 189.1: Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings.

- Legislate requirements for standard-setting and energy labelling of consumer appliances;
- Where public funds are used to implement any EE project or programme, mandate the *publication* of the applicable results on a public website;
- *Develop and monitor indicators* of national EE (e.g.: energy intensity—amount of energy required to produce a unit of GDP or energy service).

The passage of such legislation will effectively set the stage for ensuring that EE has an important role in the development of the country's energy future. It should be noted here that several countries and jurisdictions have over the past twenty years implemented EE legislation, addressing areas identified above. A frequently cited example is California, where the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) in 2005 adopted California's Energy Action Plan II, which set a loading order for the provision of the state's energy needs and identified "*EE and demand response as the State's preferred means of meeting growing energy needs*" (State of California 2005).

More recently, the European Union adopted directives, in 2006 on energy end-use efficiency and energy services, and in 2010 on energy use in buildings. The former, Directive 2006/32/EC, includes an indicative energy savings target for the member states; obligations on national public authorities regarding energy savings and energy efficient procurement, and measures to promote EE and energy services.[26]

**g) Specific Government projects**

In light of the arguments outlined above, we recommend that over the next five years, the government should seek to become the country's most visible EE customer, primarily in relation to buildings energy use and, to a far lesser extent, in street lighting. The MEEA has commenced leading by example here, and has undertaken, under this consultancy, a programme of energy audits of public buildings that has now been concluded and whose main findings are detailed in Chapter 5.6.

**h) Buildings**

No specific information on the contribution of buildings to energy consumption in T&T is available, but the International Energy Agency (IEA) estimates that residential, commercial, and public buildings account for 30% to 40% of the world's energy consumption. We assume that figures of that order are likely to apply in highly commercialized and industrialized T&T.

No special incentives or programs are in place for EE in public buildings and the proportion of buildings owned by and/or occupied by the public sector is not recorded. Some

[26] See http://ec.europa.eu/energy/efficiency/end-use_en.htm.

new buildings (such as the MEEA building now being audited) incorporate some form of energy management system, but it was noted that the system in the ministry's building has not yet been commissioned.

T&T has a draft Small Building Code that does not address EE matters and the GoRTT has advised that it is moving towards establishing a national building code.

Government should perform a review and inventory of existing buildings owned and occupied by the public sector to determine the baseline status of building stock, as a first step to designing the appropriate EE interventions. Interventions will include:

- Air conditioning retrofits;
- Lighting retrofits;
- Use of integrated building energy management systems;
- Passive cooling retrofits.

Government should further

- work with the Green Building Council, the Board of Engineering, the Bureau of Standards and other professional organizations of engineers, architects and energy service providers to move towards specifying EE requirements in existing and new building codes;
- select one large and/or prestigious Government-owned or -occupied building to implement a national demonstration project on EE, addressing air-conditioning and lighting retrofits, integrated energy management systems, water use and occupant behaviour modification. Possible candidates would be the Piarco International Airport complex or the Republic Bank of T&T;
- develop and institute specific EE engagement (awareness, education and communications) programmes for public sector employees.

### i) Street Lighting

The other area to be addressed is street lighting, for which the GoRTT (through T&TEC) is responsible. Over 180,000 street lighting lamps are installed in T&T. The vast majority (95%) of these are low pressure sodium lamps and the balance is comprised of mercury vapour and high pressure sodium lamps. These lamps account for an annual electricity consumption of over 110 GWh (about 1.5% of total electricity consumption).

The replacement of the existing lamps with LEDs will certainly reduce the energy consumed by street lighting, but the economics of the intervention are prohibitive. Assessments of street lighting replacement programmes in the USA (where electricity prices are significantly higher than in T&T) indicate payback periods of 23+ years for LED replacement programmes (PNNL, 2012). It is noted that T&TEC, in its *Business Plan 2011–2016*, cites a weak balance sheet, negative cash flows and high debt as limitations to its performance. In this context and giving very low existing tariffs, such investments would be prohibitive to T&TEC in the absence of significant subsidization from GoRTT. Given the constraints, the most suitable approach would be to implement one or more relatively small, strategically-located, pilot projects for demonstration purposes at this stage. See **Appendix F**: Street Lighting Pilot Project for further information.

## 5.3 Energy Efficiency Action Plan & Budget

### Existing Activities

The GoRTT has implemented several incentives (**Table 20)** and a national energy awareness campaign aimed at reducing energy consumption by individuals, households and businesses.

### Energy Efficiency Targets, Action Plan and Budget Plan

The overall objective is to reduce T&T's per capita energy consumption from present-day levels, which, as described above, are unsustainable over the medium to long term. Short, medium and long-term targets are proposed as shown in **Table 22** to **Table 24**. The budget figures presented are recommended budget numbers for 5 years in the first instance.

The estimated outcome is an expenditure over 5 years of US$ 23.3 million, resulting in energy savings of 972.9 GWh, cumulative cost savings of US$ 48.6 million and avoided emissions of 681 kt of $CO_2$ over the period; as summarized in **Table 21**.

## 5.4 Energy Policy measures with regards to EE

To be able to reach the proposed measures as detailed in the action plan, a coherent policy response will be necessary. Only if the Government undertakes certain changes the energy efficiency potential can be used to its full potential.

### General recommendations for EE Policies

- T&TEC should be obliged to carry out demand-side-management programmes, e.g. by replacing inefficient refrigerators and providing rebates for the purchase of new efficient refrigerators or by purchasing efficient refrigerators in bulk. Such measures should either be financed through the Green Fund (see above) or through an extra levy on revenues of the power generation utilities.

**Table 20 Existing EE measures implemented and funded by GoRTT**

| Sector | Description of the Measure | Cost & Benefit |
|---|---|---|
| Residential sector | 2010<br>Household Solar Water Heater Tax Credit<br>Households are eligible for a 25% tax credit for SWH installations of up to TT$10,000 (US$1,560) in value. | The uptake through end 2012 has been negligible: Seven tax credits were granted, having a total cost of US$4,000 and providing estimated energy savings of US$1,850 |
| Commercial sector | 2010<br>150% ESCO Tax Allowance<br>Companies that engage certified ESCOs to design and implement energy savings projects are entitled to a 150% tax allowance on their investment, provided at least a 15% energy reduction is achieved as a result of their investment in the recommended EE activities. | The programme has not yet been operationalized, and no tax revenue impact or sector-wide benefit has been estimated. |
| | 2010<br>ESCO Depreciation Allowance<br>Where a certified ESCO has acquired plant and machinery for the purpose of conducting energy audits they are allowed:<br>• 75% accelerated depreciation on the acquired assets in the first year;<br>• 25% wear and tear allowance on the acquired assets in the following year | No tax revenue impact or sector-wide benefit has been estimated |
| Hotel sector | 2010<br>150% ESCO Tax Allowance<br>Hotels that engage certified ESCOs to design and implement energy savings projects are entitled to a 150% tax allowance on their investment, provided at least a 15% energy reduction is achieved as a result of their investment in the recommended EE activities. | The programme has not yet been operationalized and no tax revenue impact or sector-wide benefit has been estimated. |
| Light Manufacturing Sector | 2010<br>150% ESCO Tax Allowance<br>Companies that engage certified ESCOs to design and implement energy savings projects are entitled to a 150% tax allowance on their investment, provided at least a 15% energy reduction is achieved as a result of their investment in the recommended EE activities. | The programme has not been quantified. |
| General Public | Reduction or removal of import duties from specified EE items | Costs and impacts have not been quantified by the relevant authorities. |

*Note*: The 150% tax allowance applies to the commercial and industrial sectors.

Tariff policy would need to be amended by the Regulated Industries Commission in such a way that costs incurred for such programmes can be claimed by T&TEC and would form part of the overall cost statement which determines the rate setting.

**Table 21 Summary of 5-year Budgets, Estimated Savings and $CO_2$ avoided**

| Item | Residential | Hotels | Commercial & Industrial | TOTAL |
|---|---|---|---|---|
| Expenditure, '000 US$ | 12,950 | 1,750 | 8,622 | 23,322 |
| Energy Savings, MWh | 929,986 | 10,286 | 32,604 | 972,876 |
| Cost Savings, '000 US$ | 46,499 | 514 | 1,630 | 48,644 |
| Cost Savings, '000 TT$ | 297,595 | 3,291 | 10,432 | 311,319 |
| $CO_2$ emissions avoided, kt | 651 | 7.2 | 22.8 | 681 |

Incandescent light bulbs should be banned from the market by setting minimum performance standards for lighting. Incandescent light bulbs have been banned from the European Union market since September 2012 and will be banned in the United States of America and Mexico by 2014. Also other Latin-American countries are currently in the process of taking legal actions against inefficient lighting or have already done so. It is recommended that CARICOM countries take a harmonized approach, where T&T could take a lead as one of the major markets in the Caribbean for light bulbs. During the course of the consultancy, GoRTT has started an exchange programme for incandescent light bulbs which are a good first step in the right direction.

Minimum efficiency standards and labelling programmes should be implemented. Minimum performance standards for EE and consumer information about energy consumption through labels are normal and often mandatory procedures in many jurisdictions. Currently OECS member states are considering how to establish own standard and labelling schemes and set up testing facilities for verification. We propose that T&T takes initiative at the CARICOM level for a common and harmonized approach. In particular efficient light bulbs (compact fluorescent lamps) should be required to carry a minimum amount of information about their performance on the packages. This will increase the general product quality and make consumers aware of the differences between apparently similar products on the market.

Minimum building standards will be established and applied initially for social housing projects and for all public and government buildings. Currently T&T has no standards for EE in the construction sector. As mandatory standards are difficult to control and need a strong administrative structure, the introduction of building standards for the suggested construction areas under direct government control is recommended as a first measure. In particular social housing projects are a good starting point as most of the buildings are not adapted to tropical climate leading to a low comfort and/or high electricity costs if dwellers purchase air-conditioning systems to lower high room temperatures. Examples in Mexico have shown that small investments can leverage substantial increases in comfort by insulating roofs and sun-exposed walls, improving natural ventilation.

**Table 22** Proposed Residential Sector EE measures to be implemented by GoRTT

| RESIDENTIAL SECTOR | | | | |
|---|---|---|---|---|
| **Summary of objectives** | **Summary of Targets** | | | **Budget Responsibility or Source of Funding** |
| | **Short Term** | **Medium Term** | **Long Term** | |
| | **5 years** | **6–15 years** | **15+ years** | |
| The overall objectives for EE interventions in the residential sector are to:<br>• Reduce the use of electricity for water heating;<br>• Encourage the use of energy-efficient appliances & lighting;<br>• Reduce energy consumption in the social housing sector;<br>• Engage & motivate consumers to adopt no-cost, durable energy savings behaviours. | Reduce per capita energy consumption by 20% from 2010 levels | Reduce per capita energy consumption by 25% from 2010 levels | Reduce per capita energy consumption by 30% from 2010 levels | |
| | **Specific Activities & 5-yr Budget to meet Targets** | | | |
| | Design & implement comprehensive awareness, information & engagement programme to quantify, analyse & improve general public awareness of & engagement with energy issues, encompassing the benefits of solar water heating, energy-efficient appliances & lighting<br>**Budget US$ 2,500,000** | Continue, review and appropriately modify the programme | | GoRTT |
| | Develop a programme for appliance EE standards and labelling<br>**Budget US$ 5,000,000** | Implement, continue and improve the programme | | GoRTT, TTBS |
| | Increase import duty on tank water heaters from 20% to 30% & continue provision of tax credits for solar water heating<br>**Budget US$ 1,400,000** | Increase import tariffs to 50% | Increase import tariffs to 65% | GoRTT |
| | Provide tax credits & financial incentives for efficient appliances (based on established EE standards and labelling programs such as Energy Star or equivalent), including incentives to retailers to aggressively market EE appliances<br>**Budget US$ 1,500,000** | Increase import tariffs on inefficient appliances as designated by the adopted standards; | | GoRTT |
| | | Continue fiscal & financial incentives for efficient appliances | | GoRTT |
| | Reduce the import duty on high efficiency air-conditioning units to 10% and progressively increase import duties from 20% to 50% on low-efficiency units<br>**Budget US$ 0.00** | | | GoRTT |

(*continued on next page*)

**Table 22 Proposed Residential Sector EE measures to be implemented by GoRTT** *(continued)*

| | | | | |
|---|---|---|---|---|
| | Increase import duty on incandescent light bulbs from 20% to 30% and announce intention to phase out in 5 years. Design & implement CFL disposal programme<br>**Budget US$ 500,000** | Incandescent bulbs are no longer able to be imported. Existing stock can be sold | No incandescent lighting in use | GoRTT |
| | Pre-installation of CFLs to new HDC social housing units<br>**Budget US$ 550,000** | CFL bulbs are pre-installed in all HDC units | No incandescent lighting in use | HDC |
| | Implement programme of replacement of incandescent light bulbs in existing HDC social housing<br>**Budget US$ 300,000** | No incandescent lighting in use in existing HDC units | No incandescent lighting in use in existing HDC units | HDC |
| | Other Project: T&TEC is considering moving from bi-monthly to monthly billing for residential & commercial customers. GoRTT should encourage and support this project.<br>**Budget US$ 1,200,000** | | | T&TEC |
| | Identified benefits are increased customer goodwill and reduced receivables. An additional benefit is potential increase in consumer awareness & engagement. T&TEC has not quantified any likely benefits. | | | |
| **5-Year budget, US$** | **12,950,000** | | | |
| **Aggregate Energy Savings, MWh** | **929,986** | | | |
| **Cost Savings, '000 US$** | **46,499** | | | |
| **Cost Savings, '000TT$** | **297,595** | | | |
| **$CO_2$ Emissions avoided, kt** | **651** | | | |

*Notes*:
CFL price is retail price. CFL retail price will average US$ 5.07 to 2016; Inflation average 8% over the period (based on data from TradingEconomics.com); Assumed 2,000 SWH tax credit applications @ average US$ 700 each; HDC will deliver 3,200 units per year over the 5 year period; Other energy savings estimates and assumptions are detailed in Appendix C: Methodology for Residential Baseline and Savings Estimates.

**Table 23** Proposed Hotel Sector EE measures to be implemented by GoRTT

| HOTEL SECTOR | | | | |
|---|---|---|---|---|
| **Summary of objectives** | **Summary of Targets** | | | **Budget Responsibility or Source of Funding** |
| | **Short Term** | **Medium Term** | **Long Term** | |
| | **5 years** | **6–15 years** | **15+ years** | |
| The overall objectives for EE interventions in the hotel sector are to:<br>• increase the use of efficient air-conditioning systems;<br>• use more efficient lighting & controls;<br>• use more efficient equipment & appliances back of house;<br>• encourage environmental & sustainability certification. | Reduce average sector energy consumption by 15% from 2010 levels. | Reduce average sector energy consumption by 25% from 2010 levels. | Reduce average sector energy consumption by 35% from 2010 levels. | |
| | **Specific Activities & 5-yr Budget to meet Targets** | | | |
| | Design and implement a national sustainable tourism education & awareness programme, targeted at owners, operators and stakeholders in the hotel & tourism sector.<br>**Budget US$ 1.5 million** | | | GoRTT, TDC, THRTA |
| | Implement the 150% Tax Allowance programme.<br>**Budget included elsewhere** | Review, continue and improve the programme. | | GoRTT |
| | Provide support for expenditures on approved environmental certification programmes (Earth Check, Green Globe, etc.). Properties will be reimbursed from the grant fund on completion and award of the certification. | | | GoRTT (via TDC) Green Fund |
| | **Budget US$ 250,000** | | | |
| **Total 5-yr budget, US$** | **1,750,000** | | | |
| **Aggregate energy savings, MWh** | **10,286** | | | |
| **Cost Savings, ‘000 US$** | **514** | | | |
| **Cost Savings, ‘000 TT$** | **3,291** | | | |
| **$CO_2$ Emissions avoided, kt** | **7.2** | | | |

**Table 24** Proposed Commercial Sector EE measures to be implemented by GoRTT

| COMMERCIAL SECTOR | | | | |
|---|---|---|---|---|
| **Summary of objectives** | **Summary of Targets** | | | **Budget Responsibility or Source of Funding** |
| | **Short Term** | **Medium Term** | **Long Term** | |
| | 5 years | 6–15 years | 15+ years | |
| The overall objectives for EE interventions in the commercial sector are to:<br>• increase the use of efficient HVAC & cooling systems.<br>• use more efficient lighting systems.<br>• use more efficient process technology & control systems. | Reduce energy consumption compared to baseline by 15% from 2010 levels. | Reduce energy consumption compared to baseline by 25% from 2010 levels. | Reduce energy consumption compared to baseline by 35% from 2010 levels. | |
| | **Specific Activities & 5-yr Budget to meet Targets** | | | |
| | Implement the 150% Tax Allowance programme **Budget US$ 8,622,000** | Review, continue and improve the programme | | GoRTT |
| **Total 5-yr budget, US$** | **8,622,000** | | | |
| **Aggregate energy savings, MWh** | **32,604** | | | |
| **Cost Savings, '000 US$** | **1,630** | | | |
| **Cost Savings, '000 TT$** | **10,432** | | | |
| **$CO_2$ Emissions avoided, kt** | **22.8** | | | |

*Notes*: Budget and savings based on assumptions and estimates presented in Appendix C: Methodology for Residential Baseline and Savings Estimates.

- Infrastructure should be expanded in such a way that small or medium-sized consumers can benefit from direct supply of natural gas, e.g. for use in absorption chillers for air-conditioning systems of larger buildings and for cogeneration (in particular trigeneration to produce electricity, heat/steam and cooling energy). Currently only a very limited number of clients outside of the industrial complexes are receiving piped natural gas. It is recommended that T&T takes measures to expand the grid and allows the direct decentralized and efficient consumption of natural gas for various purposes, in particular where it can substitute electricity without lowering the quality and amount of energy services.
- The use of solar water heaters should become mandatory for all new housing projects, hotels, guesthouses and other major hot water users (according to iisd "Financing Low Carbon Development in Tobago", 13% of total electricity consumption is being used for water heating). Solar water heaters are currently not cost-competitive in T&T, but can easily

save electricity and reduce greenhouse gas emissions with proven and reliable technology. It is therefore suggested to amend the general building code in such a way that solar water heaters become a mandatory feature in such constructions that by determination use high volumes of hot water.

- The most inefficient turbines for electricity generation should be decommissioned as soon as possible. The current thermal efficiency for electricity generation with 26–27% is extremely low. Modern combined-cycle power plants with natural gas supply can reach at least 50% efficiency. It is therefore recommended to retire all inefficient turbines and substitute the generation fleet by new efficient plants as soon as possible. In this regard, the Regulated Industries Commission (RIC) should set maximum annual heat rates per kWh and provide a timescale for further efficiency increases.
- Smart meters should be installed and the introduction of time-of-use rates considered. Smart meters offer the opportunity for electricity consumers to better manage their consumption pattern and get first-hand information on the use of electricity at a certain period of time. In combination with time-of-use rates, they can contribute to a shift of power demand from peak times into low load periods. An investigation of whether smart meters can support in lowering electricity consumption and whether time-of-use rates would be suitable for curbing peak demand is recommended.

## Proposed Trinidad and Tobago Energy Agency

To support the MEEA in undertaking the change towards EE, the consortium proposes the development of an Energy Agency for Trinidad and Tobago (TTEA). The TTEA would complement the activities of the MEEA to make sure that it can focus on its core activities. See **Table 25** for information on the typical core activities of an energy ministry.

**Table 25 Typical responsibilities of an Energy Ministry**

| |
|---|
| ✓ Define **energy strategies and policies** |
| ✓ **Planning** of longer-term energy supply |
| ✓ Design the **legal framework** |
| ✓ **Mandate** specific studies |
| ✓ Harmonize **norms and standards** with neighbouring countries |
| ✓ Maintain **energy statistics**, observe market developments |
| ✓ Take over **regulatory role** unless left to separate entity |
| ✓ Establish and monitor **support programmes**, e.g. on energy efficiency measures |
| ✓ Engage in **international institutions** |
| ✓ Attract **financial resources/donors** |

*Source*: Detlef Loy.

Based on international experience, as well as discussions with relevant stakeholders from T&T, especially the MEEA, the Consultants propose that the TTEA have the following mandate:

- Provide general and technical guidance on EE and RE.
- Pool and transfer knowledge and information on national energy supply, efficient energy use and resources management.
- Act in the triangle of government, private sector and financing institutions.
- Promote three general objectives of energy policy: secure, environmentally friendly and economically viable energy supply.

Based on the discussions with the MEEA, as well as the experience of the Consultants, the following areas of activities would be of special interest, to fulfil its mandate:

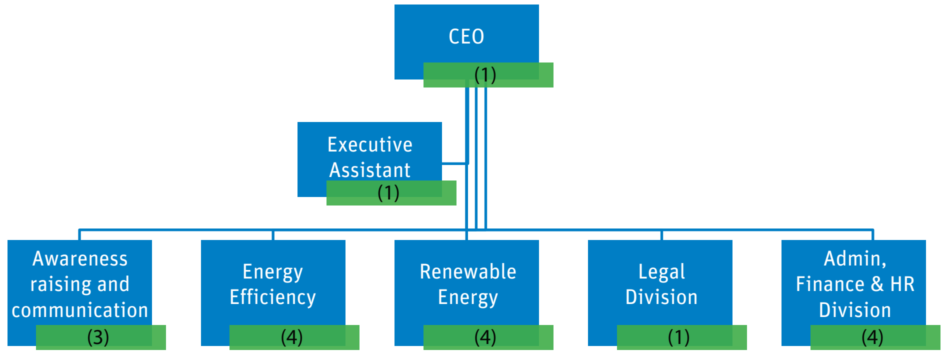
a. Development of studies and research on energy policy related matters;
b. Consultancy for public and private sector;
c. Information, awareness raising and motivation services for energy consumers, including the implementation of public awareness campaigns and public education services;
d. Organization and implementation of events with regards to EE and RE;
e. Demand-side-management programs for/with utilities;
f. Assistance for Government in funding programs, implementation of pilot projects, planning for long-term energy supply, statistical services on energy supply and consumption;
g. Capacity Building and Training for different energy-related aspects;
h. Implementation of ESCO services;
i. Assessment of energy resources, e.g. hydro power, wind, biomass, solar;
j. Advise state-run public sector and municipalities in assessing energy saving potentials and purchasing energy-efficient equipment;
k. Support T&T education stakeholders to develop a program for the incorporation of education on sustainable energy to the national curricula at all levels;
l. Bring building EE and energy efficient construction to the forefront by implementing a comprehensive program of training for engineers, architects and craftsmen.

It is envisaged that the TTEA will operate at a high level, with a suitable budget and authority to implement recommendations and to delegate actions. It will deliver its mandate through collaboration with relevant Government agencies, NGOs, the private sector, regional and international bodies.

To make sure that an energy agency can operate efficiently, it is important that it is independent from direct political influence, and that it is especially not influenced by political changes. It should operate at least as a semi-autonomous institution with its own budget and should have autonomy to take its own operational decisions. To make it financially sustainable and more independent, it should be allowed to earn income.

**FIGURE 22**

Proposed Organisation Chart, T&T Energy Agency




*Source*: Own elaboration.

Based on discussions with relevant stakeholders in T&T, the most suitable business model for the TTEA would be a Public Private Partnership. This would allow the integration of different relevant stakeholder groups into the operations of the TTEA and would guarantee that the interests of all relevant stakeholder groups are represented. Potential partners for the energy agency could be the Energy Chamber, as well as the Ministry of Planning and Sustainable Development and the Ministry of the Environment and Water Resources.

It is proposed that the organization be structured as follows (maximum staff numbers in brackets):

Generally energy agencies are characterized by low hierarchies and a flexible structure. A maximum number of staff has been proposed for each division indicated in the chart. The staff will most likely develop over a period of time and should be adapted to the needs in T&T.

## 5.5 ESCO Certification Committee

### Background

The GoRTT in 2010 passed the Finance Act 2010 which provides legislation on specific EE incentives and subsequently set up an ESCO Certification Committee (ECC) under the chairmanship of the MEEA, which is scheduled to meet on the second Thursday of every month.

The work of the ECC is primarily carried out by an ESCO Working Group comprised of some of its members.

The ECC's Terms of Reference are:

- to develop regulations and standards for the conduct of energy audits to ensure adherence to minimum industry requirements in accordance with best international practices;
- to make recommendations for the certification of ESCOs through review and evaluation of applications and credentials to enhance professionalism and quality of services offered;
- to make recommendations for the award of the 150% Tax Allowance on the basis of criteria to be established by the Certification Committee with respect to:
    - qualifying expenditures
    - the level of energy savings to be achieved through the installation of energy savings equipment and devices.

The ECC has decided that registration is better than certification for the ECC and MEA as it relates to indemnication issues.

The Committee bases its proposals on international examples, such as the New Brunswick (Canada) Efficiency Industry Program, the UK Enhanced Capital Allowance, the Energy Conservation Promotion Fund of Thailand and the Accelerated Capital Allowances for energy-efficient equipment of Ireland.

During the SEP, the Consultants assisted the ECC with the development of a framework document which will be issued for stakeholder consultations, scheduled to occur in 2015.

## 5.6 Energy Audits

As part of their work with regards to EE, the Consultants have carried out energy audits on eight public buildings in T&T.

Undertaking energy audits has various key objectives:

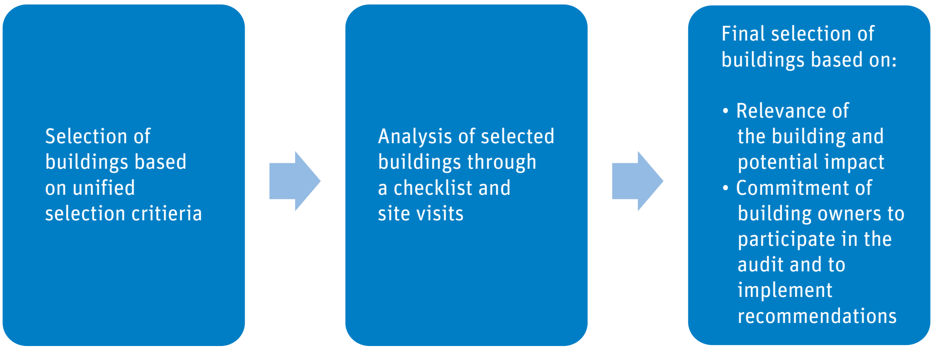
1. Show that the GoRTT is leading EE by example, through the implementation of energy audits in various key Government buildings;
2. Collect first-hand data on energy consumption, as well as energy saving potentials in a variety of different buildings in T&T;
3. Support local consultants and audit firms through capacity building measures and guided implementation and establish a local market for energy auditing.

### Building selection methodology

The selection of buildings to be audited followed a stringent process of analysis based on a number of unified criteria and a predefined approach:

**FIGURE 23**

Selection process




*Source*: Own elaboration.

Apart from this unified selection process, two additional buildings were chosen due to their specific relevance for the project or the MEEA:

1. **Ministerial Tower at International Waterfront Centre:** The offices of the MEEA are located inside the Ministerial Tower at International Waterfront Centre. As the MEEA intends to lead the process of converting Trinidad and Tobago into a country with a more sustainable energy framework, the Ministerial Tower has been chosen as the first building to conduct an energy audit.
2. **The Speyside Secondary School in Tobago:** The Speyside Secondary School has been chosen as the location for a pilot project under the Technical Assistance provided by the IDB. As a first step and necessary precondition to be able to define the exact scope of the RE pilot project, an energy audit and feasibility study will need to be undertaken at Speyside Secondary School.

Pre-selection of the buildings was based on a number of criteria (**Table 27**):

Based on the pre-selection criteria, the MEEA defined a list of buildings to be considered for the energy audits.[27] The building operators were requested to submit a checklist with regards to some basic criteria such as:

[27] Based on the fact that no co- financing has been expected from the buildings, as well as due to the specific situation in T&T, the consortium, jointly with IDB and the MEEA have decided to focus all energy audits on public buildings.

**Table 27 Criteria for Pre-selection of buildings**

| |
|---|
| Substantial electricity consumption (> 100 MWh/a) |
| Substantial electric lighting, cooling & ventilation loads |
| Fulfil common public purposes (such as schools, hospitals, airport, office & administrative buildings) |
| Have had a separate electricity meter for the past three years |
| Be able to act as model case for similar buildings at other locations |
| Be located in different parts of Trinidad and Tobago |
| Be older than 10 years and have not been remodelled in the last 5 years |
| The building operators and or users should have a genuine interest in an energy audit, support its implementation and be willing to conduct changes and investments |

- General data on the building
- Overall consumption data
- Existing appliances
- Some basic facts about energy efficiency.

Site visits took place in all the buildings throughout the month of June 2013 with representatives from the consortium, as well as the MEEA and included discussions with relevant building administrators and facility managers.

Based on the results of the checklist, the pre-selection table developed (see **Table 28**) and the site visits, the following buildings were chosen:

- NALIS Port of Spain[28]
- Port Authority Administrative Building
- THA Administrative Building
- National Treasury Building
- UTT San Fernando Campus
- Port of Spain General Hospital
- Tunapuna Administrative Complex.

**Table 28 List of preselected buildings**

| Building |
|---|
| San Fernando General Hospital |
| NALIS Port of Spain |
| Port Authority Administrative Building |
| Port of Spain General Hospital |
| THA Administrative Building |
| Policy Research Development Institute Building (Planning Division) |
| National Treasury Building |
| UTT San Fernando Campus |
| Tunapuna Administrative Campus |
| Siparia Administrative Campus |
| St. James Library |
| Maloney Library |

[28] The NALIS building was finally removed due to an internal decision at NALIS.

As mentioned previously, the **Ministerial Tower at International Waterfront Centre** and the **Speyside Secondary School in Tobago** were also chosen and selected as the first buildings to be audited due to their potential awareness impact.

## Auditor selection

An open and competitive process was sought to assess the whole range of qualifications and costs for auditing available in Trinidad & Tobago. Insight of the audit market on the islands is fundamental to not only identify the most competent companies but also promote and encourage the service locally.

In order to compile a complete list of companies and individuals offering the services of energy audits, references were taken from the MEEA database. In order to promote local services, only Trinidad & Tobago based companies were invited.

Nineteen companies were identified as offering energy audits or related services and were invited to present proposals in the first tender for the MEEA Ministerial Tower building and Speyside school. Nine companies responded with proposals.

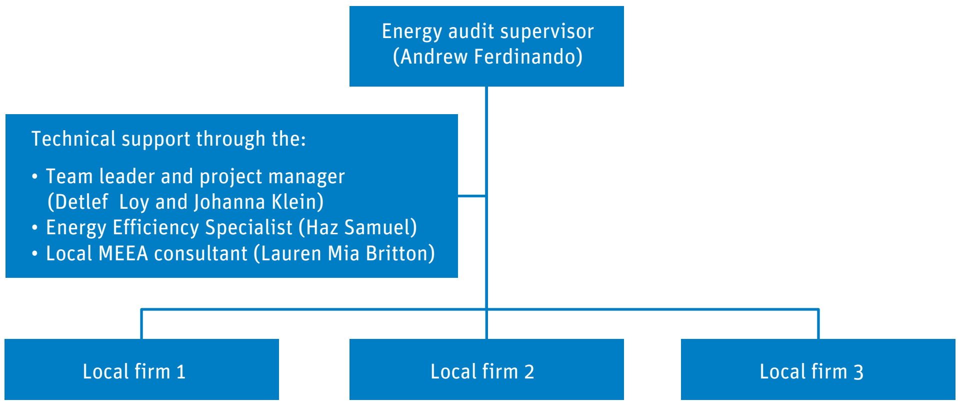
Although an open and wide identification process was chosen, it was essential that the selected companies demonstrate a high quality of service in line with the complexity of the proposed work.

A remaining seven buildings were selected, the audits of which needed to be carried out in a short period of time hence it was unlikely that one company could cope with the workload. Furthermore, the philosophy of the consortium was to give opportunities to several companies in order for them to gain experience and understand the correct procedures needed to carry out energy audits based on international energy auditing standards.

The selection process for the first audits therefore allowed an initial overview of the qualifications of the firms in the energy audit market in T&T, thus providing a baseline for creating a shortlist for further tenders.

## Audit support

The consultants set up a sound technical structure to support the implementation of the audits. The consortium implementation team were also supported by the MEEA who were closely involved in the selection of the buildings and the elaboration of the audits.




An energy audit expert was chosen from LKS, as part of the consultant team, who has experience in the implementation of complex audit projects. He supervised implementation and guaranteed the quality of the energy audits. His main tasks were:

1. Support the evaluation of technical tenders and selection process of audit firms.
2. Provide guidance for the execution of the energy audits depending on the type of buildings selected.
3. Supervise, guide and assist the audit firms throughout the implementation process providing individual support according to auditing experience.
4. Provide quality control of the audit reports and organize feedback loops with selected consultants.
5. Implement a capacity building workshop on energy audits in Trinidad (topics selected based on the experiences from the initial audits).

## Guidelines for Energy Audits

As part of the implementation process, guidelines for energy audits in the context of T&T were developed as part of the ToR. The guidelines supported the energy auditors in the implementation of Level 2 audits, and are based on the principles of the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).[29] Reference was also made to the ISO 50001 energy management.

The guidelines include the following specified component activities:

[29] The reference document is "ASHRAE: Procedures for Commercial Building Energy Audits. Second Edition".

- End-use breakdown;
- Detailed analysis;
- Costs & savings for EE measures;
- Operations & maintenance changes.

The document proposes "process and scope of the energy audit", which includes a list of data to be collected, and deliverables as well as a "suggested structure of the energy audit report".

Within the data collection section, both passive and active systems are highlighted in order to obtain full information on the demand and consumption of the buildings.

The developed guidelines can be used by the ESCO committee, as well as the MEEA as guidance for conducting an energy audit (please see **Appendix H**: Guidelines for Energy Audits for the full guidelines).

Additionally, amplified guidelines on passive solutions and awareness were issued for the pilot project.

These guidelines were then developed into a series of presentations that formed the focus of the capacity building workshops given to both the auditors and representatives of the Government, local banks and building managers. Presentations and the capacity building report are available upon request from MEEA.

## Results of the Auditing Process

Detailed findings and conclusions of each audited building can be seen in the final reports available upon request from MEEA.

### *General Observations*

The energy saving potential is high in all the selected buildings. In all the resulting reports, energy savings of over 25% have been claimed through implementing Energy Conservation measures or RE measures that have a payback time of under 5 years. In some cases, such as the only recently constructed Tower C Ministerial building, up to 45% energy savings can be achieved implementing the proposed measures, which can be paid back in just half a year based on existing consumption costs. Energy savings are equivalent to an average of 1,033 metric tons of $CO_2$ emission reduction per building.

The existing energy consumption in most of the buildings is far higher than in comparable buildings in moderate climates. It is clear from the reports that a lack of comparative data for T&T or similar countries makes benchmarking difficult; however, the results imply that climatic, passive and operational influences are greatly affecting the consumption. These are areas, which must be tackled apart from simply upgrading active systems.

In all the buildings audited, common issues have been identified when it comes to energy consumption. The major consumption is air-conditioning: from 40% to 89% (Tunapuna Administrative Building Complex) of the overall energy demand. It is this area that needs to be tackled, when it comes to making the buildings more energy efficient and falls in line with the above observation about climate influencing the demand for energy.

One of the major reasons for excessive energy consumption and low EE is poor energy management, which contributes to a large percentage of the overall building consumption. Even without costly substitution of the existing active systems, building owners could greatly reduce their annual energy bills by turning lights and AC units off when occupants are not in the building. This is especially critical in the case of AC systems that contribute to the principal proportion of energy consumption in every building audited.

Another fundamental issue of high importance (as reflected by the results of the audit reports) is the building design and the building envelope. The latter is often not appropriate for reducing the cooling load, and as a result increases the demand for energy consumption. This factor is critical as it relates to the sizing of cooling systems and must be carefully considered when retrofitting older buildings as 'active systems' can be installed in 'passive spaces' and solar gains can be overlooked in newly constructed building designs.

To name a few examples of increased energy demand from passive gains; the audits have identified:

- Spaces which have air conditioning running with shutters, but no glazing in the windows, causing a loss of cool air to the outside and infiltration of warm air from the exterior.
- Large roof surfaces that have no thermal insulation incorporated, causing increased thermal conductivity as well as having dark surfaces (high albedos), which reduce the possibility for reflecting solar radiation. Both of which implies the over sizing of cooling systems to meet the extra demand from heat gains.
- Lighting zoning that does not respond to incoming natural daylight. The zoning of the artificial lighting circuits are too large or in adequate resulting in lights switched on in areas which could take advantage of natural daylight.
- Large glazed facades that have insufficient solar protection causing direct solar heat gains. Curtains and internal blinds are often used however this does not impede solar radiation entering the space and reduces the possibility of accessing daylight.

Other important issues are related to the operational management and the implementation of EE measures:

In many buildings, the owners' internal organizational structure means a separation of responsibilities, which makes decision-making difficult. Although some public buildings are occupied by various entities, the Government pays the electricity bills. The buildings systems are therefore operated and maintained by other agents. This structure means that there is no direct relationship between how efficient the building is and how much it costs to run, which complicates the decision-making process when it comes to implementing EE measures.

Most buildings have just one electric consumption meter for the entire building or compound, this means it is difficult to relate consumption patterns to specific end-use facilities or applications. This is problematic, as excessive consumption or wastage is difficult to identify when auditing and monitoring the building. In order to provide an accurate breakdown of the buildings consumption, data logging is required for different end-use sectors.

## Shortcomings and Conclusions of the Auditing Process

### *Shortcomings*

**Initial bids**

The relatively low number of companies with experience in energy auditing in T&T complicated the selection process, with resulting bids that were hard to compare for the following reasons:

- Extreme variation in the price of the bids
- Varied experience demonstrated by team members
- Lack of references of similar work

In preparing the TOR for the bids the consultant team also came across the problem of little available information about each building. Generally, building owners do not have full sets of drawings or technical information about the buildings systems. Ideally this information should be available to include in the TOR documentation.

Due to the need to amplify the capacity for energy auditing in the region, the buildings were distributed between three companies. Although some of these companies relied on external international auditing experts, as it was felt that their inclusion would encourage and improve the capacity of the local experts.

**Audits**

The initial draft reports focused purely on the efficiency of active systems without also analysing passive issues which the Consultants believe is essential in order to provide complete energy audit reports in T&T. The energy consumption not only depends on the efficiency and use of the machinery installed but also on the energy demand of the building and the management of these systems.

The thermal envelope is another system that needs to be described and analysed. Combining this with climatic studies provides solutions for reducing the energy demand of the building. Auditors focused on artificial lighting and AC as the main consumption sources without taking note of improvements of the building envelope which could have reduced the cooling and lighting load.

It was also detected that auditors had little experience with comparing the EE of electrical equipment and making suggestions for replacement of inefficient appliances.

It is also vital to investigate, state and analyse the way the active systems are managed, which means getting adequate information from building users and service personnel. In many cases this information was not provided, however this is not simply a shortcoming of the auditors but also a failing by the building managers to provide the information solicited.

To summarize where improvements could be made, the following points should be mentioned apart from the issues on passive solutions and operational management commented beforehand.

- Know-how about insulation material (effect and application) and different window specifications needs to be improved.
- Recommendations for no-investment measures need to be based on realistic scenarios.
- Efficiency of existing electrical equipment needs to be assessed and compared with new equipment on the market.
- Recommendations should include guidance for procurement of office equipment.
- Summaries have to be written from the decision maker's perspective.
- Assumptions for costs of measures are often not well justified.

**Capacity building**

In order to provide guidance on the shortcomings detected in the first audits and to provide capacity building for the local members of the auditing teams, the consultant team organized workshops that coincided with the start of the second batch of audits. The workshop titled *Building EE: Getting the most out of auditing* demonstrated what a complete audit report should contain and placed special focus on awareness and passive measures. Capacity Building Report and presentations are available with the MEEA.

### *Conclusions*

These shortcomings are normal and understandable considering the early stages that T&T finds itself in relation to analysing and implementing EE. There is no existing market for energy audits and so it is not surprising that there is a shortage of professionals with experience in carrying out complete optimal audit reports. The word "complete" must be reiterated, because in some cases auditors went beyond what was expected of them, for example measuring loads, $CO_2$ content in room air, etc. and the fact that the overall reports were late or incomplete should not take away from these efforts.

The shortcomings should not be a barrier but instead provide insight for future improvements. The conclusions can be very constructive for guiding the ESCO committee in providing a solid foundation for a future auditing market. The energy auditors were keen to learn and responded constructively to the consultant team's suggestions, which demonstrates their enthusiasm to form part of a future where building energy consumption analysis is common place.

- Although not thoroughly complete, the findings of the auditors are very valuable. In all the buildings which have been audited common denominators have been identified when it comes to energy consumption. This implies that EE potential is very high and through the measures proposed, large energy savings can be made as indicated in the section above.
- In the final presentations given to the building owners by each auditing team, the participating building managers or representatives expressed their gratitude for this whole exercise and demonstrated willingness to implement at least those recommendations with short payback times.
- In view of future auditing programs and providing constructive advice for the ESCO committee, the following points can be highlighted:
- Although ASHRAE procedures are a good guideline for buildings in the US, in countries such as T&T it is important to include requirements for analysing passive issues to reduce building energy demand.
- ESCO committee needs to emphasize the need for the analysis of the building envelopes so that they can be correctly understood and examined.
- Requirements for data logging of the different systems must be included in order to provide accurate disaggregation of energy consumptions.
- Building managers should have complete information on their electricity bills and building specifications. They should be encouraged to set up a data bank with all the relevant information on their building, including technical information on all major electric equipment (capacity, brand etc.).
- Building managers need to be guided and included in the process of auditing; not only in providing the necessary information for the auditors but also encouraging them in the uptake of audit recommendations and making building users aware of energy saving potentials.
- In order to encourage building managers to carry out energy audits on their buildings, it would be helpful to install incentives (e.g. fixed amounts of grants per air-conditioned floor space).
- In order to avoid the wide ranging and very high priced bids experienced in this project, it would be advised that only maximum (capped) price for energy audits are accepted.

- The results of the audits and the observations made by the Consultants in the various missions demonstrate that large reductions in energy consumption could be made with greater awareness and better operational management of the active systems. This issue should not only be highlighted in audit reports but also reiterated to building users and service personnel through awareness campaigns.
- It is important that emphasis is placed on internal awareness programs which can be valuable tools to help engage staff in making the buildings more energy efficient. These programs can also provide building managers with an internal structure to encourage better energy management and decision making for implementing energy saving measures.
- The implementation of the identified measures requires financial frameworks that induce them to be carried out. Policy makers need to support the audit process with incentives and guidelines to ensure that on receiving the recommendations, building managers are encouraged to implement the measures.
- There are a number of barriers present in T&T, which mean that successful auditing followed by implementation of energy saving measures has a distance to travel. Good examples and show cases are needed in order to stimulate the market. These showcases can be monitored to verify if expected results are met.

The following recommendations are also made with view to improving the capacity of the auditors to carry out energy audits:

- The consultant team recommends that auditors undertake some specific training on EE aspects with regard to building envelopes (learn about insulation material, window specifications, options for shading, natural ventilation etc.)

## Next Steps

### *What needs to be done with the final auditor's reports?*

The reports delivered by the auditors need to be passed on to the building managers of each selected building. Building on the initial interest demonstrated by each manager responsible for implementation of EE, it should be encouraged that at least a proportion of the identified measures are carried out.

In the case of the Tower C Ministerial Building, it would be a great opportunity to carry out all of the ECMs and REMs as a demonstration project showing "what can be done" and setting an example to others. As commented beforehand, implementing all of the identified measures would result in a huge annual energy saving of 5,019 MWh, which corresponds to the mitigation of 3,513 metric tons $CO_2$. Due to the existing high energy prices paid annually, the cost of implementing the six ECMs and REMs would be recuperated in only 7 months.

Simply by improving the energy management within the building, which would ensure that lights are turned off at night and in the weekend, would reduce the energy costs considerably and act as a “dark beacon” for energy awareness in the city.

### *How can this step be supported?*

Guaranteeing that the recommendations are carried out in each building will no doubt require certain support from the MEEA and ESCO committee.

Firstly, in ensuring that the reports reach the correct people at both technical and decision making levels.

Secondly, it is vital that the recommendations are fully understood by these agents, in order that the correct measures are taken to achieve the predicted energy savings.

Thirdly, considering the high initial costs of many of the energy saving measures it will be very important to implant financial mechanisms and provide incentives. This is probably the most important point, as the cost of carrying out the measures will highly influence decision-making.

Fourthly, it will be important that the implementation process is pursued and the building mangers feel supported throughout.

Finally, the results of implementing the measures must be registered, firstly by monitoring the improved energy consumption and secondly by showcasing the results. The most powerful advocate for EE and promoting energy audits will be real life examples of how implementing identified measures can greatly reduce the annual costs of the building. These results should support awareness campaigns to promote further audit programs and greater energy conservation. The resulting monitored data should also be used to set up data banks of energy consumption in public buildings in order to provide benchmarks for further auditing.

### *What needs to be done with the auditing conclusions*

The highlighted conclusions made in the previous section should be addressed by the ESCO committee in order to guarantee a solid base for future auditing and EE programs.

Both the committee and the MEEA should support these findings by providing guidelines, training and programs that guarantee an understanding of the potential of energy audits and set up a technical capacity to both carry out complete audits and implement the identified measures.

In order to facilitate both the uptake of future energy audits and implementation of the recommended EE and RE measures, it would be recommended that support is provided through financial incentives. There are a number of international examples that can be analyzed in order to reach the most appropriate mechanism for T&T for all building typologies. These options could be discussed within the ESCO Committee with interested banks in order to set up mechanisms for private building owners. See **Appendix I**: International Examples of Market-based Financial Mechanisms for EE" for further information.

6

# Renewable Energy

The following chapter takes an in-depth look at the potential and the challenges with regards to different RE technologies in T&T. The consultants have analyzed the potential for solar PV systems, wind energy, biomass, waste to energy, different ocean energy technologies and other technologies, such as concentrated solar power.

## 6.1 Establishment of mechanisms for feeding energy into the grid

As a precondition to be able to feed energy into the grid different options, including Feed-in-Tariffs, Net-Metering, Net-Billing, Renewable Portfolio Standards and Competitive Bidding have been analyzed.

### Feed-in Tariffs

As has been outlined by (MEISTER, 2012), fixed feed-in tariffs (FIT) for renewable electricity have shown considerable success in many countries (see the example of the United Kingdom in the box below). As of early 2013, 71 countries and 28 states/provinces had adopted some form of FIT policy. Developing countries account for the majority of countries with FITs in place, among those countries with only recently adopted FIT schemes, such as Uganda (see box below), Jordan and the Philippines (REN21, 2013). Nevertheless, it should be pointed out that the establishment of feed-in tariffs alone is no guarantee for a successful RE deployment.

Other supporting factors, which are as important as guaranteed financial returns, include the cost and time of administrative procedures for receiving construction and operation permissions. In a number of countries, high feed-in tariffs have shown no positive effect, due to substantial barriers on the legal, technical and administrative side. E.g. unclear and exaggerated environmental requirements can block projects indefinitely and increase costs to such an extent that they cannot be compensated by even generous feed-in tariffs. It is therefore necessary to look at the installation of feed-in tariffs in an integrated manner and at the same time publish guidelines around all issues of the permission process,

### Feed-in tariffs in the UK

In addition to the Renewables Obligation existing since 2002 that requires electricity suppliers to source a specified proportion of their electricity from (primarily larger) renewable energy sources, the UK introduced a new supporting scheme for smaller renewable electricity systems with the Energy Act of 2008. A FIT scheme became effective from April 2010 for all new qualifying installations, including those that had been installed after July 15, 2009. Older systems were only eligible for a reduced FIT rate if they had been registered under the Renewable Obligation by March 31, 2010. The FIT scheme replaces the Renewable Obligation as the main mechanism of support for RE installations with a maximum capacity of 50 kW. Operators of installations over 50 kW to 5 MW have a one-off choice of applying under the FIT or the Renewable Obligation. The FIT is administered by the energy regulator Ofgem.

A FIT is paid for every kilowatt-hour that is generated from selected renewable energy sources as well as by micro Combined Heat and Power (CHP) units, be it for own use or for export to the grid. Any kilowatt-hour fed into the grid will get an additional bonus payment. The FIT can be applied for all RE facilities using biogas and for wind, hydropower and solar PV systems with a maximum capacity of 5 MW[a]. It is differentiated according to the size (capacity) of the plant. In addition, the FIT for PV installations varies depending on other factors: a lower rate is paid, if the power is supplied to a building without an energy efficiency certificate in the band A to D; a medium rate applies, if the operator owns 25 or more PV installations registered for FIT payment. Specific site conditions, e.g. wind speed or solar irradiation, are not taken into account. FITs are paid for 20 years for all technologies and are adjusted annually by the retail price index.

The bonus payment for electricity exports is set as a “floor price” in the legislation, which is also linked to the retail price index. Any operator can opt out of this fixed pricing scheme and negotiate a better tariff with his electricity supplier, who most certainly will only accept this option for larger systems. As long as smart meters are not yet common, exports are deemed to be 50% of all electricity generated for PV and wind installations up to 30 kW. If exports are considered to be higher, operators can use separate export meters.

Customers using solar PV or wind turbines with up to 50 kW need to ensure they use Micro generation Certification Scheme (MCS) certified equipment installed by an MCS certified installer.[b]

Systems operating under FITs have to be registered with Of gem after installation and an application has to be submitted to any electricity supplier participating in the FIT scheme (FIT Licensee) out of a list of currently 16 different companies.[c] The extra costs incurred, including

the technical requirements for grid integration, payment schemes or the requirements of the grid operator. etc.

Setting the right level for feed-in tariffs can be a tedious and time-consuming process. The general principle of cost coverage is easy to understand, but since cost factors are often volatile and depend on size and technology, it is difficult to find the right path between over-administration costs, are spread equally among all Licensed Electricity Suppliers according to their market shares; they can recover the payments from their customers. It is predicted that the extra costs by 2020 will be in the range of US$ 16 annually for the average customer. The main supplier of electricity to a certain facility does not have to be the same company that receives the generated RE electricity.

Default digression levels have been set legally for the different technologies: 3.5% quarterly for solar PV and 5% annually for all other RE electricity. Those levels can be lowered or increased, depending on the deployment rate of each technology, e.g. for PV systems of up to 10 $kW_p$ the default corridor is 100–200 MW quarterly; for lower installation rates the digression is zero, for installations above 200 MW the digression is doubling for every additional 50 MW, up to a maximum of 28%[d]. Furthermore, the government may review any tariff levels on an annual basis to ensure that they are achieving the desired outcomes.

The cumulative capacity of all RE systems stimulated by the FIT scheme had reached about 1,800 MW by September 2013. About 70% of the capacity has been installed in the domestic sector.

With more than 350,000 systems and a total of almost 1,500 MW until the end of 2012, solar PV is the most successful technology. The large majority of those systems are installed in the domestic sector. Despite those results, it had been previously anticipated that even a higher capacity rate would be achieved. And in 2013 the rate of capacity increase slowed down considerably.

**Further information:**

- Ofgem, Feed-in Tariff: Guidance for renewable installations (Version 5; 19 April 2013)
- Website of Feed-in Tariffs Ltd.: www.fitariffs.co.uk
- Department of Energy & Climate Change, UK Solar PV Strategy Part I: Roadmap to a Brighter Future, October 2013

[a] For community owned projects the upper level has been raised to 10 MW in July 2013.
[b] www.microgenerationcertification.org. The MCS is an internationally recognized quality assurance scheme, supported by the UK Department of Energy and Climate Change. MCS standards are predominantly based on international and European standards already in existence.
[c] Note that not all Licensed Electricity Suppliers active on the UK market offer FITs, but those with more than 250,000 domestic customers are required to join the FIT scheme.
[d] In fact, the deployment rate for this capacity range of PV systems has been continuously below 100 MW within a quarter year until September 2013, except in the very first period of May to July 2012.

and under-payment. A more pragmatic approach is suggested by starting with a more generous remuneration payment that may be downsized any time if it proves to be successful or if costs have changed considerably. Frequent adjustments of feed-in tariffs are typical, in particular in the field of solar electricity where costs have dropped considerably in recent years. It is therefore necessary to keep the market under close observation and register any shift at the price front (see box above for the UK example).

For T&T, it is suggested that concentration be placed at the moment on the introduction of feed-in tariffs for wind and solar electricity as the sources of RE that have the largest potential. In particular solar PV can easily be exploited by small domestic operators as well as on a larger scale by commercial and industrial entities. Additionally, a differentiation according to the plant size is further suggested and a capacity cap recommended for the first batch of solar installations as their costs may influence overall electricity generation costs, although with a very limited impact at low capacity volumes.

Details could be established for giving priority to self-consumption of renewable electricity, while limiting the amount of electricity supplied to the grid (see agreement on the new interconnection policy in Grenada in (GRENADA, 2012). The time of payment should not be less than ten years and allow in any case for a secure return of investment. Feed-in tariffs are mainly a guarantee for financing institutions and investors and should help to cope with the high initial costs of renewable technologies.

### GET FiT in Uganda

Several African countries, among those Uganda, Tanzania and Kenya have esablished feed-in-tariffs in the recent past. Usually those feed-in-tariffs are too low to really attract private investment. In order to remove this barrier, a donor-financed premium has been introduced under the name GET FiT in Uganda, initiated jointly by the German Development Bank KfW and Deutsche Bank. The project was officially launched on 31 May 2013. It will support approx.. 125 MW or up to 15 projects of grid-connected renewable energy with 1–20 MW each within the next 5 years.

As electricity tariffs in Uganda are already among the highest in the region, a further burden put on the shoulders of final consumers was not seen as a viable option. Furthermore, investor's confidence is at stake due to the liquidity crisis of state-owned utilities, not only in Uganda. Debt and equity financing is therefore hard to get. The GET FiT premium on top of the already existing feed-in-tariff structure will be paid once the RE plant is operating. Furthermore, the GET FiT programme consists of a Guarantee Facility to secure against offtaker and political risk, as well as a Private Financing Mechanism that will offer debt and dequity at competitive rates.It is a mechnamis to improve the risk profile and commercial viability of new RE projects, initiated by private investors.

The intention of the GET FiT scheme is that it will “kick-start” investment in small-scale grid-connected renewables, but it is expected that the “premium” will no longer be necessary after private investors' confidence has been established. The GET-FiT is in first place intended to open up a new and innovative market, before such support becomes unnecessary due to sufficient market size and lower generation costs. Payments of the premium will be availed on a grant basis, following an open and transarent Request-for Proposal process. The premium is currently only paid for small-scale hydro, biomass energy and bagasse cogeneration. Other technologies or sources are for the moment not included or may not need any additional support due to already high “regular” feed-in-tariffs (e.g. US$ 0,362 per kWh solar energy).

For further information, see: Deutsche Bank, GET FiT in Uganda, November 20, 2013 and www.get-fit-uganda.org.

As has been outlined in the section on wind and solar energy, the cap of 100 kW for feed-in tariffs per project as proposed in (MEISTER, 2012) is contra-productive, as it would in fact limit the application to solar electric systems, since the standard size of wind turbines nowadays on the market is in the range of 1.5–3.0 MW. Smaller wind turbines exist as well, but their specific costs are high (see Figure 1 in (MEISTER, 2012)) and the maintenance required does normally not allow their application by homeowners or commercial entities.

## Net-Metering

Net-metering schemes, which would value the renewable electricity self-consumed or exported to the grid on a 1:1 basis in comparison to the electricity purchased from the utility (as widely applied in the U.S. and more recently in the Dominican Republic, the Philippines and Brazil, see box below). Such schemes exist in at least 37 countries, but are not advisable in T&T under current conditions with highly subsidized and therefore low consumer tariff rates. To

### Net-metering in Brazil

Brazil has introduced in April 2012 a net-metering scheme for renewable energy power plants of less than 1 MW. These are categorized into micro-generation for domestic purposes (< 100 kW) and mini-generation for commercial and other purposes (> 100 kW) and comprise hydro, solar, biomass, qualified cogeneration and wind. Technical requirements for the implementation of this scheme were completed by the different distribution companies in December 2012.

Under the net-metering scheme, excess power exported to the grid is being credited against the consumption of the succeeding 36 months. Credit information is included in the invoice of the customer; a cash compensation for any positive balance at the end of the crediting period is not taking place. It is therefore recommended that PV systems are designed to not exceed the own average electricity demand. Public agencies and companies with subsidiaries that choose to participate may also use the exceeding electricity produced in one of their facilities to reduce the bill of another unit.

In addition, for all RE installations of less than 1 MW the administrative requirements have been substantially simplified. This entails expediting the review and processing of applications within a reasonable timeframe, requiring distribution companies to conduct interconnection studies at no cost to customer-generators and simplifying contractual arrangements. Regulations also determine that while on-site infrastructure and meter upgrades are the responsibility of the customer-generator, the distribution utility has to pay for routine maintenance of the meter, including testing and eventual replacement.

The net-metering programme is further supported with tax benefits for renewable technologies, in particular for solar PV, with reduced import duties for modules of 12% and VAT exemptions. Although the climatic conditions are quite favourable and electricity rates are relatively high in Brazil, the current level of installation costs in most parts of the country are prohibitive for a competitive operation of PV systems, in particular those of smaller size. At the end of 2013, a total of 131 RE systems had been grid-connected or received permission under the net-metering scheme.

produce electricity at competitive costs, PV investments would need significant financial and fiscal incentives, in the order of subsidies granted to electricity generation from natural gas.

The solar power generated in excess of the owner's electricity consumption is fed into the grid through a net-meter, which is a bi-directional energy meter capable of registering both import and export of electricity. This net generation is then credited to the owner's account and adjusted subsequently against imports from the grid over a defined period of time (so-called "banking") or even reimbursed at the level of consumption rates in case of a positive export balance. On the one hand, net metering is technically easy to realise, because it works solely as an accounting procedure and requires no special metering. On the other hand, this mode of renewable energy incentive places the burdens of pioneering renewable energy primarily upon fragmented consumers, who do not have the bargaining power, when negotiating with utilities.

Net-metering regulations vary strongly from country to country, mainly with respect to the period within which credits can be used for compensation of purchased electricity (e.g. relating to varying seasonal peaks).

## Net-Billing

Net-Billing can be seen as a special format of feed-in-tariffs for electricity from intermittent renewable energy sources (wind/solar). But while the latter are usually established on the basis of actual generation costs from the renewable electricity facility to allow for a reasonable return on investment, net-billing tariffs are oriented on costs of the existing and future generation pattern using conventional fuels. How the so-called "avoided costs" are being calculated varies from case to case. Some schemes take into account that renewable energy may be able to replace high-cost peak load generation, while other do not. It is also disputed, if avoided costs should be based on the average of the existing generation park or if more weight should be given to most recent capacity additions, even including capacities to be added in the future, that usually imply higher costs. Jamaica has introduced a model for determining avoided costs and pays a 15% bonus on top of this amount for all renewable electricity fed into the grid by private operators of up to 100 kW facilities.[1]

In the case of T&T, avoided costs under the current natural gas price regime for the electricity sector are too low to allow for an economical operation of intermittent renewable energy generators using a net-billing reimbursement scheme. Even if most of the electricity would be used in-house, the low electricity tariffs will inhibit a reasonable operation from an economic perspective. Substantial other financial or fiscal incentives would be needed to drive down capital and financing costs to achieve competitiveness.

[1] www.myjpsco.com/net-billing/.

## Competitive Bidding

For large-scale wind and solar plants we would recommend to consider tender schemes (also called auctions or competitive bidding), which have been successfully introduced in South Africa (see box below) and Brazil, among other countries. By early 2013, a total of 43 countries were identified with using competitive bidding for large RE additions, with 30 of these countries classified as upper-middle income or lower (REN21, 2013). Also Jamaica in 2013 has called for bids to supply renewable energy from solar and wind facilities and will sign long-term contracts (20-year Power Purchase Agreements) with providers that offered lowest prices and complied best with technical requirements.

Tendering schemes range from technology-specific to technology-neutral; include varying levels of capacity (some setting volume caps); occasionally set price ceilings; and often include various criteria for project selection, so that price is not the only or most important factor, as in the case of South Africa.

Such bidding procedures require primarily a good preparation on the side of the inviting entity (e.g. the regulator) and good knowledge of the subject for assessing the technical and financial proposals. Calls can be site and capacity specific, so that they fit perfectly into generation expansion plans and use existing resources adequately. Of course, there is a risk of price dumping among competitors and the possibility of realization failures or delays, if financing is not secured.

In the case of Jamaica, the competitive tender organized by the Office of Utilities Regulation (OUR) in 2013 called for 115 MW of RE electricity on a Build, Own and Operate (BOO) basis and at sizes of at least 100 kW. Out of the large number of proposals (28 in total, of which two for wind, one for biomass and 25 for solar energy) only three bidders qualified for energy-only supply with a total capacity of 78 MW, comprising 58 MW wind energy and 20 MW solar energy. The proposed delivery prices ranged from US$ 0.129 to US$ 0.188 per kWh. None of the bids were submitted in request of firm capacity (e.g. from biomass energy), for which 37 MW had been reserved.

## Renewable Portfolio Standards

Renewable Portfolio Standards (RPS) are binding mandates for utilities or consumers to either generate, sell or purchase certain quantities of their total electricity volume from renewable energy sources. In the case of T&T, setting legal targets for T&TEC to diversify its electricity mix away from the current 100% dependency on natural gas, would be the easiest and best way to achieve the Government's renewable energy objectives. T&TEC would have the possibility to either generate renewable electricity through own investments or purchase

### South Africa – Renewable Energy tenders

South Africa relies more than any other country in the world on indigenous coal for electricity generation and has also one of the lowest electricity consumer tariffs globally. Nevertheless, the most recent electricity plan[a] contains ambitious targets for renewable energy: 8,400 MW each of wind power and solar PV and 1,000 MW from CSP, out of a total projected system capacity of around 90 GW, by 2030. Not the least, this objective will assist in reducing greenhouse gas reductions significantly, which the government pledged to achieve.

In 2009, the energy regulator NERSA announced renewable energy feed-in tariffs for a range of technologies. However, despite a pressing demand for electricity, there was little interest in the original FIT rates. NERSA therefore raised the rates, doubling the FIT for wind and even trebling it for concentrated solar power. Rates were designed for a real return on equity of 17% with full inflation indexation. Furthermore, the payment period was extended from 15 to 20 years. Nevertheless, in early 2011, two years after FITs had been first announced, no power purchase agreements had been signed with ESKOM, the major state-owned electricity provider and official purchaser of all RE FIT electricity. One reason for this has been probably that no real procurement occurred, that licensing and permission procedures remained unsolved and that ESKOM was not really willing to purchase electricity at prices far above their own generation costs. Furthermore, some parties considered that the preferential treatment of RE electricity was unconstitutional in an environment that is based mainly on the competitive procurement of electricity supplies with regard to private producers.

The government therefore decided to replace the FIT scheme with renewable energy bids (competitive tenders) that have drawn considerable competition from international developers. The new Renewable Energy Independent Power Producer Procurement (REIPPP) program was started in August 2011. The program is mainly used to tender installations with more than 5 MW each, but a capacity of 100 MW is reserved for small-scale projects with between 1 and 5 MW. It is considered to end in 2016, after a maximum of five bidding rounds. The maximum capacity volume to be tendered has been fixed at 3,725 MW, including 1,850 MW of wind and 1,450 MW of solar PV.

So far, three auctions have taken place in 2011, 2012 and 2013. The first auction was not capped in terms of capacity (except for the overall maximum); the second round had a cap of 1,044 MW, the third (which ended on August 19, 2003) of 1,166 MW. In the third and second round, the maximum capacity was set per technology, so that there was no competition across different RE sources. Most capacity has been awarded in the first two rounds for electricity from wind energy (1,196 MW) and from solar PV (1,098 MW). All solar PV projects are large ground-mounted installations, ranging in size from 5 to 75 MW. The average contract price has decreased considerably: from US$ct 14.3 per kWh for wind in 2011 to US$ct 11.2 per kWh in 2012 and from US$ct 34.5 per kWh for solar PV in 2011 to US$ct 20.6 per kWh in 2012. Prices varied in 2012 from 10 to 12 US$ct per kWh for wind and 17 to 22 US$ct per kWh for solar PV. All those prices already contain an inflation index and will not be adjusted during the contracted period. Despite lower prices in round two, it is still expected that real returns on equity are still well above 10%. The major difference between the two auctions was, that in round one the ceiling prices (being about equal to the former FIT rates, except for solar PV) had been disclosed to the public, with price offers generally close to the limit. While in round two the ceiling prices were kept undisclosed, leading to more competition in combination with the capacity cap.

The selection of projects is following a two-step approach. In the first step, compliance with general financial and technical criteria as well as with minimum threshold requirement for economic development and other requirements is checked. For example, wind developers are required to provide 12-months wind data and a generation forecast. The economic development requirements are complex, incorporating 17 sets of minimum thresholds. Wind projects for example, have to demonstrate that at least 12% of company shares are held by black South Africans and another 3% by local communities. At least 1% of the revenues have to be donated for social purposes. Furthermore, a minimum threshold was set for the local economic content. Only bidders satisfying all criteria in the first step could proceed in the evaluation. In the second step bid prices counted for 70%, while the rest was weighted by projected job creation, local content, enterprise development and other factors. All selected bidders have to apply for a generation license with the regulator.

All projects are contracted by Eskom under a Power Purchase Agreement (PPA) and a fixed price for 20 years. All contracts out of the first auction round, including PPA and implementation agreements with the government had been signed by November 2012, after a partly lengthy administrative process. Contracts for projects from round one were finalized in May 2013. Those projects are now under implementation with the contracted of round two to be commissioned until the end of 2014. It needs to be seen, if all projects will be realized or some may fail due to financial hurdles, lack of construction permissions or for other reasons. If all works out as planned, the REIPPP program in its first phase could trigger an investment volume of up to US$ 15 billion until the end of 2016.

Critics point out that the very stringent criteria for the bidding contest (e.g. the requirement for local content) lead to high transaction costs on the side of the bidders. This could also be one of the reasons why the contracted prices are still significantly higher than in other parts of the world. High transaction costs were also faced on the site of the government that had to rely on external advisors. Size and complexity of the REIPPP program put considerable constraints on legal and financial advisory services. It has also been remarked that the stringent economic development criteria could easily lead to higher costs in a still small and non-competitive RE manufacturing market.

In December 2012, the government published a new IPP Procurement Program that calls for procuring another 3,200 MW of RE capacity, as well mainly from wind and solar PV, to be operational between 2017 and 2020.

**Further information:**

- www.ipprenewables.co.za
- Anton Eberhard, Feed-in Tariffs or Auctions?, in: viewpoint No. 338, April 2013, publication of the World Bank
- Adele Greyling/Eskom, Renewable Energy Independent Power Producer Procurement Programme – An Eskom perspective (presentation), 27 July 2012
- IRENA, Renewable Energy Auctions in Developing Countries, 2013

[a] Department of Energy Integrated Resource Plan for Electricity 2010–2030, Final Report, 25 March 2011.

the power from independent producers. Of importance would only be the total amount and share of renewable electricity fed into the public grid. In this most simple scheme, no differentiation would be made between various renewable energy sources, while a more targeted approach could also establish objectives for specific contributions from wind or solar, for example.

In any case, the setting of RPS targets needs to be realistic and cover at least a period of five years into the future with progressive increases to allow for long-term planning. Close monitoring of progress achievements will be necessary and mechanisms need to be considered in case that targets are not being met. Chile has established a mechanism, whereby utilities not complying with their RPS obligations are heavily penalized. This could be a suitable approach for T&T, which needs to be further discussed. RIC certainly could use sanctions with regard to tariff increases, as it has done in the past. However, to understand if RPS are a viable option without burdening the Government's budget has to be investigated. A better alternative could be that RIC is taking over responsibility for tendering RE projects for private investors, in case that T&TEC is not capable of meeting the Government's objectives.

## The Development of Power Purchase Agreements

Power Purchase Agreements (PPAs) are in principle contracts between operators of generation facilities and transmission or distribution operators for the purchase of electricity fed into the grid. While such contracts may not be necessary for the operation of small-scale generators with defined feed-in-tariffs and clear rules and standards defined in a regulatory framework, PPAs may be a necessary requirement for defining the obligations and responsibilities of both parties in the case of larger RE generators. It is recommended that model PPA contracts are designed in order to make potential investors aware of their future duties and to allow for a rapid non-negotiable agreement between operator and utility.

PPAs typically contain clauses on the safe operation and liability for any damages occurring on either side, they may request a forecast of the anticipated monthly generation to allow for better planning on the side of the grid operator, they will define communications on planned outages, may refer to standards that need to be fulfilled and will—as a minimum—establish rules for measuring and reimbursing the delivered electricity. They may further define responsibilities for interconnecting the system and maintaining such interconnection and how costs are being shared for connection lines and possible needs for strengthening existing grids and investing into transformers.

The content and required precision of any PPA depends in first place on the level of legal frameworks, standards and norms already existing. Whatever has been defined elsewhere, for example with regard to interconnection and parallel operation of RE power plants, will not have to be specified and repeated in a PPA. If the substantial effort needed for establishing such standards and norms (and keeping them up-to-date) is really worthwhile, will not the least depend on the number of installations expected to be affected. If only a few installations will be connected in the future, it may be easier and faster to include the main technical requirements in the PPA and revise such model agreements, whenever necessary.[2]

## 6.2 Generation Costs for Onshore Wind Farms and Small-scale PV Systems

### Levelized Cost of Energy (LCOE)—Background

The levelized cost of energy (LCOE) is the constant unit cost (per kWh or MWh) of a payment stream that has the same present value as the total cost of building and operating a generating plant over its lifetime. There are several different methods used to calculate the LCOE, a metric used to evaluate the costs of generation for energy projects and the total system impact of design changes. The methodology used for this analysis is fully described in (SHORT, 1995). It is used in several studies by the U.S. National RE Laboratory (NREL) and other major research organizations.

There are four major inputs into the LCOE equation: The first three—installed capital cost (ICC), annual operating expenses (AOE) and annual energy production (AEP)—enable this equation to represent the system impacts of design changes. The total costs of financing are represented by the fourth major input—fixed charge rate (FCR) or capital recovery factor (CRF)—that determines the amount of revenue required to pay the carrying charges on an investment. This detailed split of costs is required when analyzing the trends and comparing data, as these inputs depend on the regions or location of the investment. The currency and year will be given whenever inflation needs to be removed from the calculation, and converted to comparable values when required. Furthermore, there needs to be a distinction between real and nominal LCOE, as they may differ significantly.

No analysis will be valid, if it is not based on sound and consistent data. This holds particularly true for the comparison between renewable energies, such as wind and solar power, as in this report, as well as the comparison with conventional power plants. The underlying assumptions will be pointed out as clearly as possible in this report. An article cited in (JARGSTORF, 2011) is a great example of how wrong assumptions can lead to opposing results, if dispatchable and non-dispatchable power plants are compared and unrealistic capacity factors have been assumed and are confused with availability of a plant.

[2] An example for a standardized PPA can be found here: http://ppp.worldbank.org/public-private-partnership/library/tanzania-standardized-small-power-purchase-agreement-main-grid-connection.

## Wind Power

### *Global Development*

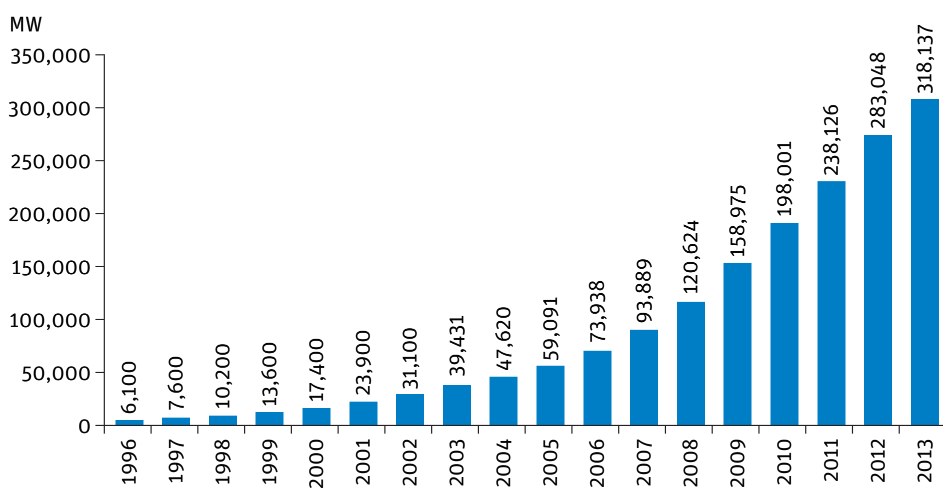
Wind power is a natural resource that has been exploited by humans since approximately 200 B.C., when the wind wheel was invented in modern day Iran. In 1888, windmills were used for the first time to power generators for electrifying isolated farms in the rural mid-West of the United States. However, the large-scale construction of horizontal axis wind turbines is a more recent phenomenon as **Figure 24** outlines:

The figure clearly shows a strong growth in the past 17 years, with an average increase of approximately 20% per annum (but also with lower growth rates in recent years). At the end of 2013 some 318 GW of wind power capacity had been installed globally. More than 70% of this capacity was concentrated in only five countries: China (91 GW), USA (61 GW), Germany (34 GW), Spain (23 GW) and India (20 GW). There are several reasons for this stormy development of wind power: political strategies, supporting mechanisms and increased competitiveness against other sources of electricity being the obvious three.

Electricity from wind energy has reached significant penetration shares in a number of countries: In Denmark it contributed with more than 28% to the generation mix (based

**FIGURE 24**

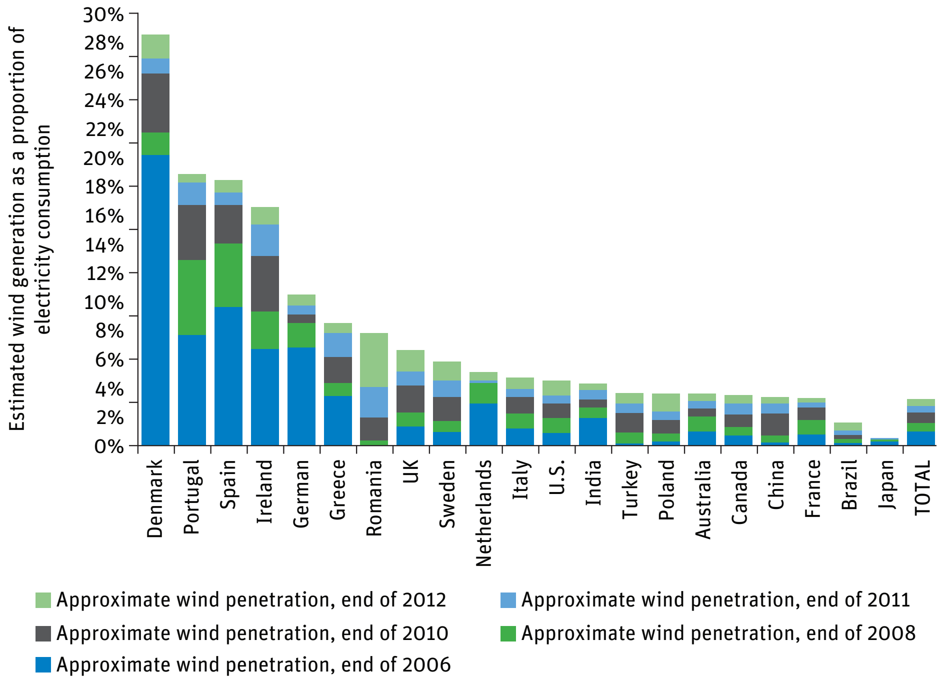
Global cumulative installed wind capacity from 1996–2013




*Source*: GWEC, 2014.

**FIGURE 25**

Wind penetration rates in different countries




*Source*: Berkeley LAb estimates based on data from Navigant, EIA, and elsewhere.

on electricity consumption in 2012), in Portugal and Spain with more than 18% (see **Figure 25**).

It is expected that in the years to come more than 45 GW wind capacity will be installed annually. By the end of 2017, total cumulative installed capacity should have passed 500 GW (GWEC, 2012).

### *Status of wind energy use in the Caribbean*

At the end of 2013, more than 230 MW wind power had been installed on Caribbean islands. The countries resp. islands using wind energy at utility scale were Aruba (30 MW), Bonaire (11 MW), Curacao (30 MW), Cuba (12 MW), Dominican Republic (85 MW), Guadeloupe (26 MW) and Jamaica (39 MW). Others, such as Grenada, are planning to install wind turbines in the near future. A small project of 2 MW is in the process of preparation with support by the European Union for the tiny island of Carriacou. Cuba has ordered 51 MW wind turbines for a farm that is planned to be inaugurated in September 2015. Jamaica's wind operator Wigton

Wind farm will construct another wind farm of 24 MW to be commissioned by August 2015, following a tender in 2013 that selected three bidders for a total of 78 MW RE electricity, among those another wind farm of 34 MW. The largest wind farm in the Caribbean with 77 MW is operated by the public-private enterprise EGE Haina in the Dominican Republic since 2013, generating about 220 GWh annually.

To date, wind power is not used in T&T. However, the main RE choice for bulk electricity generation for the national grid is wind power and a target of 5% of the present peak demand (or 60 MW) by 2020 is assumed to be realistic and achievable, according to the National Renewable Energy Committee.

In the past, only one experimental 10 kW wind turbine was installed in 1994/95 in Bacolet, Tobago by T&TEC. It revealed some favourable results, but the project was short-lived.

### *Type and size of turbines*

The following chapters will focus on the economics of wind power, from which political initiatives should be drawn. To arrive at a LCOE prediction for T&T, the NREL baseline case outlined in (TEGEN, 2012) will be adjusted to reflect the particular local conditions.

The wind turbines that have caused the large increase in installed capacity are all three-bladed horizontal axis turbines, with rated power in excess of 500 kW. Recent developments reach capacities of between 5.0 and 8.0 MW. There are plans for turbines as big as 10 MW, but these will be mainly dedicated to offshore purposes. In the past, projects in the Caribbean such as the Wigton and Munro wind farms in Jamaica have used relatively small wind turbines of between 750 and 900 kW. In other cases, wind turbines were installed that can be lowered at any time to protect them from hurricanes.

Most current projects are aiming for sizes of between 900 kW and 3 MW which—in places with large cranes available—has become the standard size for wind turbines (JARGSTORF, 2011). The detailed analysis in (TEGEN, 2012) assumes a 1.5 MW turbine. However, as all numbers are calculated by considering the energy production throughout the lifetime, the exact size of the turbine is not so important when performing LCOE calculations.

### *Installed capital cost*

The specific costs of wind turbines have decreased in the past, even though not at a consistent level, and there is still considerable disagreement over why exactly the price for installed capacity has varied in the way it has. A comparison of turnkey prices and installed capacity worldwide and their development with time indicates a learning-by-doing effect and shows that the wind turbine industry had a learning rate of 14.4% in the U.S. in the past three decades (LANTZ, 2012).

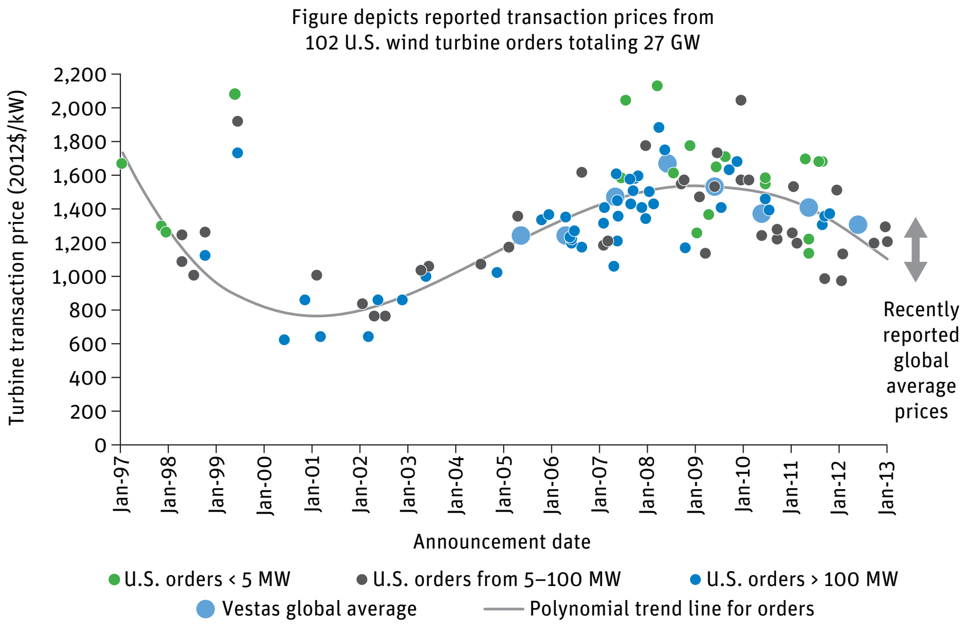
The learning rate appears to have tailed off between 2001 and 2009, as **Figure 26** highlights.

There is considerable debate and uncertainty over the exact reasons for this strong price rise after 2002. Market forces, such as higher raw material prices, increased labour and energy costs and improved profitability certainly play a role, but a reduction in the learning rate may also be to blame for the increase. Prices fell again since 2010 and this trend is expected to continue, but again this fall is from elevated prices in previous years, therefore the exact perspectives remain unclear.

Although installed capital costs are very important when calculating the LCOE, there are other factors that must be looked at in detail. In fact, LCOE of wind power have even decreased during times of rising installed capital cost, because the more expensive (per MW installed)

**FIGURE 26**

Historical wind energy capital costs in the United States




*Source*: WISER, 2013.

and larger turbines achieved higher capacity factors by reaching higher altitude winds. Therefore the elevated costs were offset by an even greater benefit in energy production. In 2010, the average installed costs had been US$ 2,155/kilowatt (kW), which then came down to about US$ 2,000/kW in 2011.

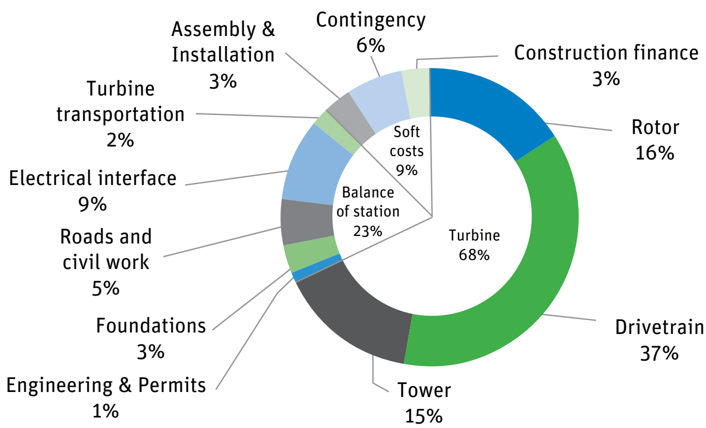
**Figure 27** gives an overview of the installed capital cost distribution of a wind turbine. This helps to understand the trends and to analyse the impact of certain parameters, such as transport or financing.

To determine the capital cost in T&T one must first establish the costs that are likely to differ from the origin of this assessment, in this case the United States. These are the costs for roads and civil construction, turbine transportation and assembly and installation. The difference is mainly due to a lack of infrastructure in T&T where the effort to move large oversized trucks would most likely be higher than in other nations as the consequence of a lack of major roads in certain regions. On the other hand, parts can be shipped to major ports and handled there with ease, reducing the distance required to travel on land.

A major constraint is the likely unavailability of large cranes near the site and the lack of trained assembly crews. This is a major cost factor. Exact values are difficult to obtain, but one can assume that the cost of installation will easily double if not triple. This may reduce very quickly as more wind turbines are installed in the Caribbean and in T&T in particular. But the longer sea transport and larger amount of required civil works also re-

**FIGURE 27**

Distribution of capital cost of a wind turbine by sectors




*Source*: TEGEN, 2012.

main elevated cost factors in the future. Unless more detailed data are available it is assumed that the overall cost of installed capital will therefore increase by about 10%. This is a major uncertainty and only a direct quote for a particular project or the obviously not publicly available cost breakdowns from previous wind parks in the Caribbean can provide a more reliable value.

### *Annual operating expenses*

Annual operating expenses are assumed to be US$ 34/kW or US$ 10/MWh (WISER, 2011). The value depends on how the maintenance is scheduled and by whom it is performed. The first wind turbines installed in T&T are most likely going to be serviced from abroad and would therefore incur higher maintenance costs, but as the number of wind turbines in the Caribbean increases those costs will quickly decrease. As no specific information on maintenance contracts to companies abroad is available, the value was left unchanged. As the LCOE is rather insensitive to the annual operating expenses due to their small contribution compared to installed capacity and capacity factor, this was deemed acceptable.

### *Capacity factor*

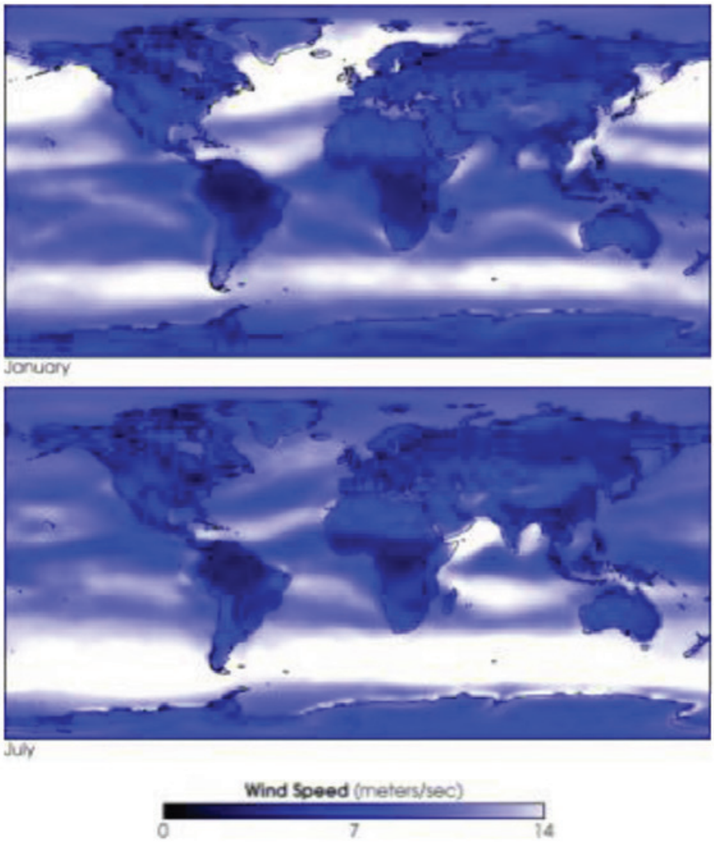
The capacity factor is the percentage of time a power plant or wind turbine would have to run at full capacity to reach its actual annual power output. The NREL baseline case assumes a capacity factor of 38% for onshore wind turbines (WISER, 2012). This is a rather high value for onshore plants and reflects the importance of the capacity factor on the LCOE. In general a high capacity factor is reached in areas with consistently strong winds. **Figure 28** shows the variation of annual wind speeds with the seasons. As the map reveals, T&T lies in an area with strong winds all year round. The southern Caribbean in general has particularly high average wind speeds. The detailed wind map of Grenada shows medium annual speeds of 6.5 to 7.0 m/s at the shore at a height of 30 m (JARGSTORF, 2011), while wind farms in the Caribbean have mainly hub heights of between 50–70 m and therefore benefit from even higher velocities.

This is reflected in the capacity factors of wind farms in the Caribbean, which achieve 30–35% in Jamaica, 28–34% in Suriname and 40% in Bonaire. There is a trade-off between capacity factor and installed capital cost as tower height, rotor diameter and generator size all affect electricity production and installed capital cost. It is up to the detailed planning to determine the optimal size of these parameters. This analysis can only assume that planners are capable of doing so.

As outlined earlier, the trend in wind turbines is towards increasing capacity factors, even at the expense of higher capital costs. However, local weather conditions also play a part in determining the capacity factor of a wind turbine. Using the above mentioned figures and comparing them to those used in the NREL wind energy report (WISER, 2012) one quickly realizes that a value of 38% seems realistically achievable in T&T.

**FIGURE 28**

Annual average wind speed distribution




*Source*: ZAAIJER, 2012.

The possible lack of large cranes and sufficient access roads may limit the construction of wind turbines in T&T and therefore it is unlikely that very large wind turbines achieving even greater capacity factors are a realistic option at least at the beginning of a wind deployment program in the country. The extent to which these factors restrict very large wind turbines needs further investigation. However, the excellent metrological conditions due to the trade winds make high capacity factors achievable even with smaller wind turbines.

Unfortunately, the above figure does not contain information on the altitude at which this speed was computed; therefore it should be used with caution. But it does clearly show the beneficial position of the southern Caribbean with respect to constant trade winds, a resource which should be exploited.

In this regard, the just recently tendered wind resource assessment for T&T by the National Energy Corporation (NEC) is a very useful and much needed activity to assess the wind potential in particular along the East coast of Trinidad more accurately. Only then can the technical and economic potential of wind power for T&T be assessed in more detail.

### *Discount rate*

The discount rate is used to convert future costs to a present value. However, it is very important to note that the discount rate given by banks is not the discount rate investors and planners will use. Therefore both values are given in the results section. Discount rates can be converted from real to nominal, and vice versa, with the following formula:

$$d_n = (1 + d_r) \times (1 + e) - 1$$

$$d_r = \frac{1 + d_n}{(1 + e)} - 1$$

where $d_n$ is the nominal discount rate, dr is the real discount rate and e is the inflation rate.

Using this discount rate the Capital Recovery Factor (CRF) can be calculated according to the following formula:

$$CRF = \frac{i(1+d)^t}{(1+d)^t - 1}$$

where $t$ is the number of years and d the (nominal or real) discount rate.

Some publications also use the Fixed Charge Rate (FCR), which takes depreciation and corporate tax into account.

$$FCR = CRF \times \frac{1 - T \times D}{1 - T}$$

where $T$ is the marginal corporate income tax rate and $D$ the present value of depreciation.

For a detailed analysis of LCOE on a project base, the attached spreadsheet provided by NREL is very useful. However, as it requires project specific information and investor decisions, it is not suitable for a general estimate of LCOE. Thus the selected method at this stage is the “simplified LCOE.

The real discount rate used in this report is 4.75% as given by the Central Bank of Trinidad and Tobago on December 6th, 2012. The nominal rate is 14.55%, using the October 2012 inflation rate of 9.35%.

To convert from US$2010 to TT$2012 a factor of 6.78 was used, based on 6% inflation since 2010 and a currency conversion of 6.4 TT$ to US$ 1.0, which was approximately the exchange rate January 2013.

### *LCOE of wind power systems in T&T*

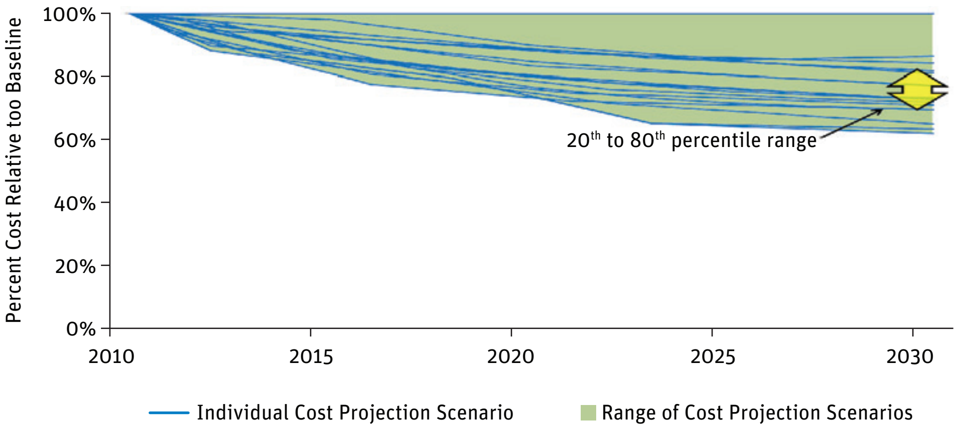
With these assumptions and estimates we can calculate the LCOE for T&T for 2012 and then extrapolate the information using the LCOE predictions from the summary study about the future cost of wind energy (WISER, 2012). As **Figure 29** reveals, the spread between the studies is considerable, but looking at the 20th and 80th percentile range, it shows that a price drop of 5 to 15% is expected until 2015 against 2010 levels. This is in line with the reported costs from 2011 and 2012.

Therefore for the prediction of the future LCOE development in T&T this price drop will be taken into account. Using the values established earlier we get the following results:

The assumptions are summarised in **Table 30** (see also **Appendix J**: Current Electricity Generation Costs for On-shore Wind Farms).

**FIGURE 29**

Scenarios of LCOE development




*Source*: WISER, 2012.

**Table 29** Prediction of levelized cost of wind energy in US$/MWh

| Year of installation | Levelized cost of energy (real) in currency/MWh | | | | | |
|---|---|---|---|---|---|---|
| | Minimum (20th percentile) | | Mean | | Maximum (80th percentile) | |
| | US$ (2010) | TT$ (2012) | US$ (2010) | TT$ (2012) | US$ (2010) | TT$ (2012) |
| 2012 | 47.4 | 321.6 | 57.2 | 388.0 | 72.6 | 492.5 |
| 2015 | 43.9 | 297.5 | 54.5 | 369.6 | 71.2 | 482.7 |
| 2017 | 38.9 | 263.7 | 50.6 | 343.4 | 69.0 | 467.9 |
| Year of installation | Levelized cost of energy (nominal) | | | | | |
| | Minimum (20th percentile) | | Mean | | Maximum (80th percentile) | |
| | US$ (2010) | TT$ (2012) | US$ (2010) | TT$ (2012) | US$ (2010) | TT$ (2012) |
| 2012 | 89.2 | 605.3 | 101.3 | 687.2 | 118.2 | 801.8 |
| 2015 | 82.5 | 559.9 | 96.5 | 654.5 | 115.8 | 785.8 |
| 2017 | 73.2 | 496.3 | 89.6 | 608.1 | 112.3 | 761.7 |

*Source*: Own elaboration.

**Table 30** Assumptions for LCOE calculation

| Parameter | Minimum | | Average | | Maximum | |
|---|---|---|---|---|---|---|
| Installed capital cost | 1,800 US$*(2010)* | 12,211 *TT$(2012)* | 2000 US$*(2010)* | 13,568 *TT$(2012)* | 2,200 US$*(2010)* | 14,924 *TT$(2012)* |
| Lifetime in years | 25 | | 20 | | 15 | |
| LCOE change in 2015 | −7.5% | | −4.75% | | −2.0% | |
| LCOE change in 2017 | −18% | | −11.5% | | −5.0% | |

*Source*: Own elaboration.

Shortcomings:

- No reduction in power production over time has been considered;
- Prices for the period after 2012 are still speculative with no hard data available, but reduced turbine costs due to increased global competition may yield very low ICC; installed costs as low as 1,600 US$/kW have been reported recently (TEGEN, 2012).

### *Conclusions and Recommendations for next steps*

Work needs to be done in T&T to assess LCOE more accurately and to estimate the economic and technical potential and impact, including:

- Perform detailed wind measurements at potential concrete sites, based on the national wind resource assessment;
- Use methods as recommended in (JARGSTORF, 2011) to find potential sites;
- Establish legislation that allows wind farms to be operated by Independent Power Producers;
- Establish a support scheme for the promotion of wind farms as long as subsidies for conventional power have not been removed;
- Address the need for priority grid access legislation and the use of tax incentives and other financial support.
- Design technical guidelines for grid connection and operation of wind turbines.
- Assess impact on grid stability and capacity if relevant levels of wind energy are fed into distribution or transmission lines.

The proposed contribution of 60 MW wind energy by 2020, will result in capital costs of about US$ 108 million, exclusive of connection costs. Doubling the share to a more reasonable and achievable 120 MW would lead to investments of US$ 216 million. The annually 368 GWh produced would reduce $CO_2$ emissions by up to 257 kt, depending on the system of fossil-fuel power plants, whose generation will be substituted.

Comment: The recent suggestion for a feed-in tariff in T&T (MEISTER, 2012) is a good starting point, but the suggested capacity cap of 100 kW for wind power does not reflect the actual needs and is contra-productive. If T&T wants to promote wind power it should not establish such a cap on wind turbine sizes which would prevent the country's ability to gain full benefit of this RE resource (see also chapter 6.1 and following).

## Photovoltaics

### *Global Market Development*

In 2012 alone, investments with a total volume of US$ 140.4 billion were made in the PV sector, down by 11% against the previous year due to falling prices, but still outperforming all other RE technologies. Out of this volume, US$ 51.7 billion were spent in developing countries, namely in China (BLOOMBERG 2013). The world's cumulative PV capacity surpassed 100 GW installed electrical power during 2012, achieving just over 102 GW at the end of the year (EPIA, 2013). An estimated 31 GW was commissioned in 2012 alone, similar to the figure a year ago, although the strong European market declined for the first time against the previous year. Germany was the top market in 2012, with 7.6 GW of newly connected systems, followed by China (estimated 5 GW), Italy (3.4 GW), the USA (3.3 GW), and Japan (estimated 2 GW).

In 2013, the picture looked slightly different, according to the European Photovoltaic Industry Association (EPIA, 2013), with a total installed capacity of 37 GW, and China (11.3 GW), Japan (6.9 GW) and the US (4.8 GW) leading the charts. Analysts of Deutsche Bank expect that the market of new installations will rise to between 45 and 50 GW in 2014, a nearly 50% increase against the anticipated implementation figure in 2013. Depending on future framework conditions, it is assumed that the global annual PV market will reach between 48 GW and 84 GW in 2017 (EPIA, 2013). In the European Union, PV covered 2.6% of the total electricity demand in 2012, while it was already close to 5% of gross electricity consumption in Germany. Within only five years, PV has gained the number one position of generation capacity addition in Europe (FRAUNHOFER, 2013b).

Between early 2009 and early 2013, levelized costs of PV installations with crystalline silicon cells fell by 57–58%, while those with thin-film cells dropped by 44%, in the face of ferocious competition and oversupply in the solar manufacturing chain.

Spot market prices for crystalline silicon modules sold on the European market in October 2013 ranged from € 0.51/W (US$ 0.69/W) for products from India and Southeast Asia to € 0.73/W (US$ 0.99/W) for products from Japan and South Korea.[3]

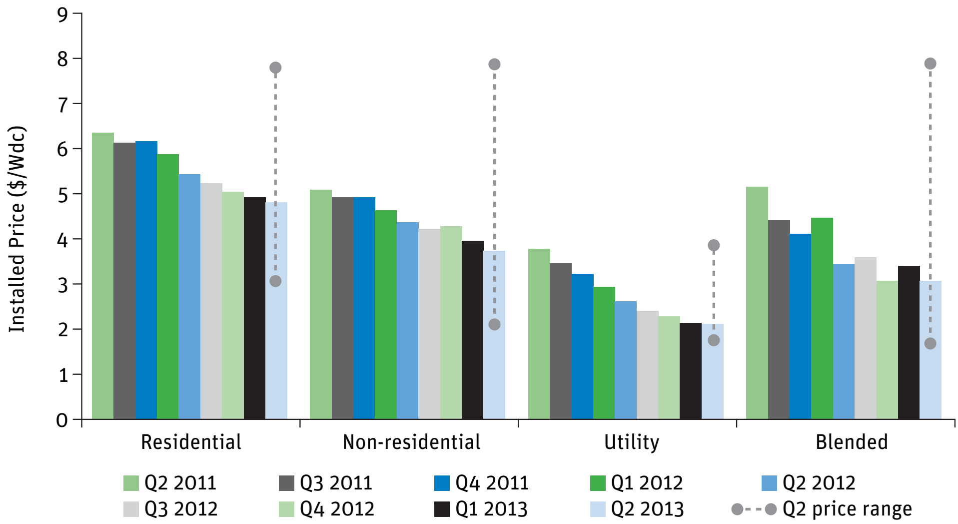
Prices for fully installed systems continue to fall in the U.S. market that is most relevant for T&T. In the second quarter of 2013, residential system prices were down to US$ 4.81/W with substantial variations from state to state (**Figure 30**). In mature solar markets of the U.S., final installed prices were in the US$ 4/W range. Non-residential system prices have fallen to US$ 3.71/W, average utility-scale prices came down to US$ 2.10/W. On the whole, installed PV prices vary greatly not only state to state, but also project to project. Even within a single state, installed costs varied by more than US$ 2/W.[4] According to a recent analysis, so-called soft costs[5] accounted for 64% of residential system prices, 57% in the case of small commercial systems <250 kW and 52% for larger commercial systems. This means that a large proportion of the total value is added at local or national level, even if the hardware (namely modules and inverters) are being imported (NREL, 2013).

In Germany, installed prices are far lower than in the U.S., mainly due to a more advanced solar market. Prices for small residential systems of between 3 and 10 kW have decreased from about US$ 18,900/kWp[6] in 1990 to an average of about US$ 2,160/kWp (ranging from

[3] www.pvxchange.com.
[4] PV magazine 11/2013, based on GTM Research.
[5] Also referred to as Balance-of-System (BoS) costs; includes acquisition, planning, permission fees, labour cost for installation, taxes, developer/installer profit etc.
[6] kWp = Kilowatt peak power, is the output of a PV module measured under Standard Testing Conditions.

**FIGURE 30**

Average installed price by market segment in the US, Q2 2011- Q2 2013




*Source*: Own calculations.

US$ 1,755 to 2,430/kWp) at the end of 2012. Further price reductions are expected from lower soft costs (for planning, installation etc.) and scaling effects of higher module manufacturing rates. Large ground-based utility-scale systems of various MW now achieve installed prices of between 1,000 and 1,400 €/kWp in Germany (FRAUNHOFER, 2013a).

Fraunhofer Institute for Solar Energy Systems in Freiburg/Germany calculated that levelized costs for new PV systems located in southern Spain—with a similar solar irradiation as in T&T—are now in the range of 6.5 to 10 €-ct/kWh (US$ct 8.8 to 13.5/kWh), depending on the size of the installation (FRAUNHOFER, 2013a).

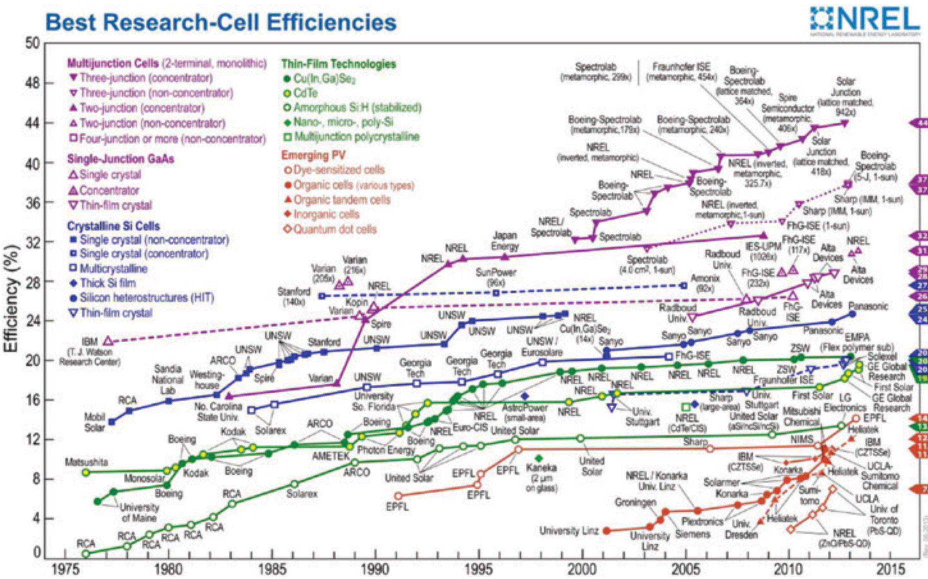
### *Background information*

Photovoltaic power generation is the conversion of solar radiation into electric current and is named after the enabling effect that was first observed by Becquerel in 1839. The creation of the first modern solar cell is credited to the Bell Lab in 1955 and development since then has been extensive (**Figure 31**).

Researchers at the German Fraunhofer Institute for Solar Energy Systems achieved a new efficiency world record of 44.7% for the conversion of sunlight into electricity in September 2013 using a new cell structure with four solar sub-cells.

## FIGURE 31

Evolution of photovoltaic cell efficiencies under laboratory conditions




*Source*: NREL 2014.

Commercially available crystalline silicon products now reach conversion efficiencies of up to 20% with average values of 15%, whereas the less efficient, but for some time cheaper thin-film technology reaches efficiencies of between 6 and 11%, with peak values of 12–13% for common market cells (FRAUNHOFER, 2013a). But the exact efficiencies, just as for wind power, are only relevant in terms of size of the system and its relation to the energy yield. What determines the LCOE is the power production per installed capital. It is best not to get distracted by efficiency values of photovoltaic cells and instead focus on the price per kW module capacity, the annually produced amount of electricity per installed kW and the reduction of the power output over the lifetime.

While with wind power turbines it is acceptable to neglect the trend of reduced power output over lifetime, as it is minimal and further reduced with regular maintenance, PV cells show a degradation of between 0.1 and 0.5% per year. Therefore, this tendency of lower output over time should be taken into account. For a dependable analysis, this report will use the guaranteed minimum performance at the end of the lifetime as the actually achievable. This is a worst-case scenario, but considering the corrosive tropical and maritime environment prevailing on T&T, this seems the right assumption to consider.

Furthermore, the energy production is calculated for a PV panel facing South at a 15% incline, the recommended angle for locations close to the equator. Solar tracking is not considered, due to the complexity this would add to the analysis and the general unsuitability for tropical regions and their high irradiance. In general, tracking devices do not offer great gains in terms of LCOE and therefore can be lumped with the fixed systems. Furthermore, their global market share is small (except for single-axis trackers), thus leading to reduced economies of scale and generally worse LCOE except in a few special cases.

As in the wind case, the LCOE is calculated based on installed capital costs, the annual maintenance and operation costs and the energy produced. Again, the exact plant size does not matter, nor the site-specific values as the analysis can only use average values expected for certain conditions.

### *Installed capital cost (ICC)*

The installed capital cost[7] varies greatly and unlike wind power, larger plants tend to be cheaper (see above). Therefore, it is advisable to look at a certain band of sizes before proceeding with the analysis. This report looks at smaller-scale PV systems defined as between 1 and 500 kWp as this is the typical range of roof-top installations.

The main contributions to ICC are the module cost, the cost of the inverter and other electric equipment and installation. Due to the compact nature of the modules, transportation is rarely an issue, nor is there need for large cranes or other specialized equipment, which might drive up the price in new or remote areas.

The cost of the module is now usually below 1 US$/Wp and therefore only a fraction of the total ICC, but as module costs have varied substantially recently, predictions on the future cost development is difficult. The general trend shows strong cost reductions, but the dependence of the market on subsidies and thus political support make module costs volatile (IRENA, 2012b).

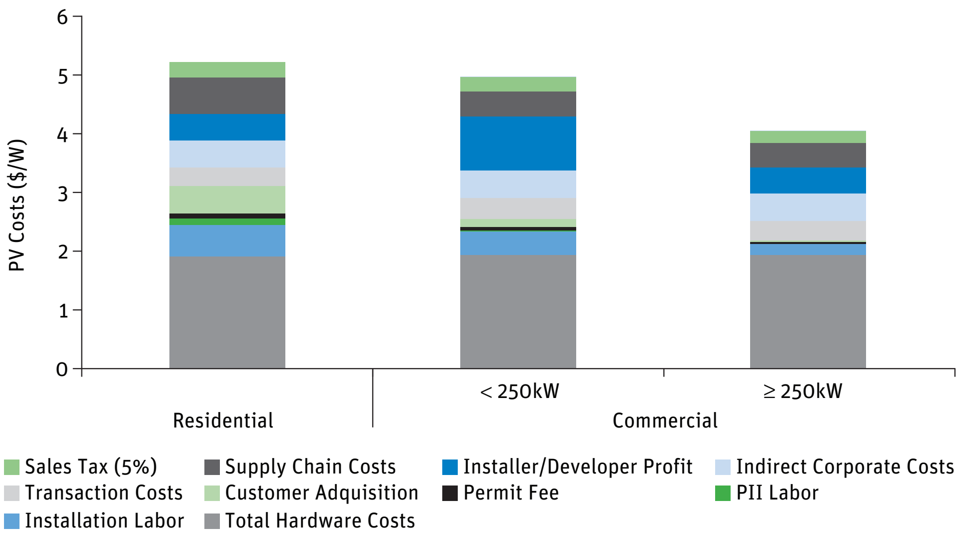
Inverter costs are also decreasing, but neither in such a drastic way nor are the prices fluctuating as heavily. Average wholesale prices for PV inverters are US$ 550/kWp for smaller systems (< 5 kWp) and slightly lower at US$ 400/kWp for larger systems (WHOLESALE, 2012).[8]

Installation costs are significant, especially in a new market, such as T&T. Even in “mature” markets, such as the U.S., profit margins of 30% for the installer are the norm. This is mainly

[7] Also referred to as “system prices” or “installed prices”.
[8] Fraunhofer Institute for Solar Energy Systems is giving higher prices with 15–20 €-ct/Wp for string inverters up to 100 kWp and 10–20 €-ct/Wp for central inverters and larger systems (FRAUNHOFER 2013c).

**FIGURE 32**

Contributions to installed cost of residential and commercial PV systems in the U.S. (first half of 2012)




*Source*: FRIEDMAN, 2013.

due to a lack of competition and high prices of the goods installed. In the United States, installation costs contribute US$ 1,300 per kWp to the base case, according to an NREL analysis of February 2012, but in T&T higher costs of up to US$ 2,000 per kWp seem more likely (GOODRICH, 2012). This value relies heavily on estimates and the effects will be outlined in the results to isolate this unpredictable factor. However, as these are costs that stay within the local economy, one must consider the opportunity to establish a profitable sector for contractors.

As the next figure demonstrates, only between 48% (for commercial systems > 250 kWp) and 36% (residential systems) of the ICC are hardware costs (modules, inverter, cables etc.) in the U.S, with the remainder being soft costs for supply chain, profits, sales tax, permission, installation etc. Detailed analyses of the difference in ICC between the U.S. and Germany, which is considered to have a well-developed PV market, revealed that German installed prices in 2011 were only about half of those in the U.S., where average soft costs for small-scale residential PV systems made up US$ 3.34 of the total ICC of $6.19 per Wp (SEEL, 2012). On the more competitive German market, these soft costs were down to only US$ 0.62 leading to a system price of just US$ 3.00 per Wp! This example highlights how strongly the competitiveness of the market and the available experience of the involved players influence the ICC.

As the comparison figure above highlights, the cost contributions for the soft cost share heavily depend on the size of the project, while hardware costs were quite similar for all sizes. This explains the previously mentioned difference in LCOE depending on size, and highlights the importance of the aforementioned differentiation when comparing LCOEs.

### *Annual operating expenses (AOE)*

The operating expenses of PV systems are minimal and proportional to the installed capacity, and therefore do not vary with the energy production. The average value given in studies is US$ 24/kW per annum and is expected to decrease slightly over the next five years (OEI, 2012).[9] Additional expenditures could occur in case of vandalism and theft and if safety and protection measures have to be applied.

### *Energy yield*

The high capacity factor[10] is the main argument for PV solar systems in the Caribbean, as it easily offsets the higher initial cost of installation caused by a young and emerging market. Because there is no market yet in T&T, it is difficult to obtain data from real PV systems, which are the most reliable source of performance information. For future use, a database listing of PV system energy yields and influencing factors would be a useful tool to establish the LCOE of a planned system.

Due to this lack of data, meteorological software was used to establish estimates for cloud cover intensity, solar irradiation density and duration (GAISMA, n.d.). The total solar irradiance on 1 m² of horizontal surface (GHI = Global Horizontal Irradiance)[11] is given as 1,761 kWh/yr at Crown Point Airport and therefore similar to the conditions in southern Spain.[12] Crown Point Airport weather information will be used as representative for the whole of T&T. The values for other locations in T&T are similar (with some exception of the mountain areas); therefore, this is a fair assumption.

The overall system efficiency of a silicon-based PV system with high quality modules[13] and an inverter with low losses is assumed to be 12.2%. This leads to a specific energy yield in T&T of 1,450 kWh/kWp. The respective capacity factor is then 16.5%. For this system a per-

[9] Fraunhofer Institute of Solar Energy bases its calculations on higher operational costs of 35 €/W (47 US$/W).

[10] Capacity factor or capacity utilisation factor is the ratio between the theoretical annual maximum output of a plant and the real output.

[11] Global Horizontal Irradiance (GHI) is the sum of Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI).

[12] Source: MeteoSyn® (Meteorological Software) developed by Valentin EnergieSoftware.

[13] For calculation, the use of Sanyo HIT - 210N modules was assumed, with a rated power of 210 W, a module efficiency of 16.7% and a size of 1.26 m².

formance ratio[14] of more than 81.5% is assumed, which is considered as good.[15] To reflect the influence of degradation during the 25-year operation, a 10% reduction in average output over lifetime was considered. As a result, the specific electricity output was conservatively assumed to be 1,300 kWh/kWp.

It shall be noted that the capacity factor is not generally used in PV system calculations, as it is largely meaningless for such electricity generators. The specific annual yield in kWh/kWp is a more suitable factor. However, for comparing different methods, it will be used here by translating the specific yield into the capacity factor.

### *Discount rate*

The discount rates used are the same as those documented in the wind power section, as these are independent from the technology. The cost of capital is generally a key factor in the LCOE. A report by EPIA states that the cost of capital has a greater impact on the LCOE than module prices, insolation at the site and plant lifetime (EPIA, 2011).

### *Results*

Due to the complex development of the PV market, a simple analysis like the one for wind power was not possible. Several factors can have significant impact on the LCOE and they may change independently from each other. Thus, this analysis would run risk of being incorrect if all factors would be bundled. Therefore, three estimates based on different assumptions of module prices are used and then for each module price the LCOE with three different installation costs has been calculated. The calculated LCOE was then extrapolated using the 20$^{th}$, median and 80$^{th}$ percentile expectation of the LCOE change. **Table 31** summarizes the results. All prices are in US$2012.

As the German example shows, prices used in the right-most column are not unrealistic and can be used for current LCOE considerations. However, as the prices of PV modules are very volatile the other two estimates representing a broader spectrum of module prices are more appropriate for policymaking considerations, while the "best possible option" demonstrates what is possible nowadays.

The assumptions for module prices and installation costs lead to an LCOE between about 29 and 14 US$ct/kWh at 2012 prices.

[14] Performance ratio is the ratio between the system output at the a/c side of the inverter and the nominal capacity of the module based on standard conditions. Losses occur due to deviating insolation and temperatures against the standard values, shading of modules, dirt on the module surface, reflections as well as electrical losses. Typical systems have performance ratios of between 80 and 90%.
[15] Using the software tool PV Sol® Software Expert 5.5 (R4 version).

**Table 31 LCOE for PV systems in Trinidad and Tobago**

| | | NREL base-case module | | | Median IRENA module | | | Best Possible option | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | Medium | Low | High | Medium | Low | High | Medium | Low |
| Module | US$/kW$_p$ | 3,200 | | | | 2,080 | | | 950 | |
| Inverter | US$/kW$_p$ | | | 1,320 | | 500 | | | | |
| Installation[a] | US$/kW$_p$ | 2,000 | 1,660 | 5,020 | 2,000 | 1,660 | 1,320 | 2,000 | 1,660 | 1,320 |
| ICC | US$/kW$_p$ | 5,700 | 5,360 | | 4,580 | 4,240 | 3,900 | 3,450 | 3,110 | 2,770 |
| AOE | US$/kW$_p$ | | 24 | | | | | | | |
| Capacity factor | % | | 16.5 | | | | | | | |
| Discount rate | % | | 4.25 | | | | | | | |
| Operational life | years | | 25 | | | | | | | |
| CRF[b] | | | 0.066 | | | | | | | |
| System efficiency | % | | 12.2 | | | | | | 14.0 | |
| Spec. solar yield | (kWh/kW$_p$) | | 1,300 | 25.4 | | | | | | |
| LCOE 2012: | US$ct/kWh | 28.8 | 27.1 | 23.7 | 23.1 | 21.4 | 19.7 | 17.4 | 15.7. | 14.0 |
| LCOE 2015: | US$ct/kWh | 26.9 | 25.3 | 22.8 | 17.6 | 16.3 | 15.0 | – | – | – |
| LCOE 2017: | US$ct/kWh | 25.9 | 24.4 | | 16.2 | 15.0 | 13.8 | – | – | –[c] |

[a] Installation costs vary dramatically, but they will depend significantly on the economy of T&T and local market conditions; any prediction of the development will be inaccurate and beyond the scope of this analysis.
[b] CFR = Capital Recovery Factor
[c] For the best possible option, no prediction of module cost development and installation costs has been done.
Inflation: 9.36%/a
Real discount rate $d_r$ = 4.25 (quoted by Central Bank of Trinidad and Tobago)
Nominal discount rate dn = 14.55 %

### *Development trends in the region*

With the medium-term objective of achieving 25% RE use by 2025 and adequate framework conditions, such as a net-metering scheme for private solar electricity generation that started in June 2011, the **Dominican Republic** has become a major destination in the Caribbean for solar installations from rooftop sizes to large ground-mounted systems. By mid-2013, a total of 6 MW solar PV had been realized under the net-metering agreement, reaching from small residential systems to larger sized installations on hotels (such as the 267 kW plant on the Hotel Dominicana Fiesta in Santo Domingo), factories and the 1.5 MW facility at Cibao International Airport in Santiago de los Caballeros serving about 50% of the airport's electricity needs. The construction of a solar farm with 50.6 MW peak capacity was started in 2012 near the capital Santo Domingo. The region's by far largest solar farm with a capacity of 64 MW began completion in 2013. The electricity generated will be sold under a Power Purchase Agreement to the state utility CDEEE. The country passed a law to incentivize the growth of RE: it waives import duties for RE equipment, allows for the writing-off of 40 percent of sales tax on electricity sales from renewable sources for 10 years, and makes the tax on equipment deductible up to 75 percent for that same period.

A 1 MW ground-mounted solar plant has been commissioned in October 2013 on **St. Kitts** just next to the runway of the airport. The US$ 2.5 million investment with 3,500 panels is operated by the Port Authority and part of a government plan to achieve 60% of electricity generation from green sources by 2015. The plan includes solar street lighting and the installation of solar systems at the government's headquarters. Furthermore, a Taiwanese company has settled a small manufacturing facility for the assembly of solar kits and panels. Also in October 2013, a smaller solar facility of 72 kW came into operation on the roof of a major retail store on St. Kitts. The project was facilitated by a government policy to remove import duties on all RE equipment.

On Grand Cayman, part of the **Cayman Islands**, the utility CUC selected two ground-mounted solar projects of 5 MW each for realization after a bidding process. The plants will sell all their electricity to CUC at a fixed price and should commence operation in 2015. A total of 31 companies had responded with around 50 proposals to the original request for bids asking for the delivery of electricity from wind and solar.

Facing high electricity costs and a huge debt burden, **Puerto Rico** is seeking to expand its renewable electricity portfolio from a mere 1% share to 6% by the end of 2014 and 15% by 2020 under its RE Portfolio obligation. The country is already home to a large solar plant with 24 MW and investment costs of US$ 96 that was inaugurated in 2012 in the municipality of Guayama and sells electricity under a 20-year Power Purchase Agreement for US-ct 13 per kWh. It now intends to create incentives for the installation of solar systems on schools and other public buildings. Several plants have already been installed on commercial buildings. A huge ground-mounted 52 MW is currently under realization in the East of the island. It will sell all electricity to the state utility PREPA and can serve the needs of about 130,000 homes.

**Jamaica** has selected a 20 MW solar farm out of a well-attended competitive bidding process with 20 proposals from local and international companies, for realization in 2015. The implementation of a net-billing scheme introduced in 2012 for small-scale installations with relatively low rates for excess electricity sold to the utility has not been taken up much, as conditions were not attractive for investors (see chapter 6.1).

### *Recommendations for PV*

The recommendations for activities required to be done in T&T are as follows:

- Establish a database where PV system operators can log the performance and capacity factors of systems. This will enable better calculations for future investors.
- Due to a lack of PV systems in T&T that would reveal the specific energy yield of systems, the Meteorological Service of Trinidad and Tobago should acquire and provide local solar radiation data and allow easy access to this information, especially to reflect local conditions on the different coastal sides of the islands.
- Currently higher generation costs should not be seen as deterrence as the profit from this cost contribution remains in the local economy.
- Establishment of a data base where PV system operators can log the performance and capacity factors of systems.

#### 100-roofs PV programme

PV is competitive in T&T in the long run, so no time should be wasted to put in place measures that will promote PV installations that could drive down local installations costs, as seen in Germany. The initial uptake of PV home systems should be stimulated with a 100-roofs programme (up to 5 kWp) that will provide a relatively high amount of direct investment subsidy (about US$ 2,000 per kWp). With an average of 3 kWp being installed this would amount to a total subsidy of US$ 600,000. The private investment could be remunerated over 20 years with a fixed rate (excluding inflation adjustment) of about 10 US$ct/kWh, thus in the range of the full costs (excluding subsidies) for conventional electricity generation in T&T.

Such a targeted programme with limited cost efforts could efficiently promote solar PV technology and stimulate the establishment of a new market as well as create awareness among the general public about the potential of solar electricity. A similar programme targeting 1000 roofs has been the starting point of a blossoming PV industry and market in Germany in the early 1990s.

## 6.3 Offshore Wind Energy

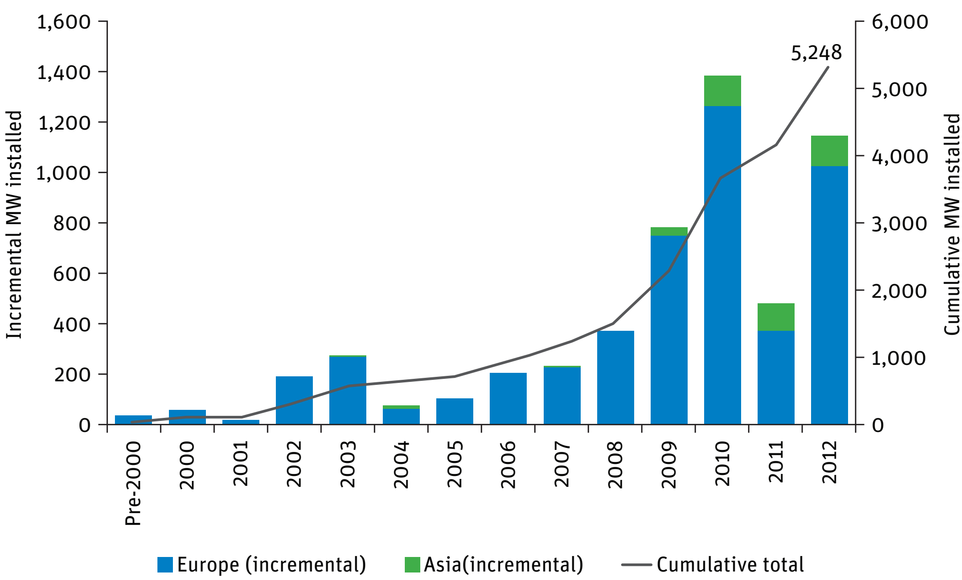
### Status of offshore wind energy

The first wind turbine that is considered to be offshore was erected in Nogersund, Sweden in 1990. More recently, there has been a surge of offshore developments, mainly in Europe, but also in China, South Korea and Japan. The US and other countries are expected to follow very soon (**Figure 33**).

By the end of 2013, 2,080 offshore turbines had been installed and grid-connected in Europe, with a total capacity of 6,562 MW, in 69 wind farms in eleven countries (EWEA, 2014). Almost all projects have been realized in just six countries: UK (56%), Denmark (19%), Belgium (9%), Germany (8%), Netherlands (4%) and Sweden (3%). The average wind turbine size is 4 MW, whereby a significant number of new turbines is now in the range of 5 MW. Due to the high costs for interconnection and logistics, average offshore wind farms completed in 2013 are fairly large with 485 MW and medium distance to shore is in the range of 30 km. Similar installation rates (close to 1,600 MW) as in 2013 are also expected for the following two years.

**FIGURE 33**

Historical Growth of the Global Offshore Wind Market




*Source*: NAVIGANT, 2013.

Offshore wind power has two major advantages that in the long run will make it a very important source of electricity. These are the higher capacity factors that are achieved due to the stronger, steadier winds. And due to their distance from the coast, they are less likely to produce "not-in-my-backyard" debates and are thus easier to implement for both developers and politicians alike (ZAAIJER, 2012). But they have also disadvantages and face significant challenges: long submarine interconnection cables, difficult terrain for foundations in deep water and movement of parts and rough conditions for regular maintenance and repairs.

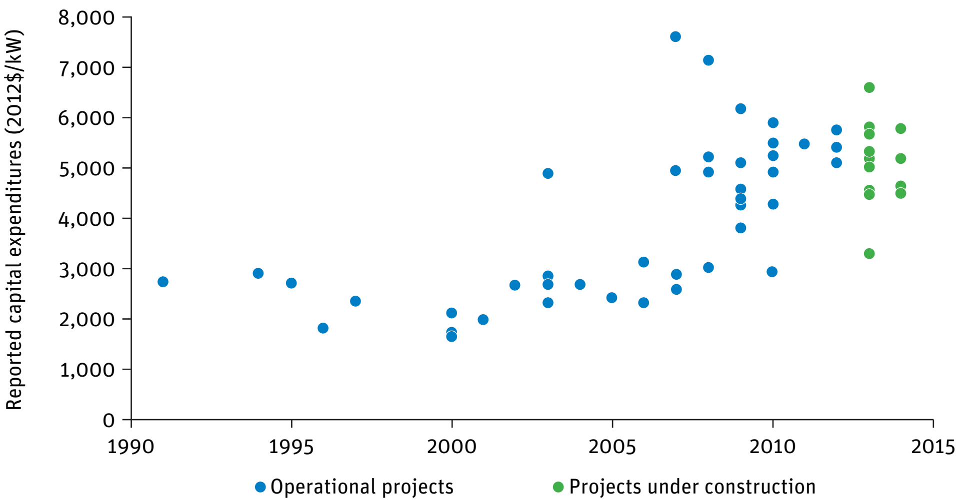
## Costs of offshore wind power

The increased capacity factor promises cheap production in the long run, but currently the difficulties with maintenance, availability and reliability as well as the more expensive construction make offshore wind power significantly more expensive than onshore power.

According to the latest publication of IRENA on renewable power generation costs, offshore wind farms are much more expensive than onshore and cost US$ 4,000 to 4,500 per kW installed, with the wind turbines accounting for 44% to 50% of the total cost (IRENA, 2012a). In the past years, project costs have shown a generally increasing trend due to a movement toward deeper-water sites, increasing site complexity and higher contingency reserves (**Figure 34**). For projects installed in 2012, average reported capital cost was US$ 5,384/

**FIGURE 34**

Reported Capital Costs for Global Offshore Wind Project over Time




*Source*: NAVIGANT, 2013.

kW (NAVIGANT, 2013). In the future and with growing learning experience, capital costs are expected to decrease to US$ 2,500 to 3,000 per kW.

The LCOE of offshore wind, assuming a 45% capacity factor[16] and O&M costs of US$ 0.035 per kWh, is between US$ 0.15 and US$ 0.17 per kWh. It drops to US$ 0.14–0.15 per kWh when the capacity factor is 50%. The high O&M costs add significantly to the LCOE of offshore wind farms and cost reductions in this area will be critical to improving their long-term economics (IRENA, 2012a).

Therefore the recent interest in offshore wind power is not so much driven by economic reason, but more by political support and the expectation that experience will drive down costs. Just as it has been the situation with onshore wind power and PV.

But for the case of T&T it is too early to estimate the LCOE of offshore wind power, as not even onshore wind power is developed and in use. One must note that all nations where there is an interest in offshore wind power have had significant previous experience with onshore wind energy. The already mentioned difficulties with maintenance, reliability and monitoring of wind turbines require a step-wise approach with first gaining knowledge on land.

### Offshore wind power and risks of hurricanes

However, in the Caribbean there is yet another issue that so far has been overlooked in Europe, but is posing a significant risk to US based developments: the threat from hurricanes and cyclones. A recent research paper suggests that a significant number, up to 50%, of wind turbines in areas at risk could be damaged from Hurricanes during their expected 20-year operational life (ROSEA, 2012).

As stated in the section on wave power (chapter 6.7), the prediction of peak offshore conditions is very difficult as the extremes may be very high but rare. And even though T&T is not in an area with very regular Hurricane impacts, there have been wind speed extremes in the last 20 years and there is nothing to suggest that this will change in the next 20 years, so this risk must be considered.

### Environmental impact

The visual pollution by onshore wind farms and possible negative effects on tourism may also be considered, while moving towards offshore wind power. The effect of offshore wind farms on the marine life is still not well understood, with some studies suggesting

[16] New offshore wind projects have capacity factors between about 38 and 50%.

benefits, while it is certain that the construction phase can be harmful to local marine life (WILHELMSSONA, 2006).

### Offshore location availability

To benefit from a deduction in visual impact, the turbines must be placed at a considerable distance from the shore. As mentioned in the section on OTEC (chapter 6.7), deep water can be found close to Tobago making it unsuitable for offshore wind power, as floating structures are still in the research phase. Trinidad has less slope in the surrounding ocean floor, with depths of less than 20 m still found 5 km offshore, making it potentially suitable.

### Conclusions and recommendations

Offshore wind power will be a significant source of electricity in the future in the world, but before T&T can start to exploit this resource, the onshore market should be developed, as experience gained with wind turbines on land is essential.

Furthermore, the report on the LCOE of onshore wind power and experience from other Caribbean islands show that onshore wind power in T&T can already expect a rather high capacity factor as the country lies in an area of very steady winds and all potential sites are in close proximity to the coast (JARGSTORF, 2011).

This very good onshore wind power potential should be first developed before thoughts are given to offshore wind power.

One of the problems on the islands is land availability and that in this case offshore might be a viable alternative. This might be one of the major driving forces to consider offshore wind power for the Caribbean islands, like in T&T. But as offshore wind requires substantial technological and logistical inputs especially in transport, construction, commissioning and O&M it is strongly suggested to first get experience with onshore wind power and to wait at least for 5–10 years, until the worldwide experience on offshore wind power led to reduced costs and better support schemes for transport, construction, commissioning and O&M outside of Europe and the US.

In addition, as offshore wind power is still in an early development stage worldwide and its deployment has just started mainly in Europe, it requires strong and long lasting technology support schemes by governments and even stronger engineering capabilities to overcome the technological challenges. Therefore it is not advisable for T&T at this stage to use its resources on this technology development.

If T&T wants to prepare the field for offshore wind, it might enter into a first evaluation of potential sites in the coastal areas around the islands and assess their suitability for offshore wind power and start clarifying if other environmental concerns exist for future use. Wind assessment to establish the capacity factor should be part of that evaluation.

## 6.4 Potential for Solar Water Heating

### Introduction

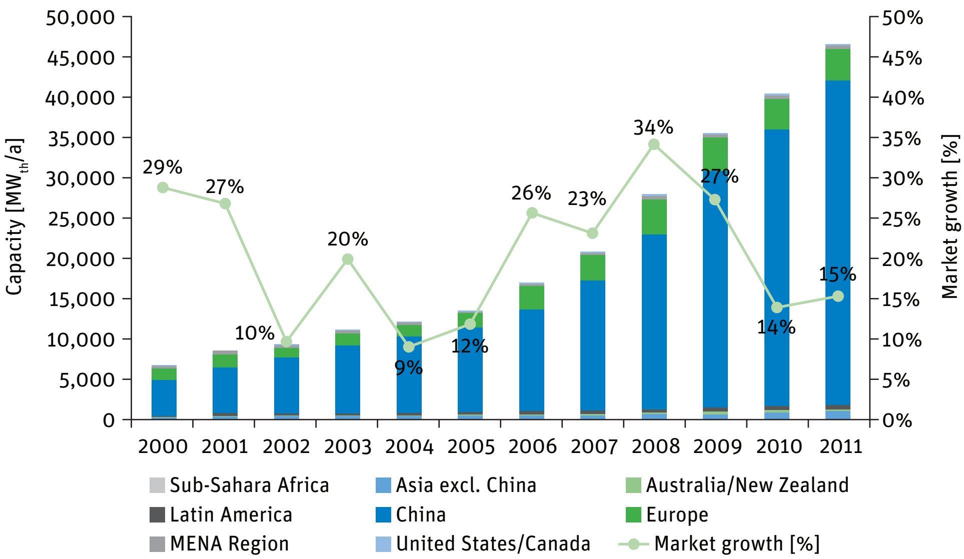
Solar energy can play a significant role in saving fossil fuels which would normally have been diverted to water heating, and subsequently in mitigating greenhouse gas emissions. In T&T, hot water is predominantly generated by using electricity. The application of LPG for water boilers is rather limited. The situation is therefore different from most other Caribbean islands where LPG plays a major role in this consumption sector. Due to the low tariffs for electricity in T&T, the use of hot water in the domestic sector for sanitary reasons is also more widespread than on other islands and the per capita consumption is likely to be higher than elsewhere.

According to a report by the Solar Heating and Cooling Programme of the International Energy Agency (IEA), by the end of 2011 the total installed capacity of Solar Water Heaters (SWH) in 56 countries recorded was 234.6 GWth, corresponding to a total of 335.1 million m² collector area. The annual collector yield of all water-based solar thermal systems in operation by the end of 2011 was 195.5 TWh. This corresponds to an energy saving equivalent of 20.9 million tons of oil and emission abatement of 64.1 million tons of $CO_2$. The installed capacity in these countries represents more than 95% of the solar thermal market worldwide (MAUTHNER, 2013). Between 2000 and 2011 the global annual installed glazed water collector area increased 7-fold (**Figure 35**). In 2011 alone, a total capacity of 48.1 GWth, corresponding to 68.7 million m² was installed. In 2012, the total installed solar thermal capacity in operation (268.1 GW) was only slightly lower than the cumulated worldwide wind power capacity (282.6 GW).

Globally, 85% of the overall capacity installed was used for domestic hot water in single-family houses and 10% was attached to larger hot water consumers such as multi-family houses, hotels, hospitals, schools, homes for elderly people, etc. In Latin America the market was dominated by single-family house systems (77%) among all new installations in 2011, while systems for multi-family dwellings, tourism and public purposes on one hand, and solar process heat on the other hand only reached 22 and 1%, respectively. As in most regions with warmer climates and relatively low income levels, 90% of all systems with glazed water collectors in operation in Latin America by the end of 2011, have been thermosyphon types, while only 10% were pumped solar heating systems.

**FIGURE 35**

Annual installed capacity of glazed solar collectors worldwide




*Source*: MAUTHNER, 2013.

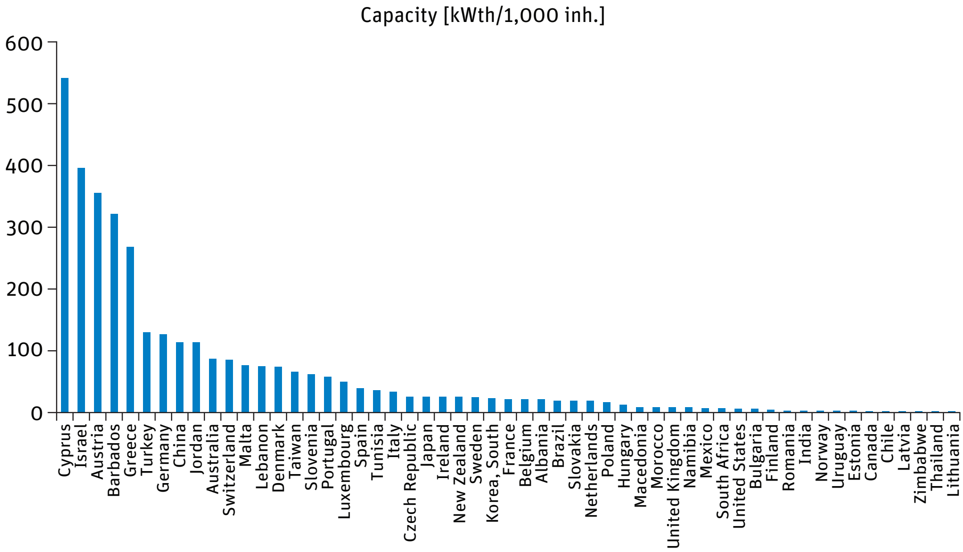
For end of 2012, preliminary estimations expected a worldwide capacity of solar thermal collectors of 268.1 GWth or 383 million m². This corresponds to an annual collector yield of 225 TWh, which is equivalent to savings of 24.0 million tons of oil and 73.7 million tons of $CO_2$ respectively. The number of jobs in the field of production, installation and maintenance of solar thermal systems has been estimated to be in the range of 420,000.

Among the leading countries worldwide was Barbados with 321.5 kWth per 1,000 inhabitants at the end of 2011 (**Figure 36**). T&T is not included in this group of countries as the SWH penetration is still relatively low.

For T&T, the upward trend of the oil price in the last few decades has led to a significant advantage and increased economic competitiveness as the state's natural resources can be sold at premium prices or preserved for future use instead of unnecessarily exhausting the supplies when alternatives are available. This report reviews and analyses the potential for solar water heating and its application for T&T. It further makes recommendations for its deployment in the residential, commercial and hotel sectors.

**FIGURE 36**

Total capacity of glazed flat plate and evacuated tube collectors in operation, end of 2011




*Source*: MAUTHNER, 2013.

Currently the application of SWH in T&T is very limited, different from a number of other islands in the Caribbean, where fossil fuels and subsequently also electricity are far more expensive. About 55% of all SWH systems within CARICOM are currently in operation in Barbados, with major shares also in Jamaica, St. Lucia and the Bahamas (see **Figure 37**). All SWH in T&T so far are imported models as no local manufacturing exists. It is estimated that the number of installed SWH in T&T is only of the order of a few hundreds.

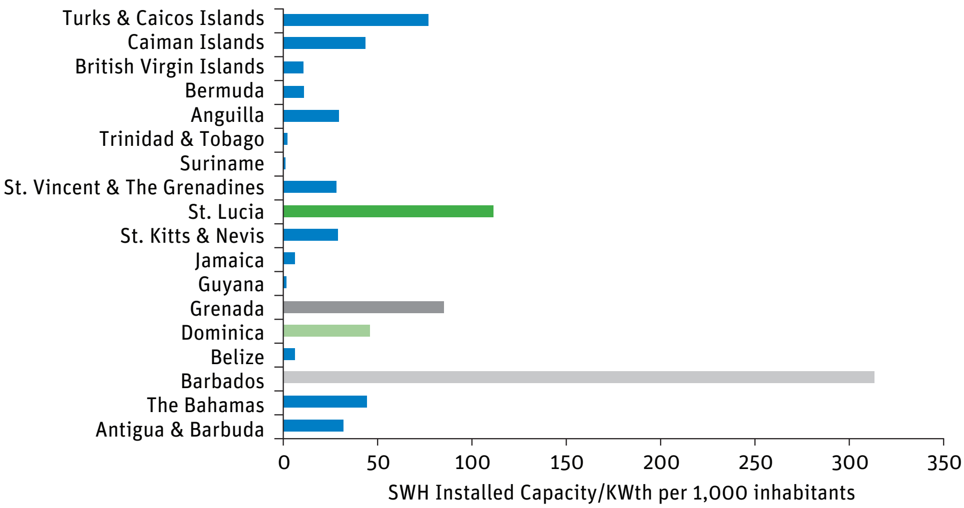
## Solar Resources

T&T lies within a belt where the solar insulation levels are relatively high (**Figure 38**), providing an invaluable indigenous resource which can be harnessed and developed to overcome the unnecessary usage of its fossil fuel reserves.

**Figure 39** give a close-up view of the annual levels of Direct Normal Irradiance (DNI) in the Caribbean, while **Figure 40** gives the annual values for a flat plate tilted at latitude. These maps indicate that the average solar irradiance for T&T lies in the range of 5.0–6.0 kWh/$m^2$day. Because T&T is situated near the equator, the DNI values are close to the Global Irradiance values on an inclined surface, for optimal performance of solar energy systems.

## FIGURE 37

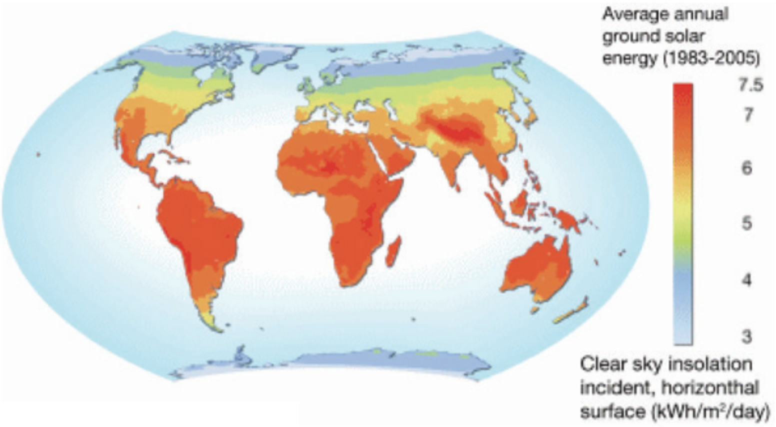
Solar Water Heating penetration in CARICOM states




*Source*: GARDNER, 2012.

## FIGURE 38

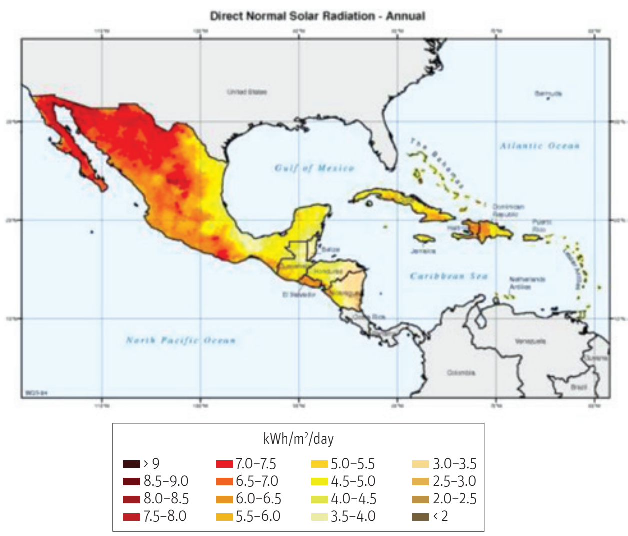
World map of potential solar power (solar insolation in kWh/m²/day




*Source*: NASA, 2008.

## FIGURE 39

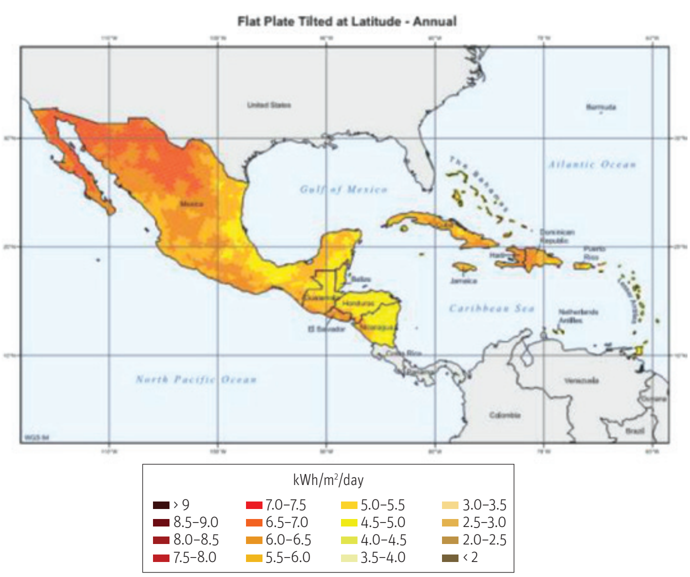
Solar insolation map of the Caribbean – Direct Normal Irradiance




*Source*: OEI, n.d.

## FIGURE 40

Solar insolation map of the Caribbean – Global Solar Radiation tilted at latitude




*Source*: SWERA, n.d.

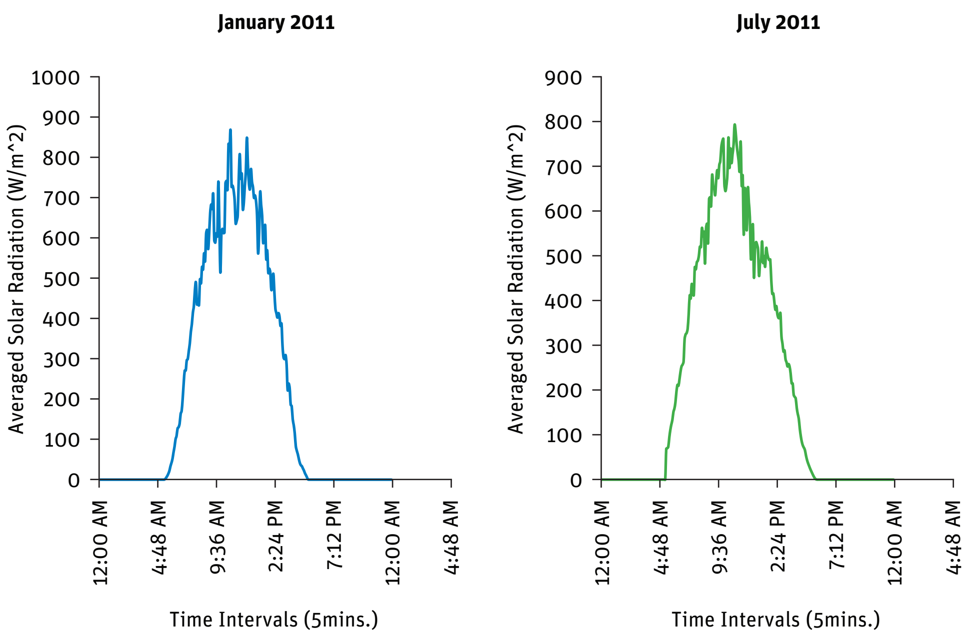
This is consistent with actual readings taken from the weather station located at the campus of the University of the West Indies (UWI) in St. Augustine, Trinidad.

The graphs in **Figure 41** show the medium daily solar radiation at UWI/Trinidad for a January and July 2011. Solar radiation measurements were taken every five minutes and averaged over the corresponding periods for each day. While the readings were taken at the UWI in St. Augustine, the insolation levels are quite similar for most of T&T. These graphs provide concrete evidence of the excellent conditions for solar thermal systems on both islands.

Furthermore, **Figure 42** and **Figure 43** show for comparison the Daily Solar Radiation averaged over a month for both a horizontal surface and an inclined plane for a twenty-two year measurement period. These graphs also consistently show values ranging from 4.9 to 6.4 kWh/m$^2$day on a horizontal surface and 5.5 to 6.4 kWh/m$^2$day on an inclined surface for optimal year-round performance. Therefore, for a horizontal surface the annual average solar radiation is 5.3 kWh/m$^2$day, and for an inclined surface it is 5.9 kWh/m$^2$day, indicating a small difference of 0.6 kWh/m$^2$day.

**FIGURE 41**

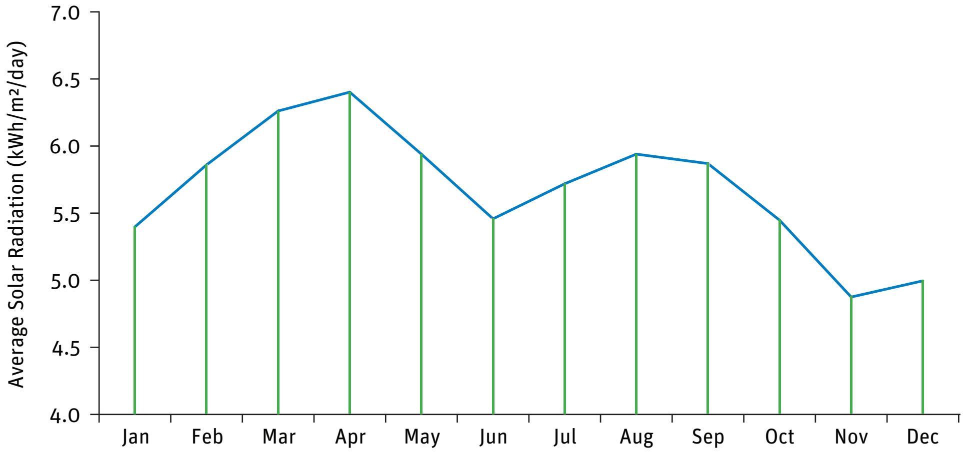
Average Daily Solar Radiation at UWI, Trinidad




*Source*: Own graphs using data from Weather Station at UWI.

**FIGURE 42**

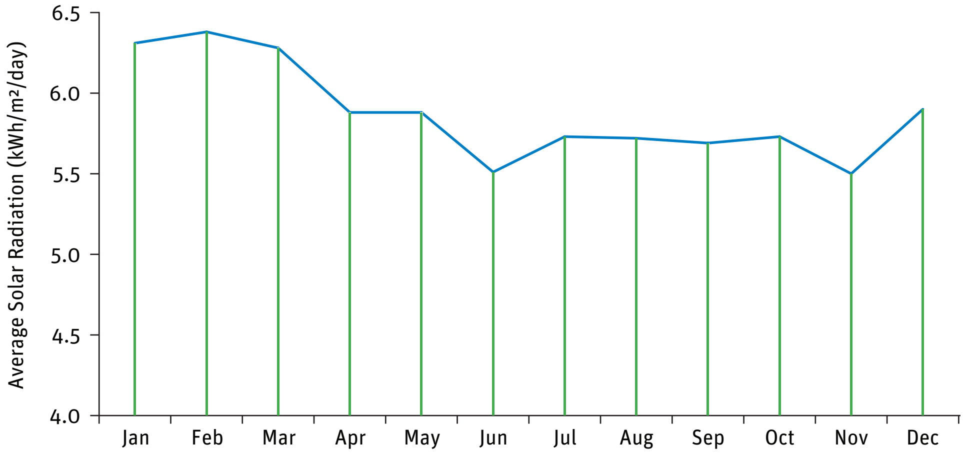
Average Solar Radiation on a horizontal surface in each month




*Source*: SOLAR, 2012.

**FIGURE 43**

Average Solar Radiation on an Inclined Surface in each month




*Source*: SOLAR, 2012.

This means that the potential for solar water heaters in terms of available resource is excellent. However, before embarking on a project which involves the use of large quantities of hot water for commercial or industrial purposes it will be important to conduct a more detailed resource assessment at the specific site.

All the graphs indicate that conditions in terms of resource are favourable for effective deployment of solar water heaters in T&T for most of the year. Insulation levels are relatively high year-round and thus successful water heating using solar energy can be guaranteed.

## Technology of Solar Water Heaters

Solar Water Heating (SWH) is one of the simplest applications of solar energy use and has gained experience in modern times now for several decades. Methods of harnessing solar energy have improved over the years, making the conversion especially efficient through improved glazing, better insulation of collector and tank and application of selective coating of the absorber, among other technical innovations. Well-designed SWH systems are therefore capable of covering most, if not all hot water needs in tropical climate conditions, where medium solar irradiation is high and the differential between the temperatures of water inflow and outflow is relatively low. Its application can therefore lead to significant savings through the displacement of fossil fuel based electricity generation or other sources of energy, such as LPG that are usually applied for water heating.

The technology for solar water heating is fully developed and continuously lends itself to further enhancement. Therefore, given the resource and the state of technology, the potential for solar water heating (SWH) is high, both in terms of its application and feasibility for manufacturing. Solar water heating is a very reliable technology, if the system is produced and installed with proper quality and the sizing is properly quantified. Maintenance for SWH systems is usually minimal.

The most common systems in the Caribbean are *thermosiphon* SWH with an open loop circulation of the water. These systems are also called “passive” as they rely completely on heat-driven or natural convection to circulate the water or heating fluid through the system. These systems usually come in an integrated form with the tanks directly attached above the collector, but the tank and collector can also be placed separated from each other. While passive SWH systems are less expensive, their efficiency is significantly lower than that of active systems.

If the tank is placed below the collector, e.g. at ground level or in a basement, it becomes an “active” one, as it now requires the use of a pump for the circulation of the water. If static reasons are not preventing it, all systems are normally placed on the flat or tilted roof, where sufficient space is available and shading might be less of a problem. Water pressure from the mains needs to be high enough to transport water from the ground onto the roof. And the distance between tank and consumption point needs to be sufficiently high so that the hot water can reach its final destination by gravity flow, without the use of a pump.

Both, active and passive systems can be direct (open-loop) systems, which circulate potable water through the collectors, or indirect (closed-loop) systems, which use a heat exchanger that separates the potable water from the heat transfer fluid that circulates through the collector.

Active systems are still less common in the Caribbean, although they are often better suited for larger systems, as in hotels, and for aesthetic reasons. In this case, the collectors can be installed in homogeneous fields on the roof or substitute roof tiles, while the well-insulated storage tank is located in a maintenance room. Also closed-loop systems are not so common in the Caribbean. These systems operate with a closed circulation of water (or other liquid) between tank and collector. The fresh water is heated within the tank through a heat exchanger. These systems are advantageous as the quality of liquid in the inner loop can be controlled and particles such as calcium will not plug the absorber pipes. They require therefore less maintenance, but lose some efficiency through the exchange of heat between the two circuits.

Most collectors used in the Caribbean are of the flat-plate type, i.e. the absorber and circulation tubes form a flat area that is housed in a glass-covered and sealed casing. Less common are evacuated tube collectors, where the heat pipe is inserted in a vacuum glass tube. The vacuum reduces the convection heat losses to the ambience, thereby increasing the efficiency of the collector. Vacuum tube collectors always run in a closed cycle mode and therefore need a heat exchanger. These collectors have efficiency advantages in colder climates, but do not offer substantial extra energy gains under Caribbean conditions.

To allow for high energy gains the optimal positioning of the collector is determined by the latitude. For maximum solar gains, the collector should be tilted at 90% of the latitude and be oriented facing the equator. Therefore, for locations in the Northern hemisphere, the collector should be tilted facing due South. While existing roofs may not always offer the best solutions, for countries lying close to the equator, such as T&T, inability to correctly orient the collector will not necessarily result in excessive losses. It is also possible to use software programmes to calculate the energy lost in the case that non-optimal conditions are the only choice for installation.

Some SWH are offered with the option to install an electric back-up heater, either directly in the storage tank or at any point between the SWH and the showerhead or faucet. The need for such an option certainly depends on the expectations of the consumers. Securing hot water availability at any time might be more sensitive in luxury hotels than in the domestic sector. For properly designed and positioned SWH the coverage of water heated by the sun will be close to 100% in T&T.[17] Of course it can never be prevented that a number of overcast days or failure of the system may lead to a deficit in hot water supply.

In most cases the frequent use of the electrical booster should be discouraged. Those devices with a capacity of 1.5 or 3 kW impact severely on the peak power demand. It is therefore advisable to avoid electrical back-up heating and instead provide an adequate volume of hot water using solar energy in a well-insulated storage tank. If boosters are kept permanently in the “on” position, any failure of the collector may not be detected since availability of hot water will not be interrupted.

## Consumption of Hot Water

We first want to see how much energy is used to heat up 10 U.S. gallons (37.85 litres) of water.

The temperature of fresh water is normally between 25 and 27 °C in T&T. To heat 10 U.S. gallons up to 60°C about 5,400 kJ or 1.5 kWh thermal energy are needed. This is also about the electric energy required if a pass-through heater near the point of consumption is being used. An efficient and well positioned SWH system may have an overall efficiency of around 40%.[18] The assumption of an insulation of 5 kWh/m²day is also made. Thus, to heat the 10 gallons of water by 34 K on such a day would require a solar collector area of about 0.75 m².

The aforementioned example is intended only to give a rough indication. The energy available from the sun and the performance characteristics of solar collectors vary in a complex way and generalisations should be used with caution. As can be seen below, in practice solar collectors intended for application in the Caribbean are somewhat smaller dimensioned.

### *Domestic sector*

The Government of Trinidad and Tobago recommends the dimensions as shown in **Figure 44** for hot water requirements depending on the size of the household and the related sizes of storage tanks and collector areas. It should be noted that the hot water demands mentioned here appear very generous with daily consumption of 20 to 30 gallons per person based on temperatures of 50–60 °C[19]. Taking the lower water consumption figure into consideration,

[17] According to J. Husbands, a well-designed hot water system will efficiently provide 95% of the hot water needs effortlessly for most of the year.
[18] For comparison: The company Solar Dynamics of Barbados states that its collector has a performance of about 2.7 kWh/m²day, not counting the losses through tank and pipes.
[19] Lower volumes of 15–20 gallons per person and day are mentioned in (LOY, 2005). The Florida Solar Energy Research and Education Foundation calculates daily usage of 20 gallons each for the first two occupants and 15 gallons for each additional occupant.

**FIGURE 44**

Dimensions of SWH systems

| No. of persons in household | Recommended storage tank size gallons (litres) | Recommended collector area squares feet (squared meters) |
|---|---|---|
| 1–2 | 60 gallons (227 litres) | 30 sq ft (2.8m$^2$) |
| 3–4 | 80 gallons (303 litres) | 40 sq ft (3.7m$^2$) |
| 5–7 | 120 gallons (454 litres) | 60 sq ft (5.6m$^2$) |

*Source*: MEEA.
N.B the specifications given in this table are based on a hot water temperature range of 50–60° C minimum at the outlet of the storage tank.

the electricity consumed by a 4-person household will be 12 kWh daily (or about 4,380 kWh annually) just for water heating. As the average electricity consumption per household for all energy services is only about 16.5 kWh/day in T&T, such figures have to be handled with caution. Besides lower hot water consumption values in practice, it could also indicate that by far not every household is equipped with electrical water heating.[20]

Thermosiphon systems are offered normally in standard packages, expressed by the storage tank volume. Typical sizes for collectors respectively storage tanks vary from 50 to 80 gallons. The related collector area may vary slightly, depending on the climate conditions for which the system has been designed and the solar coverage rate desired. If solar energy should cover almost all hot water needs the ratio between collector area and tank volume needs to be increased. It is therefore not unusual to find 80-gallon systems that are coupled with a 4.5 m² collector.

Important for the hot water consumption is the flow rate of showerheads and faucets. Older showerheads have flow rates in excess of 5 gallons per minute. In 2010, the U.S. Department of Energy recommended showerheads with a flow rate of 2.5 gallons per minute or less. The U.S. Environmental Protection Agency (EPA) for its part has published guidelines for what it defines as “WaterSense” labelled showerheads, which may not use more than 2.0 gallons per minute and must still provide a better shower experience than conventional devices. The EPA estimates that an average household could save more than 2,300 gallons or over 300 kWh electricity per year by installing such high efficient showerheads (EPA, n.d.).

[20] According to (GARDNER, 2012) only about 75,000 households in T&T have domestic hot water.

### *Commercial sector*

The commercial sector is perhaps one of the most critical areas for rapid deployment of solar water heaters as it provides a ready market. This sector includes hotels, hostels, hospitals, universities/schools and dormitories.

Hot water and air-conditioning are two main requirements for guest comfort in the hospitality industry. SWHs can be employed to service the needs for hot water and solar assisted cooling.[21] According to J. Husbands, the daily volume of water needed to achieve guest comfort is 40 gallons for a two-person room with showers, and 60 gallons rooms with whirlpool or other tubs. The required temperatures for avoidance of harmful bacteria in the pipes are 55 to 60° C (135 to 140° F). This can be easily achieved with a well-designed SWH system.

According to the Ministry of Tourism there are 6,300 hotel and guest houses rooms, then this leads to a potential of 3,150 SWHs, assuming two persons per guest room. Most hotels also offer swimming pools for their guests and many provide heated Jacuzzi. Hot water for both of these facilities can also be provided by solar collectors, with designs varying according to application.

Hospitals/clinics utilize large quantities of hot water on a daily basis for sterilization, baths, kitchen/cooking use, and others. These provide an even greater potential than the hotel sector. In T&T, most schools do not have dormitories, but the few that do, together with University Halls of Residence, utilize a significant quantity of hot water also on a daily basis. All of these provide a ready market for large-scale deployment of SWHs. Depending on the distribution pattern of hot water, the systems could be either modular or be installed with a large capacity single tank.

### *Industrial sector*

The industrial sector is one of the key areas for possible targeting of SWHs. Pre-heating of water using SWHs provides a huge benefit for companies as this significantly reduces the overall electricity cost for water heating operations. SWHs can be used as a heat source for solar assisted cooling systems. The food industry is one where proper hygiene is compulsory. Solar water heaters can be effectively utilized in numerous areas in the food industry. One such area is in the Dairy industry. Most of the hot water demands occur at the dairy processing plant. Employment of SWHs in dairy processing can result in large savings for companies which would normally utilize petroleum based fuels for processing.

Clothes laundry is another sector which utilizes large quantities of hot water for their operations. SWHs can provide heat for feed water for the boilers which run the laundry.

[21] Solar cooling is not a topic of this report, but could be further looked at within a later version.

## Costs

Typical costs of SWH in T&T range from approximately US$ 1,000 to 3,000 depending on the type and origin. The evacuated tube collectors typically originate in China and are sold at about US$ 1,000 to 1,250. There are only a few of these installed in T&T, and while they are cheaper than the other designs, their life span has not been tested in T&T, as well as there are problems with breakage of the evacuated tubes, and replacement can increase the cost overall. The price of the SWHs manufactured in the Caribbean range from approximately US$ 1,800 to 2,400, depending on manufacturer and size of the water heater. Some of these SWHs are manufactured to a high standard and have proven to outlast some of the SWHs imported from outside the Caribbean both in terms of performance and durability. Some of the SWHs imported from outside of the region can cost significantly more, sometimes close to US$ 3,000.

Calculations indicate that an average family of four can use approximately 12 kWh of electricity per day for water heating (see above). Using an average cost of 6 US$ct/kWh in T&T (2009 tariff), the annual cost is US$ 263 (TT$ 1,577) as opposed to US$ 1,605 in Barbados.

At an average cost of US$ 2,200 for an 80-gallon capacity standard thermosiphon SWH, this would indicate that the payback period is approximately eight years. With the tax credit of 25% on the cost of a SWH, up to a maximum of TT$ 10,000 offered by the Government of Trinidad and Tobago, the payback period would be reduced to six years. Prices vary considerably depending on origin and quality of the product. In Barbados the systems will pay back for themselves after only 1.5 years. Well-designed and manufactured SWHs will operate for more than 15 years without major problems, adding further support for their viability.

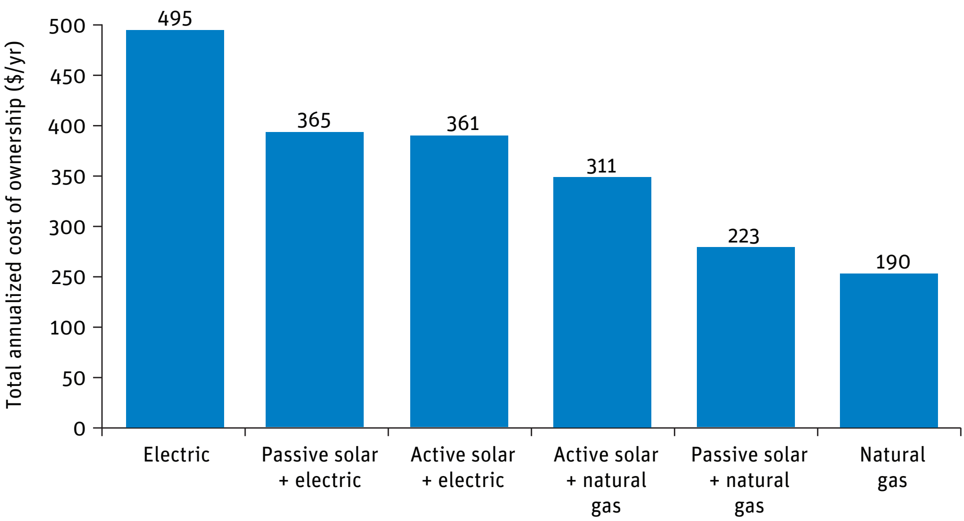
In the tourism sector, each hotel room requires approximately 2,000 kWh of energy per year to satisfy the hot water needs. At average costs of US$ct 6.5 per kWh for electricity, the cost for hot water is US$ 130 per room and year in T&T. With similar costs assumed for the installation of SWH systems as in the residential sector, solar energy is not cost-competitive against the established way of water heating under current pricing conditions and without major incentives.

## Cost Comparison

**Figure 45** shows a comparison of various types of water heating systems in the USA. While the price of electricity in the U.S. is different from the one in T&T, it is still relatively low, as is the case in T&T. The comparison is therefore generally appropriate for T&T as well. The "total annualized cost of ownership" is the cost to install, maintain, fix, replace, and oper-

**FIGURE 45**

Cost comparison of various water heating systems




*Source*: ENERGY GUY, n.d.

ate the water heating system over a 30 year period. *In economics terminology,* this is *the annualized value of the life cycle cost.*

From the comparison below, it becomes clear that natural gas is the cheapest of the options, if infrastructure allows a direct supply of final consumers. Clearly, going electric is not a good option since the cost is significantly higher in the U.S. T&T is well endowed with natural gas as feedstock for its electricity generation. Nonetheless, the supplies are finite, and it makes good economic and environmental sense to conserve the remaining resources where alternatives are possible.

**Figure 45** highlights relative prices alone and does not take into account environmental factors and external costs. Hybrid systems of solar collectors and natural gas back-up, as they are common in the U.S. and Europe, will have much less impact on the environment than conventional heating systems. Their emission of greenhouse gases (GHG) and other pollutants will be significantly lower than equivalent systems based on fossil fuels.

## Environmental Benefits

Depending on the size, a domestic SWH substitutes between 2,000 and 3,600 kWh electricity annually and consequently offsets 1.4 to 2.5 tons $CO_2$ under T&T conditions. With a medium value of 2.0 tons $CO_2$ and an assumed coverage of 25% of all households (equivalent to about 100,000 households), the use of SWH systems in the residential sector would mitigate $CO_2$ emissions by about 200,000 tons annually.

According to the Ministry of Tourism (MOTTT, 2010), T&T had approximately 6,300 hotel and guesthouse rooms in 2009. On average if an 80-gallon SWH services two hotel rooms, then 3,150 SWHs would be necessary for the accommodation sector. Using again a realistic average offset of 2.0 tons of $CO_2$ per system annually implies a total abatement of approximately. 6,300 tons $CO_2$ per year for all hotel rooms, assuming full occupancy. Under normal circumstances, 50% room occupancy is more realistic, in which case the total abatement would be approximately 3,150 tons of $CO_2$ per year.

While globally T&T emits only a small percentage of greenhouse gases, in the Caribbean it is by far the largest emitter of GHGs. Therefore through the use of SWHs, T&T can take its first steps to reduction of dangerous GHG emissions and take its responsibility to the region seriously.

Carbon abatement from solar water heating for various countries is shown in **Table 32**. The country which situation compares closest to the T&T one is Mexico. The table also shows the difference of costs per system which are particularly high in the Caribbean, Mexico and South Africa with less developed or relatively small markets. China offers low-priced SWH systems, but very often lacking quality and only lasting for a limited time period. The carbon abatement depends on the $CO_2$ emission factor of the existing electricity system or whatever ener-

**Table 32 Carbon abatement from solar water heating in selected countries**

| Country | Data source | Retail cost per liter | Number of liters in average system | Average cost of system | Tons $CO_2$ abated/ 100L/yr | Tons $CO_2$ abated/ 100L/yr |
|---|---|---|---|---|---|---|
| Barbados | Government | $6.00 | 300 | $1,800 | 1.07 | 3.20 |
| Brazil | Vitae Civilis; Econergy | $4.20 | 200 | $840 | 0.46 | 0.92 |
| China | Hua | $1.45 | 180 | $261 | 0.45 | 0.81 |
| China | Hua | $2.17 | 150 | $326 | 0.45 | 0.68 |
| India | MNES | $3.50 | 100 | $350 | 1.50 | 1.50 |
| Mexico | Quintanilla | $6.65 | 300 | $1,995 | 0.59 | 1.77 |
| Mexico | Davila | $5.66 | 265 | $1,500 | 0.90 | 2.39 |
| South Africa | SSN | $5.63 | 150 | $844 | 0.96 | 1.44 |

*Source*: MILTON, 2005.

gy source for water heating will be substituted. The 3.2 tons $CO_2$ for an 80-gallon SWH system in the case of Barbados have been calculated on the basis of a fully diesel-reliant and relatively inefficient power system, but might be too high.

One of the earliest initiatives in T&T was the joint convening by BPTT, the University of the West Indies and the Caribbean Solar Energy Society (CSES) of *SATIS 2003 – Sustainable Applications for Tropical Island States* – a regional bi-annual conference which focused on RE as a pathway to energy security. At this conference, various recommendations were made regarding implementation of RE technologies in T&T. Included among these was solar water heating (Haraksingh, 2003).

Coincidentally, the Trinidad and Tobago Bed and Breakfast Association (TBBA) had presented a proposal to UNDP/GEF Small Grants Programme (SGP) for support towards a pilot project on greening the TBBA through the introduction of SWH systems. The MEEA was sufficiently stimulated to pursue the development of the SWH industry by the introduction of a pilot project on SWHs for the TTBA. It was named the *Solar Water Heater Project* and developed under the UNDP GEF/SGP. The project agreement was signed in January, 2006, and included in the list of stakeholders were bpTT, the Tourism Development Corporation (TDC) and the Tobago House of Assembly (THA). The project focused on six host homes in Trinidad and five in Tobago. The SWHs installed in Trinidad were a different type from those in Tobago and originated from outside the region as opposed to those from Tobago, which were manufactured in the region.

There were many technical and logistical challenges, ranging from plumbing, electrical etc. to design of the SWHs employed. Nonetheless, all the homes reported successful water heating by solar energy. Two components of the assessment were establishment of baseline data and monitoring of electricity costs. Unfortunately, assessment of the economic impact fell short as the project was prematurely brought to an end. Nonetheless, all the host home owners reported a significant drop in their electricity bills.

Some of the other benefits of the SWH project included awareness building on the application of solar technologies in T&T. Since most of the host home owners were unaware of the technical aspects of SWHs, the project and stakeholders involved benefitted from two technical workshops on solar water heating facilitated by the Chair of the Monitoring and Evaluation committee of the project, both in T&T.

Lessons learnt from this project included the importance of provision of sound technical advice from the start of the project, the need for proper institutional arrangements, the urgent need for adequate training and capacity building in the SWH industry to enhance the local capacity to service the industry, and public education.

## Current Fiscal Incentives for SWH

By amending several fiscal acts, the Government of Trinidad and Tobago has put the following incentives in place at the beginning of 2011:

- 25% Tax Credit on SWH (up to a maximum of TT$ 10,000.00 acquired for use by households);
- 0% VAT on SWHs;
- 150% Wear and Tear allowance for SWHs; SWH plant, machinery and equipment;
- Conditional duty exemptions for SWH manufacturers.

While these incentives definitely stimulated some growth in the SWH industry in the last two years, the uptake has been slow both from the business perspective as well as from the consumer acceptance point of view. While a scientific survey on the number of new installations has not been done, some information was gathered from informal discussions with business persons from the industry as well as some consumers who have new installations. A few small businesses mushroomed across the country, but more importantly two major companies established presence here in the country. The amount of business they generated during the last one and a half to two years remains to be evaluated as information has not yet been gathered and collated.

## Barriers and Recommendations

### *Financing*

For T&T, one of the major barriers is the low cost of electricity, coupled with still insufficient/ inadequate incentives and rebates for SWH application. The policy framework does not allow easy access to SWH loans. The initial installed cost of an average sized solar water system with 80 gallon (approximately $10.000 to $12,000 TT) is prohibitive, in particular for low-income households which would instead generally use the far less expensive and easily available electric showerheads. In addition, hot water may not be a priority for homes with limited financial resources.

Loan schemes are not easily available for SWH systems and even middle-income families are not fully convinced about the value of their application. If further incentives are offered by the Government, banks and other institutions may foresee less of a risk to implement loan schemes for SWHs.

### *Public Awareness*

While the economic return can be attractive in the long term, public education about this is not yet in place to encourage the uptake of SWHs. Informal surveys indicate a severe lack of awareness about what is a SWH, how it operates, the advantages of using a SWH as opposed to a fossil fuel powered heater in terms of environmental concerns, the importance of life-cycle analysis, the long-term economic benefits to be derived and general lack of understanding. The free market situation and the lack of disincentives for the purchase of electrical heaters is a major deterrent to the penetration of solar water heating systems in T&T.

Architectural preferences for the traditional systems can also be a factor in considering rooftop SWHs since some architects do not like SWHs placed on the roof tops for aesthetic reasons.

*Quality Aspects*

There are also technical barriers of varying nature which persist. Sound technical designs lead to high quality products which unfortunately translate into higher costs. T&T is still not sufficiently equipped with an adequate technical workforce with competencies in design, installation and maintenance. This is an integral component of the SWH business. This deficiency often leads to a lack of confidence and distrust among consumers.

Lack of confidence in locally manufactured products and over confidence in imported products can lead to undermining of the local manufacturing capacity. On the other hand, discerning customers can detect that inferior quality goods imported from other countries are allowed to enter the country since standards are still under review for such products. This dichotomy leads to a double negative effect on the industry.

In T&T the number of experts available to adequately service the market is inadequate. As a result, new entrepreneurs acting only as sales persons are opening up SWH businesses without the capacity to technically advise and service the business. This can lead to lack of public confidence in the SWH business and diminish acceptance of the technology.

*Recommendations*

In order to make a significant impact in terms of avoided cost for electricity for water heating and also in terms of $CO_2$ emissions, a penetration of about 10,000 SWH systems in the first instance would need to be realised. This could take approximately two years to materialise. Using the incentive scheme that Barbados adopted, T&T could see a similar growth to that which took place in the 1980's in Barbados. To achieve such an objective, the Government should enrol a specific programme for the market introduction of SWH that contains different elements: incentives, capacity building, awareness raising, standards, testing etc. Examples could be taken from the Mexican PROCALSOL programme (CONAE, 2007) or the Tunisian PROSOL project (TRABACCHI, 2012) among others.

Further market stimulation could be achieved through additional support. These should include the following:

- An enabling environment for SWH penetration must be created by the Government. This must ensure long-term fiscal and regulatory framework for both manufacturers and consumers.
- 100% Tax Credit on Solar Water Heaters (up to a maximum of $12,000.00 TT acquired for use by households) for the first five years of its implementation to jump-start the industry.
- Government can work by setting example: In the short-to-medium term, all new Government housing complexes and public buildings (such as hospitals, clinics and school laboratories) that utilize a significant volume of hot water should be equipped with SWH for all the hot water needs of the establishment.
- Older Government social housing establishments should be retrofitted with solar water heaters.
- Mandatory requirement of SWH installation for all those establishments with a high consumption of hot water, such as hotels, restaurants, hospitals etc.; for new constructed buildings effective immediately, for existing buildings after a grace period (see example of Mexico City).
- Dedicated efforts towards public education should be given priority.
- Established NGOs and champions for SWHs should be allowed a greater level of prominence through public forums for sensitising the public at large.
- Choice of manufacturing options must be done largely by ascertaining quality products over and beyond other factors.
- Government must work with manufacturers to ensure that high quality products, certified and labelled by the Trinidad and Tobago Bureau of Standards (TTBS), are developed; this will ensure not only customer satisfaction, but also confidence in the solar water heater business.
- If space for manufacturing is a problem, Government should be able to lease the land space necessary to potential manufacturers to establish a production plant.

Government can also assist in other ways. These include the following:

- Government must encourage innovation through competitions with attractive prizes.
- Higher taxes/penalties for electric water heaters should be imposed to make SWH prices and benefits more attractive to the consumer. Once the cost of the electric water heaters are substantially higher than at present, investment in SWHs would become more attractive.
- Removal/reduction of taxes for SWHs will definitely give a boost to the industry.
- Government should institutionalise a system of certification for all SWH installations throughout the country.
- Carbon trading could be considered as a further incentive to stimulate the penetration of SWHs.
- The average man on the street is unaware of EE and greenhouse gas emissions. Government can assist by providing sensitization programmes to the public through collaboration with specialists and experts in these areas.

- Further stimulation of the industry can be achieved by including relevant areas of SWH Technology into the curriculum for Technical/Vocational training, and engaging the appropriate specialists in this regard.
- Continuous research and development are important for competitiveness of the industry. Both, government and private sector, can work with academic institutions to further develop new technologies/designs that support GHG emissions reduction.
- Currently there is no system in place for collecting data on SWH installations. The MEEA should consider establishing an independent body to develop and maintain a data-base of SWH manufacturing, sales and installations. This will enhance the ability to better understand the current status of the SWH market in the country, and to analyse the effects, including the environmental benefits of reduced greenhouse gas emissions, of SWH deployment and usage.

## Potential and Opportunities for Local SWH Manufacturing

Highlighting the success of the Barbados case (see **Appendix K**: Solar Water Heating) illustrates that there is huge potential for solar water heating in T&T, especially since the insulation conditions are similar. However, the main significant difference is the price of electricity in T&T which is about eight times lower than in Barbados. Nonetheless, T&T has a significant advantage over Barbados in that with the country's wealth in natural gas resources for electricity generation, manufacturing is a real possibility. Labour costs in T&T are relatively cheaper than in Barbados. In addition, some of the raw materials would also be more easily available than in Barbados. All this amounts to high potential and favourable conditions for manufacturing in T&T.

## Capacity Building

One of the major problems in T&T regarding SWH is lack of trained personnel to service the industry. There are only a couple of companies who have technicians trained in installing and servicing the SWH industry. This underlines the urgent need for training and capacity building programs in T&T at different professional levels. The UWI has conducted limited training workshops in solar water heating technology. However, there is need to widen the target group to prepare the workforce for a possible expansion of the SWH industry. In particular, training needs to be conducted for various categories/groups of personnel who would be in the SWH manufacturing and installation industry.

Although some training workshops have been conducted greater training at different levels is required and should be directed to managers, consumers, financiers, technicians, teachers, policy makers, Government officials dealing with SWHs (customs officers, and others).

## Standards for SWH Systems in T&T

Experiences in other countries have shown that the implementation of quality standards play an important role in supporting the dissemination of SWH technology in the long run. The Trinidad and Tobago Bureau of Standards (TTBS) has published two documents on SWH systems so far and is currently working on a third. The first, TTS 106:2012, deals with "*Solar Water Heater Systems – Design and Installation Requirements*", and the second, TTS/EN 12975–1:2012, deals with "*Thermal Solar Systems and Components – Solar Collectors – Part 1: General Requirements*".

The information from these documents is the result of the work of the "Specification Committee for Solar Water Heaters" set up by the Trinidad and Tobago Bureau of Standards and chaired by Professor Gurmohan Kochhar of the Faculty of Engineering, UWI. This Committee comprises representatives from other relevant government ministries, the Regulated Industries Commission, private companies, the University of Trinidad and Tobago, and the Bureau of Standards.

### *TTS 106:2012*

The first standard is based largely on the requirements specified in the FSEC (Florida Solar Energy Centre) Standard 104–10 "*Florida Standards for Design and Installation of Solar Thermal Systems*". It also benefitted from the adoption of standards set up by the *Barbados National Standards Institute* (BNSI), the *British Standards Institute* (BSI) and *Standards Australia* (SA)/ *Standards New Zealand* (SNZ). This document is intended to assist manufacturers, importers, distributors and consumer groups as a reference in the adoption of solar water heating technology in T&T.

The standard comprehensively outlines the scope of the work regarding the requirements for the design and specification of individual components and the installation of solar water heater systems. It states the normative references, the terms and conditions for the purposes of the document, and the design and installation requirements. It also details the requirements for reliability and durability of the systems and components, safety requirements, operation and servicing indicators. The need for documentation in terms of provision of manuals and proper labelling for the systems has been highlighted.

Section 4.7 states that "Pumps, fans, ducts, piping and other components shall be sized to carry the heat transfer fluid at design flow rates without significant erosion or corrosion". It is not so much the design flow rates which will impact on the corrosion, but the quality of the components. Also because it is a closed component, the storage tank is especially glass-lined to prevent corrosion and properly designed systems include a sacrificial anode which attracts corrosion, if any. This section can therefore be removed and replaced if necessary.

Section 5.14 states that "Underground piping subject to vehicular traffic shall be installed to withstand the additional loading by this traffic. The trenches and backfill shall be free of sharp objects in contact with the pipe". This condition generally does not apply to T&T, especially in the case of domestic installations where the piping would normally be incorporated into the existing plumbing for the homes. It may of course be important for large-scale commercial installations where significant underground piping may become necessary.

### *TTS/EN 12975–1:2012*

Standard TTS/EN 12975–1:2012 is compulsory and deals specifically with solar collectors. This standard was adopted from the *European Committee for Standardization* (CEN) standard EN 12975–1:2006+A1:2010 "*Thermal solar systems and components – Solar collectors – Part 1*: *General requirements*", and modified for T&T conditions and purposes. Manufacturers, importers and distributors would be expected to adhere to these requirements.

CEN started its work for standards on solar thermal collectors and systems back in 1994 with the operation of a newly set-up Technical Committee. For the elaboration of European Technical Standards, corresponding national documents as well as international standards (ISO) have been taken into consideration. Compared to the then existing standards, the European norms have incorporated new features such as quality and reliability requirements. Besides the standard mentioned here, CEN has published several other standards for solar thermal products, among those about the design and manufacturing of different systems and respective test methods.

The general terms, scope and normative definitions have been modified for relevance to T&T in this standard. Under "Durability and Reliability, Safety, Collector identification" the clauses have been largely replaced, incorporating ISO 9806–1:1994 (*Test methods for solar collectors – Part 1: Thermal performance of glazed liquid heating collectors including pressure drop*), ISO 9806–2:1995 (*Test methods for solar collectors – Part 2: Qualification test procedures*) and ISO 9806–3:1995 (*Test methods for solar collectors – Part 3: Thermal performance of unglazed liquid heating collectors—sensible heat transfer only—including pressure drop*), and statements regarding snow load have been eliminated for irrelevance.

A section on compliance is also included and this largely deals with a certification mark and relevant documentation acceptable to TTBS. Since the European standard is generally forming the base of the new local standard, the modifications made according to the T&T situation are relevant and adequate.

In general, standards TTS 106:2012 and TTS/EN 12975–1:2012 are comprehensive and sufficient. It needs to be seen and further evaluated to what extent TTBS will able to perform conformity tests and which equipment and staff capacity will be needed to enter into such undertaking. To ensure compliance with the standards, the MEEA is planning to set up a special committee to investigate adherence to the standards. They also plan to establish a testing facility for solar water heaters.

### Conclusions

The potential for SWHs in Trinidad is sufficiently large is terms of the resource and demand for water heaters to safely establish viable industry both for implementation and manufacturing.

The SWH industry will benefit T&T in numerous ways, namely:

- Through manufacturing of SWHs, T&T could create an export market in the region and beyond.
- The creation of jobs and business opportunities.
- To mitigate some of the economic effects of the current decline in petroleum reserves.
- Contribute to improvements in living standards, income levels, health and hygiene, and environmental protection
- The commercial and industrial sectors in T&T represent an excellent target for large-scale deployment of SWH systems, as the need for hot water is crucial to their operations
- The environmental benefits gained will place T&T in a positive light with respect to the rest of the Caribbean.
- The development of the SWH industry provides an assurance for future investments in RE technologies.
- With the right incentives and people's acceptance of SWHs, the industry can flourish, as was the success story of Barbados.

## 6.5 Waste to Energy (WtE)

T&T is currently planning to diversify its energy mix to reduce the environmental impact (e.g. greenhouse gas emissions) and economic risks associated with the dependency on a single source of electricity generation. In keeping with this, the GoRTT has decided to evaluate the potential for RE.

Like most countries worldwide, T&T also faces increasing problems with the disposal of its Municipal Solid Waste (MSW). As the standard of living in T&T increases, so too does the amount of MSW generated daily. The existing disposal facilities are simple dump sites without proper environmental protection, leading to increasing environmental pollution of surrounding surface and ground water. In addition, these landfill sites are operating far beyond their originally planned capacity and should have been closed years ago.

Due to the difficulties in establishing new landfill sites as a result of the limited availability of land space in Trinidad, and the probable resistance of the residents close to these proposed new sites, the current dump sites are still in operation which is increasing the environmental damage.

An ideal solution for solving the MSW problem while providing T&T MSW into energy. This is standard in many countries and regions such as in the European Union, the USA, Japan, China, etc.

In this regard, a fact-finding mission was conducted to preliminarily investigate the potential for Waste-to-Energy (WtE) in T&T.

## Limitations of this Chapter

Due to the limited time in which this fact-finding mission was conducted, the findings have to be regarded with certain limitations:

a. Many of the published data on waste management in T&T are based on estimations of the authors. Due to the time constraints, all data that could not be verified personally during the mission were accepted from reference literature if plausible.
b. Due to the very small amount of MSW in Tobago, WtE is not a feasible option for this island. The feasibility of transporting the waste to facilities in Trinidad could be investigated in a further study.
c. Only MSW has been considered. Non-hazardous Industrial Waste and Commercial Waste have been excluded at this point.
d. Prices for equipment, maintenance and operation are based on international practices. For exact prices for T&T, additional inquiries have to be made.
e. Economic feasibility is assessed with estimations based on available information.

## Current Situation of Waste Management in Trinidad

### *Waste Generation, Collection and Disposal*

Trinidad currently generates an estimated 2,000 t of MSW per day (SMWCOL). Considering a population of 1.3 million inhabitants, this equates to a per capita generation of approximately 1.5 kg/person/day.

**Waste collection** is carried out by a number of private collection companies such as B.K. Holdings Ltd. These companies are awarded concessions to collect the MSW in specific areas in Trinidad and transport the waste to the landfills. In addition, these companies also collect waste directly from larger producers of waste such as companies, restaurants and markets.

**Waste disposal** in Trinidad is exclusively handled by SWMCOL (Trinidad and Tobago Solid Waste Management Company).

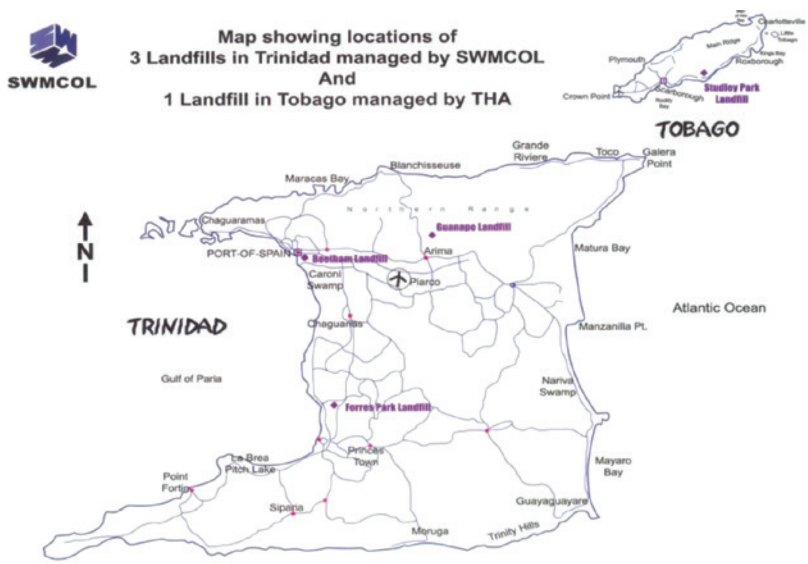
SWMCOL is a 100% state-owned enterprise which is in charge of the final disposal of MSW. For this purpose, SWMCOL operates the following three landfills (**Figure 46**):

- Beetham Landfill (approximately 1,000 t/d);
- Forres Park Landfill (approximately 500 t/d); and
- Guanapo Landfill (approximately 500 t/d).

Since SWMCOL is paid an annual lump sum treatment budget instead of a tipping fee based on the amount of disposed waste, disposed none of the three landfills provide over scales to weigh the actual amount of incoming waste. Therefore, there are no measured values for the amount of MSW delivered to the landfills. The above listed amounts of disposed waste have been estimated by SMWCOL from counting the number of arriving trucks multiplied by an estimated average load of MSW per truck. This leads to a large possible error with regard to the available amount of MSW for WtE.

**FIGURE 46**

Locations of SWMCOL landfills




*Source*: SWMCOL, n.d.

For the disposal of the MSW, SWMCOL receives varying annual budgets. For 2011 the budget was approximately TT$ 70 million. Based on an estimated value of 700,000 t/a MSW, the treatment costs are currently approximately TT$ 100/t. Since this treatment fee only covers the treatment at the landfill site "behind the gate", this TT$ 100 can be considered equivalent to a "gate fee" or "tipping fee", and has been used for the economic feasibility.

In addition to the Government budget, SWMCOL also receives additional income from private waste generators.

All landfills operated by SWMCOL are simple dump sites without protective liners, leachate collecting systems and temporary covers. Additionally, these landfills are operating far beyond their assigned capacity and were supposed to be closed several years ago. They are currently operating under temporary permits since the allocation of new landfill space is difficult mainly due to the limited availability of land space (typical for small islands).

The situation at the Beetham Landfill is particularly not ideal, as it is located in a coastal swamp area which is most unsuitable for waste (**Figure 47**). The landfill should have

**FIGURE 47**

Plan View of Beetham Landfill

*Source*: Picture taken from Google Earth.

been closed since 2003 but is still accepting approximately 1,000 t/d MSW, leading to continuing encroachment into the swamp land. This situation has already led to significant contamination of the surrounding environment. Additionally, due to the proximity of the dump site to the sea, contamination of the food chain (fish, shell fish etc.) can be expected.

By employing SWMCOL, all of Trinidad's MSW is currently under the control of the GoRTT. This is an excellent starting condition for WtE projects, as no long-term disposal concessions with private companies can block larger amounts of waste for WtE projects.

For a quantitative evaluation of the WtE potential in Trinidad, a detailed analysis of the actual amount of MSW/day has to be carried out.

### *Waste Composition and Usability for Waste to Energy*

For every WtE project, the composition of the MSW is of utmost importance. This determines the calorific value and informs on the most appropriate technology for each respective case.

Thorough waste characterization studies are therefore of great importance. Such studies should cover at least one complete year since the composition of MSW usually changes significantly throughout the year. For example, a waste characterization carried out during the days after Carnival is most likely not representative of the waste composition throughout the rest of the year. Seasonal harvests can also lead to significant changes in waste composition.

Such comprehensive studies are also important to understand the changes in the waste composition and anticipate possible future changes. Since these changes in waste composition will affect the incineration behaviour of the MSW, it is very useful to be able to predict future changes and their effect on the WtE facility.

Unfortunately, there have only been 3 isolated waste characterization studies conducted in Trinidad in 1995, 2007 and 2010. From these studies, only the data from the 1995 and 2010 studies were available for this report (**Table 33** and **Table 34**).

In 2009, K. Singh et al. published a study on the technical and economic feasibility of plasma gasification for Trinidad and Tobago. The study is based on a calorific value of 16 MJ/kg (SINGHA, 2009). This value is considered as unrealistically high and will therefore not be used in this report.

For comparison, MSW in Europe and the US, which also contains only a small organic fraction, usually has a calorific value of 9–11 MJ/kg.

**Table 33** **Waste composition at the three Landfill Sites (1995) Composition 1995**

| Type of waste | Beetham | Forres Park | Guanapo |
|---|---|---|---|
| Organics | 26.7% | 45% | 28.4% |
| Paper | 19.7% | 18% | 20.3% |
| Glass | 10.5% | 8% | 6.3% |
| Metals | 10.4% | 8% | 9.5% |
| Plastics | 19.9% | 13% | 19.6% |
| Textiles | 7.3% | 4% | 9.2% |
| Rubber & Leather | 5.3% | 2% | 6.6% |
| Other | 0.2% | 2% | 0.1% |

*Source*: SWMCOL, n.d.

The waste characterization from 1995 has to be considered with great caution. It can be assumed that the waste composition has changed over the past 17 years due to the economic development of T&T as well as changes in the consumer behaviour. Additionally, the figures derived for each of the three landfills are inconsistent and may show significant error.

**FIGURE 48**

Typical Disposed MSW in Port of Spain

*Foto*: Jochen Amrehn.

**Table 34** **Waste Composition 2010**

| Material<br>Household source | Average proportion in household waste | Estimated weight in 2010 (tonnes) |
|---|---|---|
| **Recyclable** | | |
| Organic food waste | 18.98% | 88,574 |
| Organic other | 8.17% | 38,127 |
| Plastics excluding beverage containers | 19.17% | 89,461 |
| Papers, all classes | 18.77% | 87,594 |
| Glass | 10.15% | 47,367 |
| Old corrugated cardboard | 3.83% | 17,874 |
| Metals, ferrous | 2.33% | 10,873 |
| Metals, non-ferrous | 1.41% | 6,579 |
| Beverage containers | 0.92% | 4,293 |
| Subtotal recyclable | 83.73% | 390,742 |
| **Non-recyclable** | | |
| Textiles and clothing | 7.82% | 36,494 |
| Household hazardous | 5.24% | 24,453 |
| Other | 2.71% | 12,646 |
| Construction and demolition | 0.50% | 2,333 |
| Subtotal non-recyclable | 16.27% | 75,926 |
| Grand total household source | 100.00% | 466,668 |
| **Institutional, commercial and industrial (ICI)** | | |
| Total ICI | | 2333,333 |
| Total waste disposed at all four landfills in 2010 | | 700,000 |

*Source*: SWMCOL, n.d.

The 2010 waste characterization which has been carried out by CBCL Ltd, a Canadian consulting company, is more consistent and corresponds well with observations made during the fact finding mission (CBCL, 2010; see **5–47**).

The MSW of Trinidad shows a surprisingly small organic fraction (<28%). This figure corresponds to investigations of MSW carried out during the fact finding mission. Trinidad's MSW is a very dry waste consisting in large parts of plastic, foam boxes and other non-anthropogenic materials. This composition corresponds more to European types of MSW more than to other tropical countries.

**FIGURE 49**

Disposed MSW at Beetham landfill

*Foto*: Jochen Amrehn.

**FIGURE 50**

Organic loads from plantations, markets and gardens can easily be separated from remaining waste

*Foto*: Jochen Amrehn.

### *Scavengers*

Like in many countries, scavengers form a part of the informal waste treatment sector. At all landfills in Trinidad, scavengers are separating valuable materials (mainly metals) from the incoming MSW. Electrical appliances and cables are burnt without protection in order to gather the metals.

Contrary to other countries, the scavengers in Trinidad are not separating plastic materials (due to lacking recycling possibilities).

Scavengers may strongly resist any industrialized waste treatment facility if they lose their income sources. In this regard, alternative earning possibilities need to be created for them.

One option could be the assignment of a dedicated "pre-sorting" area where the waste is dumped on specially designed floors. After pre-sorting, the waste is transferred into the waste bunker. This would provide the GoRTT with an option which possibly provides better health protection for the scavengers.

### *Future Changes in Waste Composition*

The GoRTT is currently implementing the "Beverage Containers Bill" which in the near future will introduce a deposit system for all bottles and other containers of beverages. Consequently, it can be expected the number of polyethylene bottles in particular will decrease significantly. This will lead to changes in the calorific value of the waste. To estimate the effect of the new bill on the calorific value, further studies need to be done.

## Investigated Technologies

Prior to the fact-finding mission and based on information from publications and available reports, a set of technologies was selected that could be technologically and economically feasible in the case of Trinidad.

From these technologies the most suitable option was selected based on the results of the fact-finding mission.

### *Moving Grate Incineration*

Moving grate incineration is the most widely used technology for WtE worldwide. It has been in use for over 50 years and the technology has been developed to a state that guarantees reliable operation and a high level of environmental protection.

Since moving grate incineration is capable of treating MSW with a wide range of compositions, it has been applied in both industrialized and developing countries.

The main disadvantage of moving grate incineration is that it requires large amounts of MSW (> 300 t/d) in order its operation to be economically feasible. This is because of the expensive flue gas cleaning system required for this technology.

The second disadvantage is that the electricity output of moving grate incinerators significantly drops with increasing moisture content of the waste. In this regard, MSW containing large amounts of organic waste or other materials with a high moisture content can cause serious problems for energy generation.

### *Gasification*

Gasification which refers to the combustion of fuel with under-stoichiometric amounts of oxygen has been very successful for biomass gasification. These systems have been in operation since 1935, and the technology has developed to very stable, reliable and state of the art.

This is not the case for MSW gasification. Due to the highly heterogeneous composition of MSW, its frequently changing composition and high moisture content, MSW is not suitable for direct gasification. While there are a number of companies offering gasification solutions for MSW, the direct gasification of untreated MSW is still facing serious technical problems and cannot be recommended for WtE projects.

An alternative solution is the gasification of Refuse Derived Fuel (RDF). RDF is a dried and pre-treated fuel derived from MSW (see chapter 6.5). Due to the pre-treatment, the fluctuations in the composition in RDF are significantly smaller, the calorific value is significantly higher (approximately 16 MJ/kg) and the moisture content is significantly lower (usually <15%).

However, gasification of pure RDF is currently not possible due to severe tar problems. Smaller plants (operating with a capacity < 30 t/d) with blends of approximately 50% RDF and 50% biomass have been operating in several countries, especially in South and Southeast Asia. There are no long-term experiences available to date.

The main advantages of gasification plants are:

- The significantly smaller construction area needed for the plant when compared to moving grate incinerators;
- The lower investment costs for the flue gas cleaning system; and
- No boiler systems and turbines which are difficult to maintain are required for electricity generation.

### *Plasma Gasification*

Plasma gasification and plasma assisted gasification are currently widely advertised technologies for the treatment of MSW. These technologies originate from metal melting processes and have been proven successful for the incineration of highly toxic industrial waste (hazardous waste).

Particularly with regard to the economic feasibility for MSW gasification, a number of incorrect statements are circulating about plasma gasification:

- In reports on the number of operating plants, often also included are metal smelters, hazardous waste gasification plants etc., although the process shows significant differences and the economic data are entirely different.

- The calorific value of MSW is often exaggerated in order to achieve economic feasibility (often the value of 16 MJ/kg can be found).
- The number of plants that have been shut down due to technical or economic problems are not presented.

The following gives a number of facts about plasma gasification:

- Globally there is only one full industrial-scale operational plasma gasification plant in Japan. Others are small plants with capacities of less than 50 t/d (USA, Canada). The plasma gasification plant in Japan has been built due to specific existing Government regulations.
- The initial investment, as well as the operation and maintenance costs for plasma gasification is significantly higher than for grate incineration.
- Plasma gasification requires significantly more energy for the process than incineration, thereby reducing the total energy output.
- There is very little information published about the performance of the plants leaving doubts about their technical and economic performance.
- Operation requires highly trained technicians.

Plasma gasification should only be considered for types of waste which are very difficult to treat. Since the MSW in Trinidad is a very easy to treat standard MSW, less expensive and more proven technologies should be applied.

### *Pyrolysis*

Pyrolysis is the combustion of MSW under exclusion of oxygen. It has been advertised widely over the past few years as an alternative treatment method for the thermal treatment of MSW.

Energy generation by pyrolysis consists of two consecutive steps. In the first process step, the pyrolysis reaction produces a mixture of oil, synthesis gas (a mixture of carbon dioxide (9–55% by volume), carbon monoxide (16–51%), hydrogen (2–43%), methane (4–11%) and small amounts of higher hydrocarbons) (BROWNSORT, 2009) and tar from hydrocarbons in the MSW. These three products are combustible fuels and can be converted in the second step into energy by different technologies, e.g. specialized gas engines.

For MSW, pyrolysis has a number of significant disadvantages that make it unsuitable for the treatment of MSW:

- The technology cannot cope with fluctuations in the waste composition.
- The three different output materials of the pyrolysis process i.e. gaseous, liquid and solid fuels require different technologies for their combustion.

- Since there are no existing commercial reference plants, there is no experience with the operation of such plants on an industrial scale.

### *Mechanical Biological Treatment (MBT) plus Gasification*

Prior to the fact-finding mission, it was considered that the MSW in Trinidad should comprise of a large organic fraction, as has been experienced in most tropical countries with a significant agricultural sector.

Due to the high organic fraction, the moisture content in the waste reduces the calorific value of the waste, thus making incineration less effective.

In order to increase the calorific value of the MSW and utilize the organic fraction in the most efficient way for energy generation, MBT provides a suitable treatment method.

In Mechanical Biological Treatment (MBT) the organic fraction of the MSW is converted into biogas which can be used in gas engines to produce electricity. The high calorific fraction is converted into RDF, an alternative fuel with an increased calorific value which is suitable e.g. for gasification it is mixed with other materials such as biomass. The RDF can also be used as an alternative fuel in conventional incinerators for power generation or as a substitute for coal in cement kilns.

From the energy generated from the biogas process, usually approximately 50–60% will be used to operate the plant. The remaining energy plus the energy generated from the combustion of the RDF can be sold to the grid.

In general, approximately 1 t of fresh MSW will generate 280–330 kg of RDF with a calorific value between 14 and 16 MJ/kg.

### *Summary Thermal Conversion Technologies*

As seen in **Table 35**, the most reliable technology is currently the conventional combustion (moving grate) technology.

A combination of MBT and gasification may be an option only for waste with high moisture content or waste compositions that are difficult to incinerate directly.

### *Suggested Technology*

Based on the findings at the Beetham landfill, investigations of MSW in Port of Spain and considering the limitations outlined in Chapter 6.3, the following solution is suggested:

**Table 35** **Comparison of Thermal Conversion Technologies**

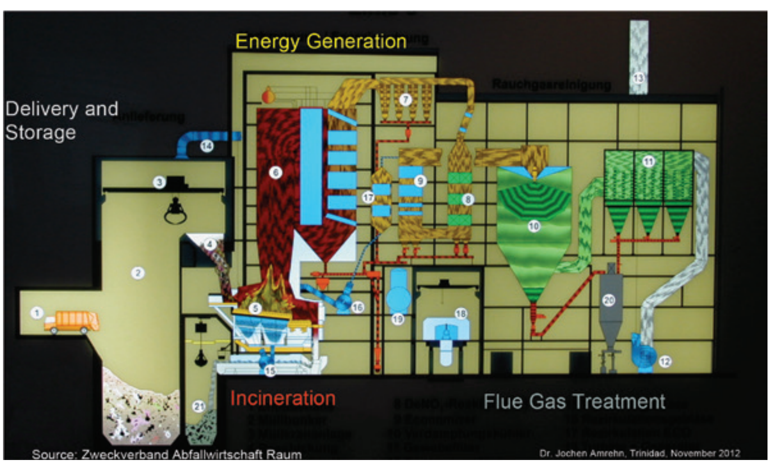
| Characteristics | Conventional Combustion | Gasification | Plasma Gasification | Pyrolysis |
|---|---|---|---|---|
| Applicable to unprocessed MSW with varying composition | Yes | No | Yes/No | No |
| Commercially proven with relatively simple operation and high degree of reliability | Yes | Commercially proven to a limited degree, more complex than combustion, requires addition of biomass | No | No |
| Reasonably reliable set of performance data | Yes | Limited data available, operational problems have been reported | Limited data available, operational problems have been reported | Limited data available, operational problems have been reported |

*Source*: own elaboration by Jochen Amrehn.

The most suitable technology for Trinidad is the moving grate incinerator technology combined with steam turbines for electricity generation (**Figure 51**).

**FIGURE 51**

Schematic Cross Section of a Moving Grate Incinerator




*Source*: ZVAWS n.d.

Reasons for this recommendation include:

- The MSW in T&T is a dry waste with less than 30% organic fraction. This type of waste is an easily combustible waste and does not require special technologies for pre-treatment. Larger deliveries of organic waste can be easily re-routed, e.g. to new composting facilities.
- Moving grate incineration is a long established and well understood technology. There are a large number of experienced engineering companies that provide this technology.
- There are a large number of experienced engineers available worldwide that can support the operation of moving grate incinerators during the starting phase.
- T&T has a large number of industrial engineers that can easily be trained to operate moving grate incinerators.

To provide scavengers with an alternative source of income generation and collect valuable materials, a pre-sorting area could be established (**Figure 52)**. This would avoid conflicts with the informal sector. In a later phase, this sorting area could be replaced by an automatic sorting machine (e.g. Trommel sieve, magnetic separator, eddy-current separator etc.).

As mentioned above, this recommendation is based on the limited information available. To provide a detailed recommendation, additional assessments have to be carried out (see chapter 5.3).

### *Expected Energy Generation*

There is currently no data available on the calorific value of the T&T waste throughout the year. Estimations of the calorific value are therefore based on the only available waste characterization from 2010 and observations made during the fact finding mission.

Since the calorific value is the most important factor in addition to the respective efficiency of the WtE plant in determining the energy yield of a WtE plant, the possible error in the calculation of the energy yield is regarded as very high.

Based on the waste analysis and observations, the calorific value of T&T waste can be estimated to be approximately equivalent to that MSW in Europe or USA, i.e. between 8 and 11 MJ/kg.

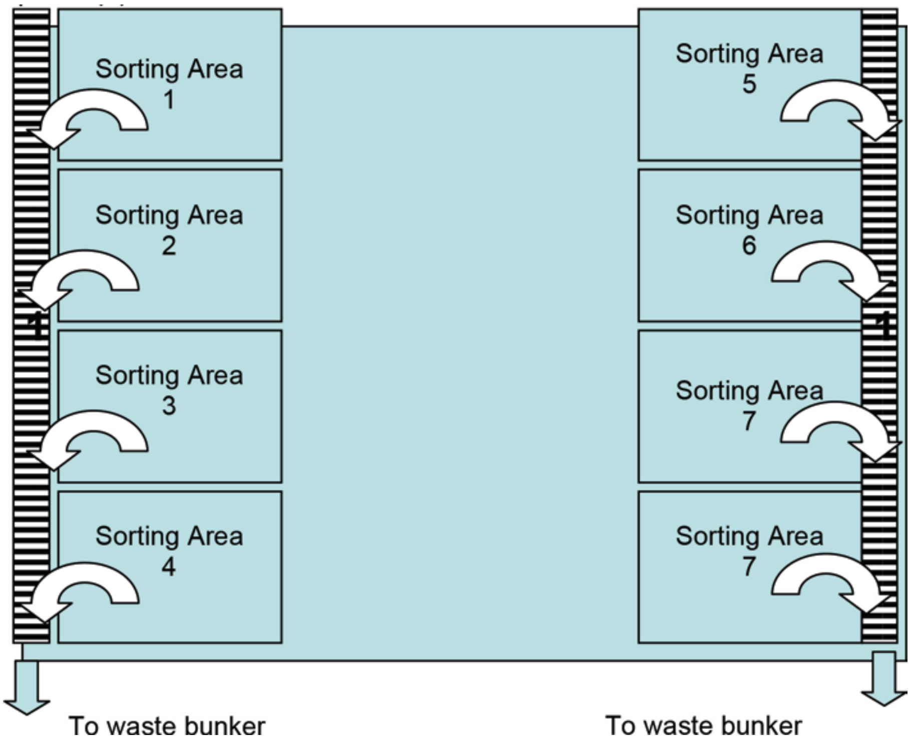
With an estimated operation of 7,500 h/a and an estimated amount of 700,000 t/a of MSW in Trinidad and Tobago, the electricity generation could be in the range of 30 to 50 MW.

The high error margin of 50% results from the limited information about the calorific value of the T&T MSW, as well as from uncertainties resulting from different plant designs.

**FIGURE 52**

Suggestion for a Manual Pre-sorting Area

*Waste is dumped in the assigned sorting areas. Valuable materials are removed and the remaining waste is transferred by a conveyor system (1) to the waste bunker.




*Source*: Own elaboration.

By applying combined cycles instead of using the steam for process heat this energy yield can be increased.

## Economic Feasibility of WtE

In addition to the technical feasibility of WtE in Trinidad, the economic feasibility is of great importance for successful implementation.

MSW incineration provides the following four sources of income:

- Tipping fee for the treatment of the waste (from communities or companies);
- Electricity generated from the MSW;

- Steam (can be sold to industries requiring process heat); and
- Separated recycling materials, such as metals, bottom ash, etc.

Particularly for tropical countries, the main sources of income are from the first two items: tipping fee and electricity. Utilization of the other two forms of income can support the revenue of the plant and can be used to reduce the tipping fee and/or necessary Government subsidies.

### *Economic Models*

Unlike many other forms of RE projects, the economic feasibility of WtE projects should not be evaluated on a commercial basis only.

WtE always has to be considered as an integral part of the waste management and treatment concept of a city or community. High investment and operation costs make a successful and sustainable operation under pure market conditions impossible.

As a consequence, WtE always requires Government subsidies in one form or another.

Globally, mainly three different economic models are employed, which are discussed below.

**Tipping-Fee Based Model (Examples: Europe, USA, and Japan)**

This model has been mainly implemented in some industrialized countries. It is particularly well suited for countries where the WtE facilities are operated by state enterprises, but the model also allows private investment as well as Build-Operate-Transfer (BOT) projects.

This model strongly emphasizes the role of the WtE as an integral part of the country's waste management concept. As such, it is also able to finance the incineration process.

In the tipping-fee based model, the main source of income for the WtE plant is derived from a high tipping fee, e.g. paid by the city administration to the operator of the incinerator.

Income from electricity is only regarded as a "top-up" to partially support the costs for maintenance and operation of the plant.

The tipping fee usually ranges between US$ 60 and US$ 200 per ton of MSW. The height of the tipping fee hereby depends on amongst other things, the respective business model (Government-owned, BOT, Build-Own-Operate-Transfer (BOOT), etc.) and the technology applied.

**Adder Based Model (Example: Thailand)**
In countries where a high tipping fee cannot be implemented (e.g. for political reasons) the Adder Based Model can be implemented. In this model, the Government introduces a feed-in tariff or adder system, in order to support various forms of RE.

For WtE, which usually includes both energy generated from biogas from mixed MSW and energy generated from fresh MSW or RDF, an adder is introduced where the energy generating organization receives payment for each kWh sold to the grid. The price is paid per kWh and is intended to subsidize the higher investment and operating costs for RE projects. The Power Purchasing Agreements (PPAs) for such projects depend on the height of the adder and are effective for a period of 7 to 10 years.

In this model the tipping fee is kept low and only partially supports maintenance and operation of the plant. The main source of income is from selling electricity to the grid.

The feed-in tariff in Thailand for WtE is currently 3.5 Baht/kWh (US$ 0.10) which is paid on top of the usual 2.5 Baht/kWh (US$ 0.075) for non-RE power generation. On islands where diesel-powered plants are replaced by RE power plants, an additional 1 Baht/kWh (US$ 0.028) can be approved (DEDE, 2010).

The PPAs for WtE projects in Thailand last 7 years and are not extendable. After this time only the normal electricity generation price will be paid.

**Government Owned Model (Example: China)**
The third model requires extensive investment on the Government's side. The initial investment for installation of the WtE plant is fully provided by the Government. The operator (state enterprise or private investor) only covers the expenses for operation and maintenance from the income received.

This model neither requires high tipping fees nor the introduction of a feed-in tariff scheme for RE.

### *Preliminary Economic Feasibility Estimations for T&T*
Due to a lack of available figures from T&T, the following estimations for the costs of a WtE plant have to be considered with great caution. Operation and maintenance costs for a WtE plant strongly depends on the respective local conditions. To be able to estimate the operation and maintenance costs, additional investigations have to be carried out in T&T.

The investment costs for a WtE plant based on moving grate technology can be estimated to be between US$ 65 and 80 million for a capacity of 500 t/d, i.e. 160,000 t/a, including commissioning and start-up.

The operating costs consist among others of fixed costs, e.g. capital charges, salaries for staff, insurances, permits etc. and variable costs, e.g. consumables (in particular chemicals required for the flue gas treatment such as CaO, activated carbon, ammonia), disposal costs for residues (ashes and materials sorted out in the arrival hall) and operating costs for the wastewater treatment system.

Since the operating costs of the incinerator in Phuket (Thailand) are unusually high due to inefficient operation, the operating costs for moving grate incinerators were estimated based on data from similar projects in Southeast Asia. Costs for the disposal of the residues are not included in the calculation.

Within the United Kingdom (LONDON 2008), operating costs range between:

- US$ 85 and 110 /t for a plant size of <100,000 t/a capacity;
- US$ 80 and 110 /t for a plant size of 150,000 t/a capacity; and
- US$ 70 and 80 /t for a plant size of 150,000–200,000 t/a capacity.

The World Bank Report "Municipal Solid Waste Incineration: A Decision Makers' Guide" (WB, 2000) states different operating costs for the same plant sizes mentioned above:

- US$ 48 /t for a plant size of <100,000 t/a capacity;
- US$ 40 /t for a plant size of 150,000 t/a capacity; and
- US$ 38–40 /t for a plant size of 150,000–200,000 t/a capacity.

This report does not indicate whether capital cost and insurances are included.

These two examples show the strong regional variations in the operating costs for WtE plants. Thus, without further studies it is not possible to estimate the exact operating costs for T&T.

**Income based on the current situation**

For the calculation of the income from tipping fee, the annual treatment budget of SWMCOL in 2012 (approximately TT$ 70 million) was considered as a tipping fee.

With a total of 700,000 t of MSW treated in 2012 the average tipping fee is approximately TT$ 100 or approximately US$ 15 per ton. The current price of electricity for the residential sector in T&T starts at US$ 0.04/kWh.

**Economic Feasibility for the suggested 500 t/d Plant**

The following cost estimations were adapted from quotations of Chinese technology providers for WtE plants in Southeast Asia.

**Cost:**

| | | |
|---|---|---|
| Initial investment: | | US$ 65–80 million |
| Operating cost: | | US$ 3–5 million/a |
| (Excludes disposal (excl. disposal, depreciation and interests) | | |

**Income:**

| | | |
|---|---|---|
| Income from tipping fee: | 160,000 t/a * US$ 15 = | US$ 2,400,000/a |
| Income from electricity: | 8 MW*7500 h/a = | |
| (Low estimation) | 60,000,000 kWh/a | US$ 2,400,000/a |
| *or* | | |
| Income from electricity: | 12 MW*7500 h/a = | |
| (High estimation) | 90,000,000 kWh/a | US$ 3,600,000 /a |
| Total income: | | US$ 4,800,000–6,000,000/a |

Income from the recovery of recycling materials and the utilization of steam was not considered.

**Summary: Economic Feasibility for T&T**

In the best case scenario (12 MW electricity generation and low maintenance costs), income from electricity generation will barely cover maintenance and operating costs of the plant.

The tipping fee itself will not provide sufficient income to ensure a reasonable Return on Investment (ROI) for the plant.

The preliminary economic estimation shows:

- It is obvious that under the current conditions WtE-projects are not economically feasible.
- In order to make WtE projects in T&T economically feasible, it is very important to assess the exact costs and develop an appropriate economic model.
- To improve the economic feasibility of WtE plants in T&T, possible utilization of the steam should be investigated.

## Current Obstacles for the Implementation of WtE projects

As the first feasibility estimations have shown, WtE projects are not economically viable under current conditions.

The main obstacles include the following:

1. The price of electricity generation in T&T is very low. Income from electricity sale will not be sufficient to achieve a reasonable ROI for the investment, as well as ensure sufficient income for maintenance and operation of the plants.
2. With the current subsidies for electricity from natural gas, alternative forms of energy generation including WtE cannot compete.
3. Regulations in T&T limit the possibility of private investors for electricity generation. In order to allow feeding electricity into the grid, T&TEC must be majority shareholder in the project based on the existing regulations. This limits the attractiveness for private investors.
4. The current waste disposal fees are too low (approximately TT$ 100 /t) to finance and maintain WtE plants.
5. There is a strong informal sector (scavengers) working at the landfill sites generating income for their families. These scavengers will resist technical waste treatment technologies in the case where these technologies will eliminate their sources of income.

In order to overcome the existing obstacles and facilitate WtE in T&T, a number of steps need to be taken, which are outlined below.

1. The GoRTT has to decide whether WtE should be operated either by Government agencies, or if the private sector should be invited to build and operate WtE plants (e.g. BOT, BOOT).
2. In the case where the private sector is involved in WtE, the following should be done:
   a. WtE should be regarded as a form of RE and an appropriate feed-in tariff mechanism has to be established (e.g. similar to the one in Thailand); and
   b. restrictions for private investors to sell electricity to the grid should be eased to allow private investor ownership or majority shares for the project.
3. If the Government should take responsibility for the establishment and operation of WtE plants, the following should be done:
   a. A budget for the construction of the WtE plants needs to be allocated; and
   b. a tipping fee should be introduced that covers operation and maintenance of the plant.
4. A solution for the integration of the informal sector has to be developed.
5. The GoRTT has to develop a Public Relations (PR) campaign in order to promote WtE to the population.

## Suggested Implementation Strategy

Based on the recommendation that the WtE system in T&T should be based on Moving Grate Incineration and on currently available information, the following implementation strategy is recommended.

As a *first step*, the GoRTT has to make a decision on the establishment of WtE in T&T. This includes decisions on the technology, the ownership and operation of such projects, the financial models and the environmental standards to be applied.

As a *second course of action*, the GoRTT should develop a PR strategy to invite public participation in the WtE concept. This will reduce later conflicts during the approval and operation of WtE projects.

*Parallel to this*, the biomass from markets and restaurants should be re-directed to a new composting plant. Apart from increasing the calorific value of the MSW, this concept will produce high quality compost which can be used either in agriculture or public parks.

In the *final stage*, MSW incineration power plants should be established at the sites of the current landfills with approximately the same capacity as the current landfills. This will have important advantages such as:

- The waste collection system does not need to be changed, so that well established routings and collection schedules can be maintained;
- The landfills have good connections to major roads;
- The land is owned by the Government, so that no land acquisitions which may face public are required opposition;
- The land is already used for MSW disposal reducing the risk of public resistance (especially if accompanied by a well-prepared PR campaign); and
- Existing waste from the landfill can be slowly added to the fresh waste for incineration, thereby reclaiming the land and reducing environmental contamination of adjacent land and waters. The old waste can be transferred to the plant with simple conveyor systems.

In order to establish the technology and provide the time needed to train required engineers, the implementation of the full program should be carried out step-wise. At first, a smaller MSW incineration power plant with 500 t/d capacity (50% of the arriving waste) should be built at Beetham landfill (**Figure 53**). This plant should be designed so that in the future an extension of the plant to 1000 t/d can be easily done. Waste bunker, filter and delivery infrastructure should be planned accordingly.

With this plant, experiments should be carried out to determine a suitable amount of existing waste from the old landfill that can be added to the fresh MSW. Since there is a distillery located close to the Beetham landfill site, the possibility of providing process heat (steam) to this distillery should be investigated. After successful operation of the plant for 2–3 years, the extension of the Beetham plant and the construction of two WtE plants at the Forres Park and Guanapo landfills can be planned, based on the experiences of the first plant.

**FIGURE 53**

Suggested Location of First Incineration Plant


Proposed plant location at Beetham landfill (1). The plant is located next to a major highway (3) and to power lines (2 not to scale). Old waste from the current landfill can be added (4).

*Source*: Own graph based on Google Maps.

## WtE in other Island Countries

### *Existing plants*

**Bermuda**

Bermuda is a self-governed territory of the U.K. with a population of 68,000 people. The waste generation is 80,000–100,000 t/a, with a calorific value of 9–11 MJ/kg (i.e. similar to T&T). Since 1994, a MSW Moving Grate Incinerator (Tynes Bay Waste Treatment Facility) has been operating in Bermuda, with a maximum capacity of 96,000 t/a and an average amount of MSW incinerated of 68,000 t/a. Electricity output is 18,000 MWh/a (i.e. approximately 2.5 MW capacity). Own consumption is 40% and includes a Reverse Osmosis desalination plant (BARRIGA, 2011).

Ash is disposed as concrete blocks in the sea.

*Comment: This disposal method is questionable and should be investigated carefully before applying it e.g. in T&T.*

In 2009, dioxin and furan emissions exceeded the legal limits indicating either operational or technical problems at the plant.

**Martinique**

Martinique is an overseas territory of France with a population of 403,000 people and a MSW generation of 375,000 t/a (2009). The calorific value of the MSW is less than 8 MJ/kg, indicating a large fraction of organic waste which is rather surprising given the existence of an 18,000 t/a biomass WtE plant. The MSW incinerator has a capacity of 112,000 t/a generating approximately 45,000 MWh of electricity annually (i.e. approximate capacity of 6.2 MW). Parallel to this, Martinique is still operating three unregulated landfills which receive approximately 260,000 t/a MSW (BARRIGA, 2011).

**St. Barthélemy**

St. Barthélemy is an overseas territory of France with a population of 8,900 people and a MSW generation of approximately 9,700 t/a.

A small incinerator (cyclic oscillating kiln) has been operating in St. Barthélemy since 2001, with an energy generation of 20,000 MWh/a thermal. The energy is used to operate a desalination plant with a capacity of 1350 $m^3$/d. There is no electricity generation. The reason for establishing a WtE plant was the acute lack of fresh water on St. Barthélemy.

Residues are transported to the capital and stored in a Class 1 landfill (BARRIGA, 2011).

## *WtE plans*

**Puerto Rico**

Puerto Rico is an unincorporated territory of the USA with a total population of 32.7 million and a waste generation of approximately 11,100 t/d in 2007 (COLUMBIA, 2007). Like other Caribbean island nations, Puerto Rico is rapidly running out of landfill space for its MSW. From the 28 existing landfills only a few meet international standards. Estimations predict that the existing landfills will be exhausted by 2018.

The Government of Puerto Rico is planning to shut down all landfills that have not fulfilled international requirements by the end of 2014, to reduce the environmental impact of the landfills. By 2020 only 4 landfills are planned to remain open. While previous U.S. Governments, e.g. under President Bush, have supported the concept of WtE in Puerto Rico; under the Government of President Obama, the policy for Puerto Rico has shifted from WtE to reducing MSW and land filling.

In May 2007, a study on the WtE potential in Puerto Rico has been carried out by Columbia University for the U.S. Environmental Protection Agency (EPA), which showed good potential for WtE in Puerto Rico (COLUMBIA, 2007). The study strongly recommends an early PR campaign to promote WtE among the population. Public hearings have been carried out in 2011and 2012 for two MSW incinerator plants (Arecibo and Barceloneta) with a total capacity of 2,016 t/d and a proposed energy generation of 77 MW (Carol, 2012) (US EPA, 2012).

**St. Kitts**

St. Kitts has a population of 39,000 people with a waste generation of approximately 130,000 t/a. In 2012, a MSW incineration plant with a capacity of 64,000 t/a or 130 t/d has been proposed by Naanovo UK as a BOOT project at the landfill site Bassaterre (information based on NAANOVO, 2012).

The contract will allow Naanovo to operate the plant for 25 years after which the plant will be transferred to the Government. In addition to fresh waste, old waste from the current landfills will also be burnt. Naanovo expects an energy generation of approximately 7–8 MW from this plant. The proposal is still in the approval process.

*Comment: Given the MSW composition of the waste in this region this estimated energy yield is far too high*.

**Jamaica**

With a population of 2.7 million people (2010), Jamaica generates approximately 1.2–1.3 million t/a MSW. Approximately 70–75% of this waste is collected. Currently Jamaica maintains 8 non-sanitary landfills and two main disposal sites. The site at Riverton receives approximately 60% of Jamaica's MSW (545,000 t/a), while the Retirement site receives about 20%, i.e. 219,000 t/a.

In 2010, the Ministry of Energy and Mining of Jamaica published its National Waste-From-Energy Plan 2010–2030 (JAMAICA, 2010). In this plan, the Government of Jamaica announced a plan to establish WtE plants as a part of its RE program. In 2009, a Memorandum of Understanding between Petroleum Corporation of Jamaica (PCJ) and Cambridge Project Development was signed to build two waste incineration plants with a total electricity generation capacity of 65 MW. The plants have not yet been constructed.

In August 2012, a new consortium was announced between British company Naanovo and a Jamaican businessman to build a MSW incineration plant at the Riverton site. The project costs are estimated to be about US$ 140–180 million.

**Mauritius**

Mauritius has a population of 1.3 million people, i.e. approximately equivalent to the population of T&T. Waste generation in 2008 was 425,000 t. Based on the waste composition, a low calorific value of less than 8 MJ/kg can be expected. Mauritius has planned a MSW incineration plant with a total capacity of 300,000 t/a that will generate 160,000 MWh (22 MW) of electricity. The expected investment costs are approximately US$ 200 million.

**United States Virgin Islands (V.I.)**

The Virgin Islands is an unincorporated organized territory of the USA with a population of 109,000 people and a MSW generation of 133,000 t/a. Since 2009, Alpine Energy Group (AEG) has proposed a WtE project comprising of an RDF processing plant, combined with combustion and energy recovery plant. The proposed energy generation is 20 MW with 16 MW available for supply to the grid. The project still faces resistance by the public.

*Comment: Based on 400 t/d fresh MSW and the additional energy requirements for the RDF processing plant, the proposed energy generation seems to be unrealistic.*

The V.I. Waste Management Authority has guaranteed AEG a minimum of 400 t/d MSW and signed a Power Purchasing Agreement (PPA) to buy at least 16 MW at US$ 0.10–0.14/kWh. The agreement has been signed for an initial 30 year operation with two possible extensions of 10 years each.

In 2011, the National Renewable Energy Laboratory (U.S. Department of Energy) published a feasibility study on WtE for the Virgin Islands stressing the beneficial role of WtE as part of the national MSW management system.

## Suggested Follow-Ups

- Whether the existing treatment facilities, e.g. at Kaizen Environmental (e.g. stabilization process and disposal facilities), are sufficient for the safe disposal of fly and filter ashes from the incinerators should be determined, i.e. stabilization process and disposal facilities (e.g. at Kaizen Environmental).
- Emission standards for exhaust gas and effluents from MSW Incinerators should be established. If standards are taken from other countries, these standards have to be adapted to the specific situation in T&T.

- A comprehensive waste characterization study has to be carried out covering at least 9 months. The study should include thorough assessments of the calorific value of the wet and dry MSW. Furthermore the chemical composition has to be analysed, i.e. ash, sulphur and chloride content, acidity, etc. Possibilities to increase the calorific value by source separation should also be identified.
- A study of composition and status of the old waste at the three landfills should be carried out to investigate its potential for co-incineration at the WtE plants.
- Technical specifications for MSW incineration power plants should be developed.
- It has to be analysed how much of an incinerator power plant can be built locally and how much of the equipment has to be imported.
- Various economic models should be calculated based on exact figures (after the waste characterization analysis has been completed).

The consultants have developed a budget for undertaking the relevant follow-ups with regard to WtE proposed. It is planned that the detailed waste characterization study as defined by the consultants will be undertaken by the MEEA.

## Conclusions

Waste-to-Energy is an attractive solution for T&T. It will assist in:

- Solving the waste disposal problem of Trinidad; and
- Providing an additional source of energy for the energy mix of T&T.

T&T MSW is suitable for direct incineration (moving grate incineration) without further pre-treatment. Standard incineration technology can therefore be used. The calorific value can be estimated to be in the range of 8 to 11 MJ/kg (based on the examined MSW during the mission).

With the current subsidies for electricity from natural gas and without subsidies for electricity from MSW and/or a significant increase in the tipping fee for MSW, WtE is economically infeasible.

The current collecting system and the Government monopoly for MSW treatment are perfect starting conditions for WtE projects. In order to evaluate the economic and social aspects of WtE in T&T, the GoRTT has to consider the economic benefits of WtE for the re-cultivation and reclamation of the contaminated areas at the current landfills, as well as the mitigation of additional environmental and health damages caused by continuing improper waste disposal.

## 6.6 Bioenergy Use for Electricity Generation

### Energy Potential of different Resources

*Solid Biomass*

Solid biomass resources are residues and/or by-products from agricultural or forestry operations. They are available at the field level,[22] at the processing level and at the end-use level. Higher accumulations are always possible at downstream processes, e.g. bagasse at sugar mills or rice husk at rice mills. Field residues need to be collected and transported first, which reduces their economic potential.

Resources in downstream operations can be used for the internal energy demands at the processing facility (as heat for drying for example or steam for process use or even electricity) and possibly for exports of any surplus. The other option is the use of resources in a specifically assigned conversion facility.

Usually (and internationally) solid biomass resources are converted to electricity and steam. Surplus power could then be exported to the national grid and substitute conventional electricity generation. Other options for decentralized utilization of biomass are gasification and use of the gas in a generator or biogas production and a similar use for power generation.

Agriculture in T&T contributes with 0.3 to 0.4% to the GDP in total (figures available up to the year 2009 in: CSO, 2009) and is therefore only a minor sector. In the following sections, a screening of potential resources is done for the different classifications.

**Field Resources**

The agricultural production in T&T is shown in **Table 36**. Most of the agricultural products are vegetables and food items for local consumption. The current production for the three main staple foods is 2,273 tons of rice (paddy), 3,150 tons of sweet potato and 5,454 tons of cassava.

The field residues of these 3 items are rice straw, cassava root and stem and sweet potato leaves. The residue to product ratio[23] for these three examples may be in the vicinity of 1.0 for rice straw, 0.2 for cassava and 0.1 for sweet potato. This gives a theoretical potential of 2,273 tons of rice straw, 1,091 tons of cassava residues and 315 tons of sweet potato leaves.

[22] Field level refers to agricultural production. For forestry products this means inside the forest area, for energy crops this refers to the original place of production.
[23] No specific residue to product ratios are available for T&T, international averages have been taken.

**Table 36 Production of key commodities**

Summary of production targets identified for priority commodities for period 2012–2015

| Commodity food group | Commodity | Current consumption (tonnes) | Current production (tonnes) | 2012–2013 | 2013–214 | 2014–2015 |
|---|---|---|---|---|---|---|
| Staples | Rice | 33,636 | 2,273 | 3,000 | 5,000 | 7,500 |
| | Sweet potato | 7,000 | 3,150 | 8,727 | 10,909 | 13,090 |
| | Cassava | 4,500 | 5,454 | 11,817 | 15,453 | 18,182 |
| | Breadfruit[a] | 10 | 10 | 11 | 12 | 13 |
| Vegetables | Tomatoes | 2,600 | 2,150 | 2,444 | 2,774 | 3,100 |
| | Hot peppers | 423 | 710 | 1,100 | 1,500 | 1,800 |
| | Cucumber | 1,050 | 1,320 | 1,400 | 1,500 | 1,760 |
| | Pumpkin | 485 | 1,790 | 1,840 | 1,890 | 1,950 |
| | Melongene | 436 | 540 | 550 | 565 | 586 |
| | Ochro | 921 | 940 | 960 | 980 | 1,000 |
| | Dasheen bush | 328 | 340 | 360 | 380 | 400 |
| | Onion | – | – | 500 | 1,500 | 2,000 |
| Fruits | Banana (sucrier) | ≤ 5 | ≤ 5 | 230 | 300 | 400 |
| | Citrus[b] | 32,271 | 1,537 | 1,614 | 1,695 | 1,780 |
| | Mangoes[b] | 50 | 50 | 50 | 53 | 55 |
| | Pineapple | 462 | 462 | 700 | 700 | 400 |
| | Pawpaw | 1,716 | 1,716 | 3,432 | 3,432 | 3,432 |
| Aquaculture | Tilapia | 112 | 22 | 90 | 180 | 270 |
| Livestock | Sheep & goat[c] | 3,369 | 355 | 360 | 375 | 425 |
| | Dairy goat | – | 20* | 40 | 60 | 80 |
| | Dairy cattle[c] | 75,864 | 4,300 | 4,750 | 5,200 | 5,650 |
| Pulses | Pigeon peas | 802 | 130 | 140 | 150 | 160 |
| | Bodi | 928 | 970 | 1,010 | 1,050 | 1,110 |

*Source*: MFMLA 2012.
[a] Backyard gardening.
[b] Tree crops – significant impact will be grom 2015.
[c] Livestock – significant impact will be grom 2016.
* Value is estimated.

The total theoretical amount of field resources for the main staple foods in T&T would result in some 3,600 tons of biomass per year. With an average calorific value of 13 GJ/t and using similar assumptions as for the biomass power plant (see chapter 5.4 and a theoretical co-firing in a 10 MW power plant) an overall power capacity of 370 kW would be available from these resources. The total amount is far too small to justify a collection and transport effort. The effect on the national power production is negligible.

The decentralised option for biomass resources is a gasification process. Smallest size on the market is around 50 kW electrical capacity. This technology would need roughly 300 to 350 tons of biomass (better dry) for a continuous operation (4,000 h/year with 25% electrical efficiency of the CHP and 66% gasification efficiency). Gasification of straw and other field residues is by far not state-of-the-art and cannot be recommended. Also, one project of that size alone would absorb 10% of the total theoretical potential.

The National Food Production Action Plan (MFLMA, 2012) foresees increases in acreage and tonnage of the three main commodities. Rice should grow on additional 1,700 ha with some 5,227 additional production, cassava with 12,728 t and sweet potato with 9,940 t. Using the afore mentioned conversion rates, this plan would result in an additional theoretical potential for field residues of 5,227 t of rice straw, 2,545 t of cassava and 994 t of sweet potato. In total, the plan might add 8,760 t of biomass material on the field (theoretically a further 900 kW installed capacity).

The other field residues would have even lower potentials (mostly vegetables); although also for these commodities expansion strategies exist.

**Processing and end-use**

We consider the same commodities that have been analysed in the previous chapter. Paddy rice would deliver rice husk at the milling location. The ratio is only 0.3 t of husk per t of paddy. For cassava and sweet potato only the peel and outer skin remain of the further downstream processing and end-use preparation. At present, the theoretical potential is not higher than 680 t of rice husk and between 500 or 1,000 t of peels.

One option related to processing and end-use is the coconut industry. By-products are the coconut husk (more wet and fibre-rich) and the coconut shell (after copra production). However, copra production is steadily declining (**Table 37**). With a maximum of 1,000 t of copra, one can expect some 1,000 t of shells and some 2,000 t of husks.

Cocoa and coffee are produced in small quantities and thus provide only limited potential for biomass energy utilization.

**Table 37** **Production of commercial agricultural goods**

| Year | Sugar, kt | Cocoa, t | Coffee, t | Copra, t |
|---|---|---|---|---|
| 2005 | 88.7 | 914.8 | 100.7 | 1,263.0 |
| 2006 | 70.6 | 569.4 | 94.3 | 1,320.0 |
| 2007 | 66.7 | 598.1 | 166.4 | 522.0 |
| 2008 | 37.6 | 574.4 | 166.5 | 469.9 |
| 2009 | 31.8 | 516.9 | 18.9 | 58.8 |

*Source*: CSO, 2012.

Other staple food, mostly root crops, are rarely processed (e.g. into cassava flour). Only the peel and skin would be a resource, which may amount to a maximum of 1,000 t/year. In total, a maximum amount of 5,000 t/year seems feasible. Due to a lower quality in possible combustion or gasification processes, the equivalent power value of this resource is 560 kW (based on 7,000 hours operation per year).

**Potential at decentralised processing centres**

During the fact-finding mission, one point of discussion was the decentralised processing of agricultural products. It was estimated, that so called agro-processors could generate volumes of by-products in ranges of 10 t/day at a larger operation or 5 t/day at a smaller location.

Additional resources are banana peels, corn cobs and over-aged roots. However, the self-assessment for the total quantity seems too high, as under this assumption total yearly production would sum up to more than 5,000 t/a. This is nearly the estimated value for the national potential.

It seems that the agro-processors only follow a seasonal operation and the 10 t/day respective 5 t/day are only available on certain days of the year. The gasification technology for a capacity of 50 kW needs roughly 2 t/day of material. Theoretically the amount from agro-processors could feed one gasifier (but not on a continuous base).

**Forestry and forestry products**

T&T has a total land area of 512,800 ha. The distribution (for Trinidad alone) is shown in **Table 38**. Nearly 70% of the land area is forested (CSO, 2012). There are other sources saying that the forest area in total is around 250,000 ha, out of which some 60,000 ha are protected, some 15,000 ha are plantations, i.e. managed forests, and 127,000 ha are natural forests (FAO, 2012).

For forestry, the potential biomass can be divided into field resources and processing by-products. Field resources would be the extraction of wood from forests. T&T has only a small area

**Table 38 Trinidad Land Cover**

| Classification | Area, ha |
|---|---|
| Urban | 31,525 |
| Agriculture | 110,565 |
| Forest | 351,819 |
| Grasslands | 4,159 |
| Wetland | 11,479 |
| Water | 1,454 |

*Source*: CSO, 2012.

of forestry under a management scheme. Most of the forest areas are protected and consist of natural vegetation forest. No potential is seen for biomass directly produced from forest, i.e. logging for firewood or wood chipping during forest management activities.

Second source are by-products from the wood industry. These are sawmilling waste and woodchips plus potential logwood or sawn wood in smaller pieces (shavings etc.). According to different sources, the forestry industry in T&T produces some 50,000 $m^3$ of round wood (TITTO, 2012). Approximately 60% are cuttings, sawdust and wood chips.

Allowing a 50% ratio for other uses (materials, energy), the maximum potential from the sawmilling industry could be based on 15,000 $m^3$ round wood equivalent. This is estimated to be 7,500 t of biomass material. Also here the total volume does not lead to a quantity, which is in ranges of a biomass power plant (results in equivalent 840 kW of a year-round power plant operation).

**Summary of potential for solid biomass**

In **Table 39** the overall potential of solid biomass is shown. It also contains the fictive electrical capacity of those specific resources as an indication of the magnitude of the resource. However, this is only a theoretical figure.

It can be seen, that the total potential with 24,860 t per year is rather limited and consists of very dispersed and unstructured items. The estimated equivalent in electrical capacity would be only 2,670 kW.

### *Liquid Biomass*

Liquid biomass is basically sourced from liquid effluents from animal production. These can be converted to biogas using the anaerobic fermentation process. More potential for biogas is seen from pig effluents in comparison to ruminants. Also most of the ruminants are held on

**Table 39 Summary of solid biomass potentials**[a]

| Source | t/year | kW |
|---|---|---|
| Field residues, straw, stems, etc. | 3,600 | 370 |
| Expansion plan for agriculture | 8,760 | 900 |
| Processing and end-use. Peels, shells, husks | 5,000 | 560 |
| Forestry, by-products of sawmill and furniture | 7,500 | 840 |
| Total theoretical potential | 24,860 | 2,670 |

[a] Own assessment; volumes according to previous analysis, electrical capacity includes different conversion processes and conversion efficiencies. Calculation example for the first line: 3,600 tons of material with a calorific value of 3.6 MWh/t and 20% theoretical conversion efficiency used during 7,000 hours per year gives a capacity of 370 kW.

a free grazing production method and the effluents are not collected. The statistics for 2004 indicate a large population of pigs compared to other larger animals (**Table 40**).

More recent statistics indicate a total pig population of some 40,000 heads. The figures for 2009 are obviously mismatched in **Table 41.** The total population is managed on more than 300 farms, which gives an overall average of a bit more than 100 pigs per farm. The distribution for the different farm sizes is shown in the following table. Nearly 2/3 of the pigs are grown in farm sizes bigger than 500 animals.

A very rough calculation for the potential biogas production from pig excrements has been developed. There are very different technologies available and each project must be assessed on its own characteristics. On average and using advanced technology, one could expect 20 $m^3$ to 35 $m^3$ of biogas per day per 100 fattening pigs. This could bring 2.5 to 3.5 kW on electrical capacity per 100 pigs. Using simple technology, productivity would be less and could be in the vicinity of 10 $m^3$ biogas per day and a maximum installed capacity of 1 kW per 100 pigs.

**Table 40 Animal population in T&T**

| Livestock | May 31st 1982 | July 31st 2004 |
|---|---|---|
| Cattle | 42,340 | 19,088 |
| Pigs | 79,366 | 54,855 |
| Poultry | 9,160,171 | 5,740,783 |
| Sheep | 11,921 | 20,726 |
| Goats | 30,273 | 12,500 |
| Total Livestock | 9,324,071 | 5,847,952 |

*Source*: CSO, 2012.

**Table 41** **Pig Population in T&T**

| Period | Total pig population | Size of farm (Number of pigs) 1–20 | 21–30 | 31–50 | 51–100 | 101–500 | 501 and over | Number of farms |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (1) |
| 2005 | 36352 | 1128 | 382 | 1078 | 2318 | 4866 | 26580 | 248 |
| 2006 | 40686 | 1289 | 920 | 1312 | 2323 | 5004 | 29838 | 272 |
| 2007 | 43502 | 1134 | 664 | 1624 | 2249 | 6686 | 31145 | 288 |
| 2008 | 40225 | 1496 | 988 | 1410 | 3081 | 6981 | 26269 | 348 |
| 2009 | 38206 | 18700 | 5501 | 5432 | 1936 | 6038 | 599 | 339 |

*Source*: CSO, 2012.
*Note*: Table 35 and 36 from agrarstat.xls, download from CSO.gov.tt.

The total theoretical potential with advanced technology for 40,000 pigs could be between 1,000 and 1,400 kW of electrical capacity. Simple technology would deliver a potential of 400 kW on the national scale.

The farm visited during the fact-finding mission had a total of 6,500 pigs. According to above estimations an advanced system would deliver 160 to 200 kW electricity, a simple system only 65 kW. There are two other larger pig farms in T&T, all the rest are of smaller size. The individual power production capacity at these farms would be rather limited.

It is a question of, whether the produced power would be enough to supply electricity for the farm operation, besides having potential for exporting power to the grid. These relatively small biogas plants (advanced technology) would produce electricity for prices between 20 and 30 USct/kWh. There is little incentive for the substitution of grid electricity on the farm, even if investment costs are reduced by employing simple systems (with less productivity). A possible feed-in tariff must also be high enough to attract investments. The overall potential however, is rather small to justify a specific mechanism for biogas alone.

Biogas technology on a smaller scale has additional benefits besides the energy production (odour reduction, better manure quality, prevention of water pollution etc.). This can be taken into account in assessing the situation of medium and small-scale pig farms. Introduction of the biogas technology would have combined benefits. In this sense, the necessary incentive programme would be socially or environmentally motivated and not driven by the energy issue.

### *Agro-industrial Activity*

Beside of the assessment of primary agricultural production, industrial activities have been analysed. **Table 42** lists the number of business establishments in three consecutive years by sector. Sectors for potential biomass energy activities include the sugar industry, food processing and drinks, as well as wood and related products.

The sugar industry is no longer in production; the possibility for an energy cane option is discussed in chapter 6.4. There are more than 300 businesses active in food processing and drinks. These would form an industrial sector with a potential for residues and by-products. More than 200 entities are active in the wood and related products sector. The potential has been discussed in chapter 6.4. All other industries would have no connection to potential biomass resources.

**Table 42 Number and type of business in T&T**

| Number of business establishments in Trinidad and Tobago by Industry (TTSNA)/Economic Activity, 2007–2009 | | | |
|---|---|---|---|
| **Industry** | **2007** | **2008** | **2009** |
| Sugar | 1 | 3 | 3 |
| Petroleum Industries | 605 | 603 | 583 |
| Food Processors and Drink | 346 | 336 | 320 |
| Textiles, Garments, Footwear and Hardwear | 129 | 126 | 121 |
| Printing, Publishing and Paper Converters | 267 | 275 | 275 |
| Wood and Related Products | 237 | 232 | 221 |
| Chemicals and Non-Metalic Minerals | 176 | 190 | 179 |
| Assembly-type and Related Industries | 335 | 331 | 314 |
| Miscelleanous Manufacturing | 150 | 147 | 137 |
| Construction | 2634 | 3004 | 2996 |
| Distribution | 15216 | 15470 | 14941 |
| Hotels and Guesthouses | 310 | 305 | 306 |
| Transportation, Communications, Storage | 1137 | 1173 | 1122 |
| Finance,Insurance, Real Estate and Business Services | 3440 | 3645 | 3536 |
| Educational and Cultural Community Services | 517 | 511 | 492 |
| Personal Services | 517 | 511 | 492 |
| Total | 29497 | 30357 | 29483 |

*Source*: CSO, 2009.

### Canning Factory

During the field trip, the largest canning factory in T&T was visited. Their solid residues are sent to the landfill (overlap with the waste study). In most cases the material is of biological origin with differing qualities. The overall volume may reach up to 1,500 kg per day, but this is a seasonal activity, when fresh fruits or ingredients are used.

There is no rationale for setting up biomass utilization at that factory. One option could be that the material is used in a biogas plant of another operator (a pig farm increasing the output). Otherwise the potential is included in the waste generation sector and is assessed in chapter 6.3 “Waste to Energy”.

### Distillery and Brewery

Two larger industries remain, which are distillery and beer. Average yearly production of proof alcohol is of 10 million gallons (average for 3 years) and some 50 million litre of beer. All other commodities in **Table 43** have no potential or have been analysed already.

The distillery was contacted by email and phone. They reported that the idea for biogas production from distillery waste was discussed and no longer pursued. The potential biogas would not satisfy the energy demand for the distillery (boiler for steam for distillation and process). A calculation had revealed that a biogas potential at their distillery stands at 13,287 $Nm^3$ per day.

Presently, the distillery liquid waste is sent to the communal wastewater treatment plant. Based on the average production of 10 million gallon, a quick estimation gives a potential for 18,000 $Nm^3$ of biogas per day (with reference to a project in Jamaica). Taking the quotation from the distillery and assuming a 35% electrical efficiency for a biogas engine, the distillery could produce 1,000 kW of electricity. The calculation with figures from Jamaica reveals even a potential of 1,500 kW. This would be up to now the biggest potential for biomass energy in T&T at one specific location.

Also the brewery process has potential for wastewater treatment and biogas production. A site visit was not possible during the fact-finding mission. Therefore an analysis based on secondary data has been prepared. The production capacity is 50 million litres of beer per year. From the wastewater stream biogas can be produced.

Using average figures from case studies and literature, a biogas production of between 140,000 $m^3$ and 270,000 $m^3$ per year is possible. This would translate (if all biogas is used in a gas engine) into between 50 and 75 kW of electrical capacity on a continuous base. The biogas potential at the brewery is much smaller than at the distillery.

**Table 43** **Different commodities and production figures**

| Economic Activity Production | | 2007 | 2008 | 2009 |
|---|---|---|---|---|
| Sugar | 000 tonnes | 67 | 38 | 32 |
| Cocoa | 000 kg | 598 | 574 | 517 |
| Coffee | 000 kg | 236 | 166 | 19 |
| Pork | 000 kg | 3866 | 3408 | 3440 |
| Broilers | 000 birds | 32652 | 33140 | 34240 |
| Rum | 000 proof gall. | 10621 | 12968 | 6900 |
| Beer | 000 litres | 51770 | 50206 | 50377 |
| Cigarettes | 000 kgs | 3797 | 5057 | 6275 |
| Cement | 000 tonnes | 902 | 952 | 869 |
| Crude Oil | 000 bbls | 43807 | 41828 | 35821 |
| Natural Gas Liquids | 000 bbls | 12450 | 12720 | 11568 |
| Fertilizer | 000 tonnes | 5617 | 5186 | 3942 |
| Methanol | 000 tonnes | 5933 | 5686 | 4455 |
| Direct Reduced Iron | 000 tonnes | 2063 | 1601 | 805 |
| Billets | 000 tonnes | 695 | 490 | 290 |
| Wire Rods | 000 tonnes | 510 | 272 | 174 |

*Source*: CSO, 2009.

The total potential (theoretical maximum) is 3,475 kW at the upper level by using advanced technologies. The realizable potential would be much smaller. The lower level reaches only 2,150 kW or even only 1,550 kW assuming simple technology for biogas at pig farms (**Table 44**).

### *Energy crops*

A theoretical evaluation is done for the set-up of a biomass power plant. Background is the sugar production history in T&T. Energy cane could be produced on part of the land, which was formerly assigned to sugar production. In the year 2000, the total area under sugarcane was some 11,000 ha.

Based on the commodity statistics in **Table 36** and **Table 43**, production of sugar was 88,700 t in 2005. Using the sugar to cane ratio of roughly 10, this translates to a production of cane

**Table 44 Potentials for biogas**

| Source | Capacity (kW) | |
|---|---|---|
| | Lower level | Upper level |
| Pig farm advanced biogas | 1,000 | 1,400 |
| Pig farm simple systems | (400) | (400) |
| Distillery | 1,000 | 1,500 |
| Brewery | 50 | 75 |
| Agro-industry not yet identified | 100 | 500 |
| Total theoretical potential | 2,150 | 3,475 |

*Source*: Own elaboration.

in the vicinity of 800,000 to 900,000 tons of cane per year. Based on an average yield of 65 t of cane per ha, this would mean a planting area of 13,000 ha. Both sources reveal similar results and magnitudes for the previous sugar cane area.

Energy cane could be produced with the same technology and with similar production methods as sugar cane. Also yield could be on the same level. Based on this assumption a project could be designed as follows:

| | |
|---|---|
| Installed electrical capacity | 10 MW |
| Overall electrical efficiency | 20% |
| Operational time | 7000 h/year |
| Calorific value of energy cane | 8 GJ/t |
| Demand for energy cane | 150,000 t/year |
| Yield of energy cane | 65 t/ha |
| Area demand | 2,300 ha |
| Production cost for electricity | US$ct 10 to 13/kWh |

(at US$ 20 to 30 /t for energy cane delivered at power plant).

This option would need roughly 1/5 of the previous sugar cane production capacity. During the field trip it was noticed that in the sugar area there are still abandoned and non-productive plots of lands. The ownership has changed, but an upcoming demand would spur any new developments. However, the situation would need a close monitoring not to counteract with food security options and plans in T&T.

Allowing a profit of US$ct 2.0/kWh for the investor, the necessary feed-in tariff for a biomass power plant based on energy crops would be in the range of US$ct 12 to 15/kWh.

### *Total Potential*

The theoretical potential from solid biomass is 370 kW (as explained this is the virtual electrical capacity of the resources) at the field and another 560 kW at the processing level. Another 900 kW at field level are possible if agricultural extension would be successful. The theoretical potential from forest industry is at 840 kW.

Biogas can be produced from pig manure and from large industrial production areas. The pig industry might contribute 1,000 to 1,400 kW in T&T. Two industries could generate up to 1,500 kW from biological wastewater. one biomass power plant fuelled by energy cane could produce 10 MW of electricity, if 2,300 ha of energy cane can be planted.

The realizable potential is much smaller than the theoretical potential (**Table 45**). On a small-scale there is no feasible potential. On a medium-scale level small biogas plants could be realized. The potential for solid biomass is too small for individual projects. This biomass could be utilized in existing biogas plants or in one large power plant. On a larger scale the distill-

**Table 45  Summary matrix for biomass use**

| | Small | Medium | Large | Theoretical Potential, kW |
|---|---|---|---|---|
| Agriculture | None | Co- substrate for biogas or co-firing at biomass powerplant | None | 370+900 solid |
| Agroindustry | None | Co- substrate for biogas or co-firing at biomass powerplant | Distillery: 1000 to 1500 kW: Brewery, 50 to 75 kW | 560 solid + 1150/2075 biogas |
| Forestry | None | None | None | 0 |
| Forest Industry | None | Decentralised gasification or co-firing at power plant | None | 840 solid |
| Animal production | Biogasin subsistence agriculture, no power but multi-beneficial | Medium scale farms may be 5 to 30 kW | 3 farms with potential, 2 times 200kW, one time 300 kW | 400 or 100/1400 biogas |
| Energy crops | None | None | One large biomass power plant with energy cane, 2300 ha | 10000 energy crop |

*Source*: Own elaboration.

ery and the brewery could install biogas technology. The three large pig farms also have a potential in a range of 200 to 300 kW of installed capacity. The biggest contribution would come from a new biomass power plant.

## Manufacturing Capacity

There is very limited scope for additional manufacturing capacity in the segment of biomass energy. A complete biomass power plant is a large industrial project and a maximum of one plant would be required in T&T. Components like turbines and boilers would need to be imported from the international market. Local production would be the steel and concrete works in such an installation.

Large biogas plants face the same problem as large power plants. They are unique and would have no replication on the island. Every biogas plant is custom made and according to the specific situation manufactured and erected. Key components like mixers, feeders, plastic cover or even the combined heat and power plant would be imported. Local content are again steel and concrete works. There would be no market for standardized equipment in the region or worldwide, where T&T could compete.

Smaller biogas plants live from the support of the later owner. Due to the overall financial situation, the farmer is required to construct and erect the biogas plant partly with his own resources. The farmers could be trained on the specific models and sizes of small-scale biogas plants. This has been executed for example by the Caribbean Development Bank (CDB) and GTZ some 20 years ago.[24] But also these plants are highly individually planned. They offer no scope for standardized production, the market in T&T is small and exports seem not viable.

## Proposals for Pilot Projects

A total of four proposals for possible demonstration projects can be made. All of them are in the area of biogas, but on different scales.

The single largest potential (up to now) is for a biogas plant at the distillery (Angostura Ltd., the only distillery in T&T) in a power range of 1,000 to 1,500 kW. This would be an individually planned biogas plant, most probably with interaction from international biogas manufacturers. A very rough estimation may give total costs of US$ 4 million if advanced technology is employed.

[24] At that time there was a regional energy project by GTZ with CDB as partner. Pilot plants were installed by GTZ. After project closure by GTZ the CDB continued some of the activities, which led to a proposal for a biogas installation.

There is potential for a larger biogas plant at one of the large pig farms (only 3 candidates). One out of the three farms might be convinced to install a semi-advanced biogas plant, which could use the pig manure and could be used as demonstration for co-fermentation from industrial or agricultural by-products. Depending on location and local conditions the output of the pig manure based biogas system could be increased by utilising additional biomass material from agriculture or processing. The size of the plant would be in a range of 200 to 300 kW.

The next group of pig farms with more than 500 pigs would have the potential for small biogas systems with an installed electrical capacity between 5 to 30 kW. Also here co-fermentation is an option. There might be potential for a total of up to 10 plants, but real potential must be assessed in more detail. The technology setup should be simple to allow self-construction and reduced investment costs. One plant could be erected as a demonstration plant and as reference for other interested farmers.

The Chinese dome or floating dome biogas plants are made for smaller animal population. Their energy delivery is not electricity but biogas for cooking and lighting. The size of the plant and the quality of the biogas supply would not justify the generation of electricity. These plants have no real impact on the electricity generation, although they would produce RE. The total cost of these plants cannot be recovered through the energy delivery as such. Added benefits are an improved environmental situation. A demonstration project would show the advantage of this alternative, but it would not be an energy driven project any more.

### Grid Availability and Grid Capacity

The grid connection in T&T in general is good. Only very remote areas are not grid connected. The main grid connecting the industrial zones and dense population areas has excess capacity. New power plants with several 10 MW are easily incorporated and there will be an overcapacity of electrical power for the coming years.

The anticipated biomass projects are all of a smaller size. They would not create any grid capacity problem. Even the big biomass power plant with 10 MW would be absorbed easily and the plant would be situated in the previous sugar cane area, which is very well connected.

### Training and Education

The potential for biomass power is limited in T&T. Realisation potential is low, especially if no special programmes or incentives are made available for biomass and biogas. It is not advisable to invest efforts and resources in capacity building if the overall projections are not clear. The number of possible projects is very low; there is no real duplication effect. Seen from that standpoint, specific programmes for capacity building would not be sustainable. The larger projects are realized with imported technology, the smaller projects rely on usual craftsmanship (concrete, steel), which is already locally available.

Some experience on biogas systems is available at UWI St. Augustine.

### Baseline $CO_2$ Emissions

Biomass and biogas have no present impact on the baseline emissions as no electricity is produced using biomass material.

## 6.7 Ocean Energy for Electricity Generation and its Applicability for T&T

### Introduction

The purpose of this chapter is to provide up-to-date information on the status-quo of ocean energy technologies as well as to give recommendations on the applicability for T&T on the background of existing natural resources. The ocean energy technologies identified include electric power generation and cooling from wave energy, tidal energy and currents, as well as ocean thermal conversion and osmotic power. The power sources are dealt with in separate sections for ease of reading and referencing.

An overview on the current status of ocean energy use in Europe can be found in OBSERVER, 2014.

The idea of utilising the energy in waves is rather old and the first experiments were made in the 1940s, but efforts intensified with the oil crisis and declined again as the oil price dropped. The recent increase in interest in renewable energies has led to a growth in research and projects in wave power generation. Due to this history, there are many different production methods being developed in parallel (CLEMENT, 2002). Over 1000 ideas and concepts for wave energy converters have applied for patenting or been patented. However, only about fifteen have reached a stage of medium-scale sea trials. Of these, only the Pelamis concept has currently registered any hours of operation at prototype scale (1:1). Globally all deployed wave energy devices have a cumulative capacity of less than 10 MW (OES 2012).

**Theoretical background**

In general any coast or body of water exposed to the waves, such as those that build up across the Atlantic due to the long fetch of the trade winds, are suited to be harnesse,d. The power of waves is given approximately by the following equation:

$$P(kW/m) = 0.49 \times H^2 T$$

where $H$ is the average height of the highest third of waves and $T$ is the mean period of the waves (Sağlam 2012).

However, the possibility to harness said power depends not only on the height but also on the period of the waves and a solution needs to be tailored to the local conditions. How drastic this change is, is best illustrated by the table in **Appendix L**: Power Output of the Pelamis System showing the rating of the Pelamis system, which will be discussed later. The choice of wave power system depends very much on the type of waves that occur at a potential location.

The Caribbean is not an area of particularly high potential from the global perspective, where most research has been focused on the extremer latitudes and their rougher waters. However, small projects have been conducted in the Black Sea and in Sri Lanka, so that a lower average wave height does not completely rule out the usage of wave power (SAGLAM, 2012).

### *Overview on existing Concepts*

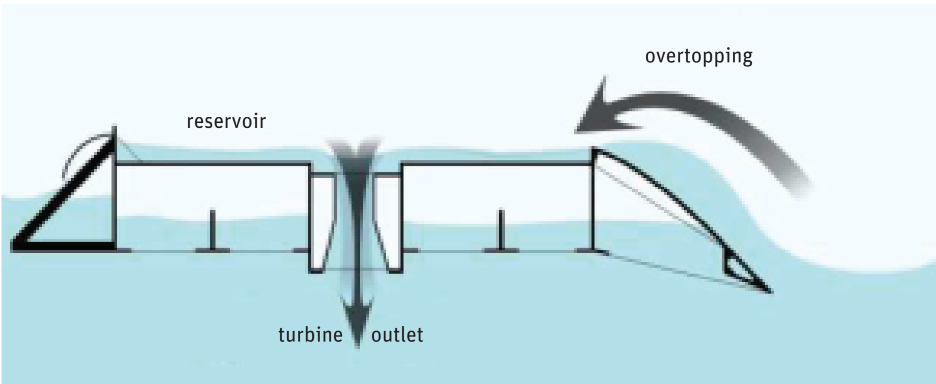
There are currently three different working principles that most devises are based on:

a. Overtopping devises which use the energy of the waves to transfer water to a higher reservoir and use this potential energy. One of the most prominent examples of this is the Wave Dragon System[25] which has undergone sea trials at test scales, but not progressed further due to technical and financial difficulties. The working principle of such an overtopping devise is shown in the sketch in **Figure 54**.
b. Another promising technology is the oscillating water column (OWC), which consists of a partially submerged, hollow structure open to the sea below the water line. A good example of such a devise is the wave power plant LIMPET in Islay, Scotland. **Figure 55** outlines the working principle. There are a few plants of this working principle operating around the world. Most are in the order of 500 kW or smaller and therefore still classified as non-commercial demonstration units. The fixed structure at the shore makes it very storm proof, however to improve the performance several floating OWC devises are needed. A prototype unit of 800 kW (Oyster 800 by Aquamarine Power) has commenced operation at the European Marine Energy Centre in Orkney in June 2012 and is to be succeeded by a second unit.
c. The third working principle is that of the **point absorbers** that use a float to translate the movement of the waves into motion that can be used to drive a generator. The

[25] www.wavedragon.net.
[26] www.oceanpowertechnologies.com.

**FIGURE 54**

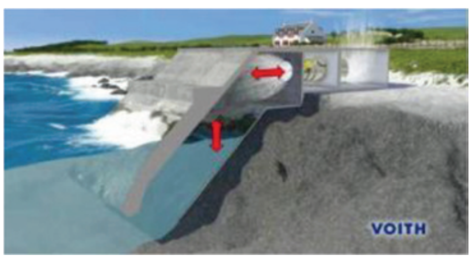
**Device working on the overtopping principle**




*Source*: Bevilacqua & Zanuttigh, 1973.

**FIGURE 55**

**Voith Turbo 500 kW plant in Islay, Scotland**




*Source*: Voith.

**Powerbuoy** by OceanPowerTechnologies[26] and the **Pelamis** by Pelamis Wave Power Ltd.[27] are examples of such a point absorber devise and are arguably the most developed concepts, with several 150 kW buoys deployed and a 500 kW buoy under development for the **Powerbuoy**, as well as prototype-scale testing underway for the **Pelamis** (DALTON, 2010). **Figure 56** shows the Pelamis prototype off the coast of Scotland.

[27] www.pelamiswave.com.

**FIGURE 56**

**Pelamis prototype in construction and off the coast of the Orkney isles in early 2012**

*Source*: IEE, 2012.

Two of those wave energy converters were deployed in 2012 at the European Marine Energy Centre.

Offshore structures, such as the above mentioned point absorbers, have the advantage of being nearly invisible and thus do not damage the landscape, an important consideration for touristic areas, but are a considerable hindrance to naval activities such as fishing in the immediate vicinity.

Other advantages of wave power is the use of many simple parts, either welded floats or a concrete dam so that local shipyards or construction crews can manufacture the equipment, while only a few specialised parts, such as hydraulic actuators and turbines, need to be imported. This provides opportunities for partnerships with regional manufacturers.

### *Status of Technology*

There is a consensus in literature that wave energy technology is still, to a certain extent, far away from maturity, however the research and comparison to other renewable sources such as wind suggests that the potentials for improvement is large. Costs are estimated for the first commercial plants to be in the range of US$ 0.27 per kWh. A reduction in costs similar to what wind power experienced in the past two decades, is expected to happen over the course of the next five to ten years for wave energy technologies if a significant capacity can be deployed (OES, 2012).

In Europe alone, some 250 MW of ocean energy systems were in operation, among those the Barrage de la Rance commercial plant with 240 MW. All the other projects are small-scale devices for demonstration and pilot initiatives (OBSERVER, 2014) Worldwide, commercial ocean energy capacity totalled 527 MW by end of 2012, most of this being tidal power facilities, with additional projects in the pipeline (REN21, 2013).

### *Potential around T&T*

The potential for wave power is not equally distributed around the world. The islands of T&T have a coastal line that is exposed to the open ocean and therefore has potential. Unfortunately no data on the average wave heights has been retrievable so far. Before the generation potential can be estimated, the exact wave power potential will need to be investigated. It is definitely recommended to explore the potential for wave power by measuring wave heights and periods over a longer period of time, before reaching a conclusion whether it is sensible to pursue wave power generation. Due to the position of T&T in the lower latitudes, wave power will not be a major source of RE, but the above mentioned advantages of local manufacturing could make it more economical.

Furthermore, T&T is not located within the hurricane belt which reduces the risks of freak loads. However, the maximum load experienced out at sea is very difficult to predict as the peak-to-average load ratio in the sea is very high. It is, for example, difficult to define accurately the 50-years peak wave for a particular site with local recordings of only a few years.

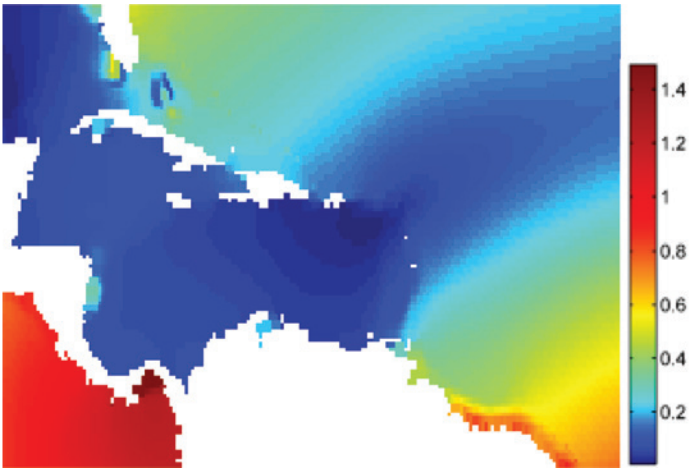
This is one of the major issues for all marine technologies and there is no fix apart from long-term measurement series and the analysis of historical data. Depending on the average wave heights found at different locations, potential partnerships with offshore wave power producers may look promising, or a local research and development campaign by universities for shore-based technologies.

## Power Generation from Tide and Current

Tidal power generated from the potential differences due to the moons movements holds the promise of predictable power generated with existing and well understood technology and is done on various scales from a few MW to GW all around the world. **Figure 57** shows the distribution of tidal energy in the Caribbean, clearly showing the small tidal amplitudes experienced.

**FIGURE 57**

**Sea surface variation due to lunar tides in meters**




*Source*: EGBERT, 2002.

## *Possible Technologies for Tidal Power and its Applicability for T&T*

There are three ways to harness the power of the tidal movement of the water masses: Dynamic tidal power, the construction of a tidal barrage and the direct use of tidal streams.

**Dynamic tidal power** is a new technology using a dam to create a potential difference, which is then exploited. It doesn't require a very high natural tidal range, but instead an open coast where the tidal propagation is alongshore; it is therefore unsuitable for Trinidad. But Tobago may be a location in the distant future. However, as this technology has not yet been employed anywhere, the tidal range is too low to make it a suitable location for the world's first power plant of this type.

The oldest form of electricity generation from tidal fluctuations is the use of **tidal barrages**. The Gulf of Paria between Trinidad and Venezuela would seem ideally suited as it has a large area of roughly 7800 km² and only two small entrances. The tidal range is rather low with a maximum of 40–85 cm. However, this would still provide 817 GWh of electricity annually assuming 30% overall conversion efficiency.[28] The obvious critical issues of building a bar-

[28] Energy production: $E = \frac{1}{2} \rho \, A \, g \, h^2 \, \eta \, N$

where $N$ is the number of tides per year (730), $\eta$ the assumed efficiency (30%), $\rho$ the density of the water (1025 kg /m³), $h$ height of the high tide (0.6m), $A$ the area of the Reservoir (7,800 km²) and $g$ is the acceleration due to the Earth's gravity (9.81 m/s²).

rage in the Dragon's mouth (in the North) and the Serpent's mouth (in the South), such as shutting off the major shipping lanes and political controversies with Venezuela, and usage of very low head heights make this only an unrealistic possibility (MOBILE, 2012).

The usage of **tidal streams or currents** for power generation has seen a recent surge of activity with larger companies such as Siemens, Voith Hydro and Andritz Hydro entering the market. However, projections for plants of several MW size are currently limited to areas with very strong tidal flows. As stated above, the tidal range and therefore the strength of the currents in T&T is small, just like in the rest of the Caribbean; however, the Serpent's mouth does have potential, not due to tidal movements but because of the discharge from rivers on the Venezuelan mainland during the rainy season. Navigational charts warn of currents up to 5 knots, but state that these are inconsistent and give no exact location (DIRECTIONS, 2012).

Further local research is required to assess the exact locations and strength of currents throughout the year. Furthermore, reports of shifting sandbanks and silt indicate both variable but strong currents and a soft, variable seabed. These features will make both, locating the strongest currents and anchoring equipment to the sea floor a difficult process. These issues need to be addressed with detailed research to collect sound information on the potential before attempting to install turbines, as premature failures due to bad research and information base are likely to discourage future investments in what appears to be Trinidad's most promising marine resource.

The importance of the strength of the current is highlighted by a quick look at the physics of the power generation which states that $P = {}^{1}/_{2}\, \rho\, A\, v^3$ (where A is the area, p the density of the water and v the velocity) and therefore power is related to velocity cubed!

**Figure 58** shows an image of the first commercial tidal stream power plant with its rotors raised above the surface. The plant has a rated power of 1.2 MW and is in operation since late 2008.[29]

The manufacturer Marine Current Turbines[30] is now wholly owned by Siemens and plans for the first larger farms are currently underway. Similar projects have been realized by Andritz Hydro, whose pre-commercial horizontal axis turbine HS1000 with 1 MW started operation in December 2011, and Voith Hydro, whose similar turbine also with 1 MW is going to start operation as commercial demonstrator in summer 2013, both at the European Energy Marine Centre.

[29] More information on this project at www.seageneration.co.uk.
[30] www.marineturbines.com.

**FIGURE 58**

**SeaGen tidal stream plant in Strangford Lough, Scotland**

*Source*: Seagen.

The maturity of the technology and the prospect of strong tidal currents in the south of Trinidad and potentially along the eastern coast of Tobago make this the most promising marine resource. As stated previously, local research is required to assess the exact locations and strength of currents throughout the year. With this information a more complete assessment of the potential of ocean/tidal stream generation can be made.

A local company (Garifuna Energy Ltd.) is currently in the early design stage for a project under the name HYDROFLOW. The project is thought to consist of a pair of turbines anchored at the seabed, with a capacity of 300 kW each. No prototype has been built yet and there is considerable risk of failure, as experiences from other projects demonstrate that problems have been underestimated and costs for first pilot units were far higher than anticipated (OES 2012).

### *Overview on worldwide Tidal Power Systems*

Commercial ocean energy capacity was about 527 MW by the end of 2012, most of this being tidal power facilities.

Most tidal power systems are one-off projects such as the tidal barrage in Incheon, Korea with a planned capacity of 1,320 MW that is under construction and should start operation in 2017. Currently, the largest commercial ocean project with 254 MW came on line in August

2011 and is also located in Korea (Sihwa Lake Tidal Power Station), overtaking the number one position after 45 years from the tidal power station at the estuary of the Rance River (240 MW) in Brittany, France. The technology used in tidal barrage schemes is tried and tested, but a tidal barrage is not a very sensible scenario for T&T. Tidal stream generators also rely on known technology, but the offshore structures are notoriously difficult to maintain and very much affected by corrosion.

The company RWE Innogy is currently seeking environmental consent after securing the seabed lease for a 10 MW/£70 million tidal stream plant off the coast of Wales (Anglesey Skerries), aiming to be operational in 2015. As of early 2013, the plant was still awaiting consent from the Welsh Government. This would be the first multi-megawatt tidal stream array in the world. The Seagen tidal stream plant pictured above has been operating successfully since late 2008. But the company behind it started development in 1994.

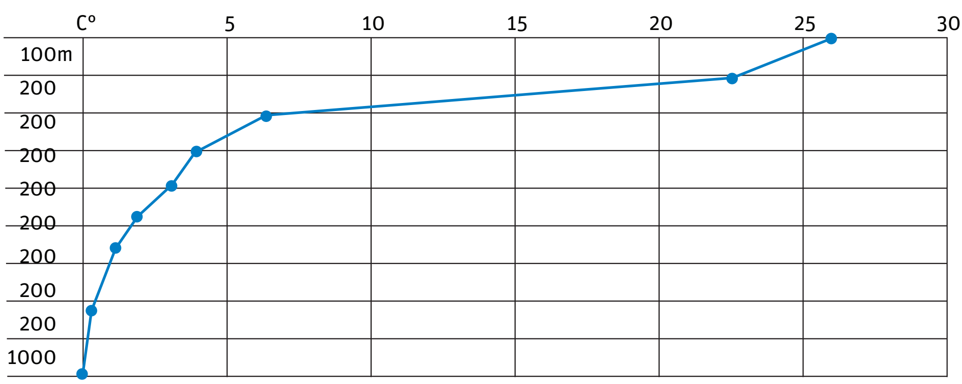
## Ocean Thermal Energy Conversion (OTEC)

### *Background and Status of OTEC Technology*

The ocean thermal energy conversion uses the difference in water temperature between the surface water and the deep ocean water. This gradient is then used to drive an organic Rankine cycle and can also provide cooling or desalinated water. The power output of such a system and its efficiency depends on the magnitude of the difference of the two reservoirs. The chart in **Figure 59** shows a general temperature curve of water found in tropical regions:

**FIGURE 59**

**Temperature profile generated with data from the Atlantic Ocean Atlas**




*Source*: FUGLISTER, 1960.

The figure clearly shows the thermocline (between 100 m and 200 m), the layer with the strongest temperature gradient. The depth of this layer depends on the seasons and, more relevant to T&T, on the perturbations of the surface water. Any OTEC plant will need to have access to a cold reservoir well below the thermocline.

The first pilot OTEC plant was installed in 1933 in Cuba and the first 1 MW commercial facility was installed in India in 2000, but despite no new technical developments required, OTEC has thus far failed to capitalize on its potential. The early projects were often too expensive and merely considered technology demonstrators, with no follow-up projects or concentrated approaches across nations. Like other RE technologies, OTEC will depend on government funding to initially kick-off and reduce costs, but unlike PV or wind power it has the possibility for base load power production.

Literature evaluating the feasibility of OTEC power plants, considers a depth of 1000 m as the required minimum for an OTEC plant. A land-based solution, such as the OTEC plant at the InterContinental Hotel in Bora Bora in French Polynesia, thus requires access to deep water within a few kilometres.

The plant in Bora Bora is one of the few plants which operates commercially and uses cold sea water to cool the air for the air-conditioning system directly; it does not produce electric power. This is commercially viable as electricity is extraordinarily expensive on Bora Bora due to its secluded location.

In September 2011, the Bahamas Electricity Corporation has signed a Memorandum of Understanding with the Ocean Thermal Energy (OTE) Corporation for the construction of two OTEC plants. One of the plants is considered to deliver district cooling for the Baha Mar Resort in Nassau, Bahamas. A loan of IDB of US$ 40 million for this project is currently under preparation.[31]

### *OTEC Potential in T&T*

A study in 1997 by Richard Crews went into great detail and examined all possible sites in the Caribbean concluding that T&T is unsuitable for OTEC due to the large distance, more than 10 km from Tobago, to reach said depth (CREWS, 1997). However, a close look at ocean maps reveals that within 8 to 10 km of the North-Eastern tip of Tobago, water of more than 1000 m depth can be found. Unfortunately no data on the exact location and its variations of the thermocline in waters near Tobago could be retrieved.

[31] For more information see www.theonproject.org and www.iadb.org/en/projects/project-description-title,1303.html?id=BH-L1032.

One of the by-products of OTEC power generation is cold water which can be used for cooling purposes. This holds further potential for energy savings, however the distance between consumer and power plant would be a very important factor to consider when analysing the feasibility of an OTEC plant.

It can be concluded that the island of Tobago has reasonable geographic features such as a medium distance to cold water and an ample supply of warm ocean water, but the lack of well-developed OTEC solutions make this option a one-off project unless allies for a larger campaign can be found. The Caribbean and Polynesian islands are ideally suited for the usage of OTEC, due to the abundance of warm ocean surface water and mostly high energy costs.

OTEC is currently only competitive on small islands where energy costs are high or there is a dedicated interest in reducing air pollution and $CO_2$ emissions by replacing conventional power plants. As fossil fuels are significantly cheaper in T&T than in other island nations this price difference does not exist. Hence an OTEC project would not be feasible in T&T. Estimates for a 10 MW OTEC plant range from US$ct 8–16/kWh, but the small number of completed projects tells another story (LENNARD).

## Conclusions and Recommendations

As the report outlines, no technology is perfectly suited or completely unsuitable for usage and deployment in T&T, but all have their individual challenges. However, a problem that is faced by all is the lack of solid information about conditions at potential sites.

The production of wave and tidal power plants has in certain areas reached commercial status. The Pelamis wave power system as well as other small projects have been running successfully for several years now and a joint European approach and coordination is bearing fruit.[32] In addition, the IEA task on Ocean Energy Systems has been working since 2001 and has revealed several useful results which can be retrieved from their website.[33]

The waves in T&T are not what would be considered large enough for the implementation of wave power plants. But as stated in the paragraph above, more data is needed before wave power is ruled out, as there are smaller research projects in areas with lower waves, as well as the first installations of commercial offshore buoys.

Additional information and studies about the following physical properties are a prerequisite to elaborate a quantitative assessment of the technical potential of these technologies for T&T:

[32] www.eu-oea.com.
[33] www.iea.org/techno/iaresults.asp?id_ia=31.

1. The average wave heights off Tobago and the East coast of Trinidad,
2. Current strengths in the Serpent's Mouth in the South of the Gulf of Paria and along the East coast of Tobago,
3. Salt concentrations of the sea water and their variations on the East and West coast of Trinidad.

Of the three different tidal power schemes only tidal stream plants are a sensible opportunity. Current tidal power plants have a capacity factor of 0.8–0.85 and operate in very strong currents caused by tides. It remains to be seen, if similar conditions occur in the Serpent's Mouth and along the East coast of Tobago to enable sensible usage.

OTEC has great potential and an international or at least a regional approach in the Caribbean should be sought. However, with no larger projects globally in existence, OTEC still needs a significant R&D push before it can provide a sizable contribution. The reward would be a renewable power source capable of providing base load power generation.

Tasks to be done in T&T:

1. Research effort to collect data on the strength, location, direction and duration of currents in the Serpent's Mouth and along the East coast of Tobago.
2. Research effort to collect data on wave heights and periods off the North and East coast of Tobago.
3. Establish local OTEC R&D efforts. (There are several potential partners like research organisations, such as NASA, or companies with experience in OTEC, such as Lockheed Martin, and Xenesys Inc., a Japanese OTEC specialist.)

At this moment, due to the lack of local data no technical potential for tidal, currant, wave or OTEC can be given for T&T. All proposed commercial initiatives for ocean energy use should be handled with extreme care and need to demonstrate their operational capacity in realized pilot and prototype units with several years of service.

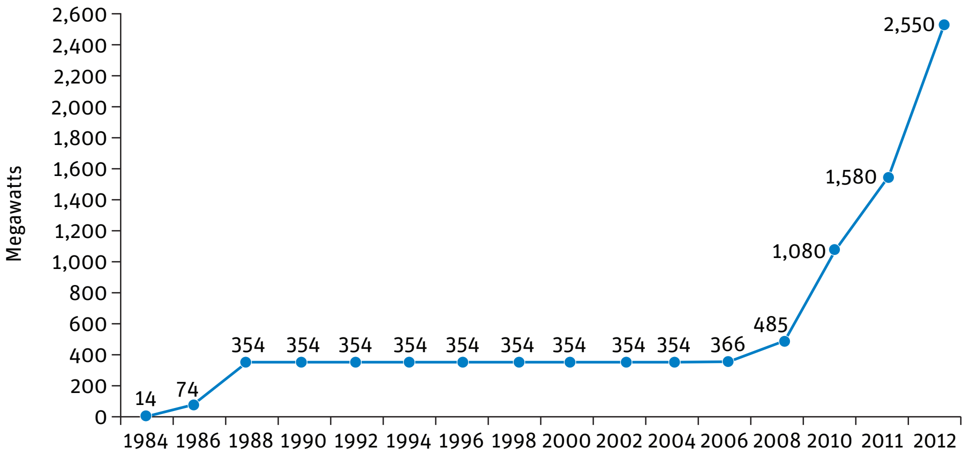
## 6.8 Applicability of Concentrated Solar Power

### Introduction

Concentrated Solar Power (CSP) requires a high direct solar radiation (DNI) to produce electricity at reasonable costs.

**FIGURE 60**

**Concentrating Solar Thermal Power Installed Capacity, 1984–2012**




*Source*: REN21, 2013.

To produce electricity from a CSP power plant with reasonable costs currently and in near term future (5–10 years) requires conditions of a minimum of around 2000 kWh/m² DNI. The Caribbean and especially T&T does not achieve the required level of DNI.

The European Academies Science Advisory Council published in November 2011 a study on the potential contribution of CSP to a sustainable energy future (EASAC, 2011). The report describes the actual technological developments, its achievements and the challenges for the future to make CSP a potential contribution to future power supply. It is recommended for further reading on the technology options, the current status of CSP worldwide and the challenges ahead.

One central statement from this report is:

> "*In general CSP is a reliable, proven renewable technology for generating electricity. Currently, electricity generated by CSP plants located where there are good solar resources costs 2–3 times that of electricity from existing fossil-based technologies without carbon capture and storage. This is mainly due to the costs of the solar field installation which are still relatively high. Considering other renewable electricity sources, CSP generation costs are on a par with offshore wind, but are significantly more expensive than onshore wind. In 2010, the average cost per kilowatt-hour for CSP and large-scale*

*PV systems were broadly comparable. But currently, intensive competition, particularly from Asia, has depressed PV prices giving them the edge over CSP systems. Future competition will depend on the speed of cost reduction of both technologies as well as on the question of how additional services provided by CSP (dispatch, capacity, etc., as discussed below) will be valued."*

There has been a rapid increase of CSP installations globally in recent years. At the end of 2012, about 2,550 MW capacity had been installed. Most of those plants operating in Spain and U.S.

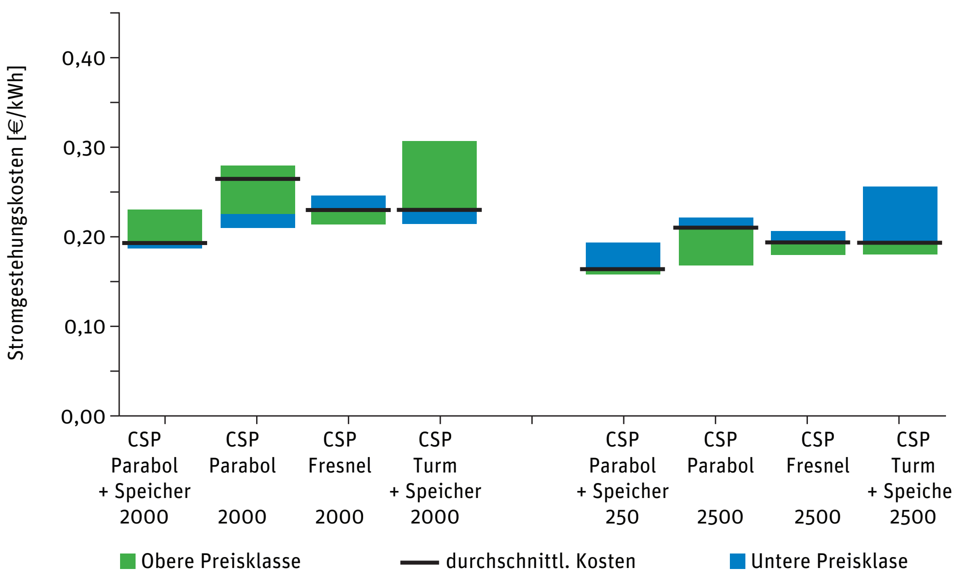
## Current and future Cost Development of CSP Technology

According to a recently published LCOE cost study of the Fraunhofer ISE (ISE, 2012), the future costs of CSP power plants will be—depending on technology and direct radiation—between 0.16 Euro/kWh (LCOE for 2,500 kWh/a DNI) and 0.30 Euro/kWh (2,000 kWh/a DNI).

Explanation of **Figure 61** as it is only available in German: The figure shows the LCOE in Euro/kWh of different CSP technologies (Parabol: Through, Speicher: Storage; Turm: tower) and

**FIGURE 61**

**LCOE of CSP depending on technology and radiation**




*Source*: ISE, 2012.

different DNI: Minimum: 2,000 kWh/a and maximum of 2,500 kWh/a). The yellow area is the upper expected cost level, while the blue one is the lower cost level. The main assumption for this LCOE is a weighted average cost of capital (WACC) of 9.9% and a life expectancy of 25 years.

The U.S. Department of Energy has published its Sun Shot Initiative in 2009 with the aim to reduce CSP costs by 75% until 2020 (DOE, n.d.). If that initiative can be realized by building many new CSP power plants in the world in the next decade, then a future minimum LCOE of US$ 0.06 /kWh is expected for Combined Cycle tower CSP with 200 MW capacity and under the assumption that a capacity factor of 66% can be achieved through molten storage and gas-firing. But at the moment the worldwide development of further CSP power plants is hampered by the lowering of PV module costs and the technological challenges of the CSP technology. Therefore it remains to be seen, if the LCOE of future CSP can be lowered as expected by DOE.

### Summary and Recommendations

The LCOE figures of CSP systems currently under planning or under construction in the world and the world map of DNI clearly show that in the near future, as long as there is no technology breakthrough of CSP, there is no technical and economic potential for CSP in T&T.

Therefore, T&T currently has no CSP potential until or unless the technology is further developed.

## 6.9 Renewable Energy Action Plan

As analysed in chapter 6, a number of RE technologies, namely solar PV, wind energy, SWH and WtE have good potential for implementation in T&T. However, in order to achieve a reasonable contribution of renewable energy sources in the electricity sector, a strong participation of the private sector is essential. This includes not only the investment into large utility-scale generation plants, but also the installation of small home-based RE facilities for own consumptions as well as for feeding excess power into the public grid.

The regulatory basis for such engagement is currently non-existent and needs to be established, starting with the amendment of the electricity act (see chapter 4.2). This should allow for a widespread, although regulated, deployment of RE technologies, avoiding bureaucratic hurdles and providing modalities that incentivize the application of RE electricity generation by offsetting existing disadvantages against the traditional and subsidized generation method.

Such new electricity market rules would allow for wheeling of renewable electricity, for example by the industry, from remotely placed wind power generation sites to the manufacturing facility, using the public grid as transport means and as “storage” for any excess electricity not needed at the time of production. It would further allow smaller producers to feed any surplus into the grid under reasonable reimbursement of generation costs that allows for an adequate return of investment during the operational lifetime of their generation assets.

While Net-Billing (chapter 6.1) and Net-Metering (chapter 6.1) may not provide appropriate financial means for a competitive operation of smaller-scale RE technologies under the very specific T&T conditions with low comparative electricity costs and tariffs, adequate and high enough feed-in-tariffs (chapter 6.1) could pave the way for entering into the renewable energy age. Such feed-in-tariffs could and should be at least technology-specific, if not even depend on the size and energy yield of individual installations, but in any case be terminated for a certain period of market entry and appropriately adjusted, if installation costs move downward. The general advantage of feed-in-tariffs is that they provide a guarantee for private investors to get a secure return as long as their generation facilities operate according to the predicted energy output.

For large-scale RE investments the introduction of auctions (chapter 6.1) would be a better choice, although such tender bidding needs to be well prepared in order to avoid unfair competition. In the case of T&T, it is advisable to preselect the installation sites, in particular in the case of wind farms or utility-scale PV plants and from this basis ask for bids. Even if other criteria than costs may be decisive it should in first place be the investor asking for the lowest electricity price who will be awarded with a long-term Power Purchase Agreement (chapter 6.1).

As the overarching incentive for meeting the Government objective of a significant RE electricity contribution in the future, it is proposed to establish mandatory annual portfolio standards (chapter 6.1), either for individual RE sources or for all RE technologies combined. Such standards would oblige T&TEC to either invest into RE facilities on its own or purchase such power from external operators. The scope of private sector engagement will then to a large extent depend on the capacity and business decision of T&TEC, while the overall goal of a step-wise increase of RE electricity in the energy mix will be met.

Apart from essential amendments to allow for electricity generation by other actors than T&TEC or licensed power producers (chapter 4.2) and definition of modalities for grid access and interconnection, modifications and additions to the existing grid code will be necessary to allow for a smooth parallel operation of RE facilities under defined and controlled technical conditions, in particular in the case of larger scale generation plants.

In order to stimulate the market and create adequate volumes that will help to reduce installation costs and enhance knowledge among all participants, it is further recommended

**Table 46** RE investment plan 2014–2020

| Project | Implementation Period | Total Installed Capacity (MW) or units | Total investment costs (million US$) | Electricity generation at end of implementation period (MWh/a) | $CO_2$ reduction at end of implementation period[a] (tons/a) |
|---|---|---|---|---|---|
| 100 PV roofs | 2014–2015 | 0.3 MW | 1.05 | 4,350 | 3,045 |
| Wind Power | 2015–2020 | 100 MW | 200.00 | 306,600 | 214,620 |
| Solar PV | 2016–2020 | 60 MW | 120.00 | 87,000 | 60,900 |
| Total RE power in 2020 | | 160.3 MW | | 397,950 | |
| Solar Water Heaters | 2014–2020 | 60,000 units | 132.00 | | 120,000 |
| Total 2014–2020 | | | **453.05** | | **398,565** |

[a] Based on emission factor of 2013.

to consider incentive programmes and introduce adequate fiscal schemes that will make RE technologies more competitive and curb high initial costs that are inherent for the market entry of new innovative products.

**Table 46** provides an overview of how an investment plan for the period up to 2020 could look like and what affect it would have on electricity generation and $CO_2$ reduction. This plan considers only solar and wind based technologies, as all other renewable energies are either marginal or will not yet be available in this period. It is noticeable that the installation of 100 MW wind power and 60 MW solar PV will need considerable efforts in the upcoming years in order to meet the objective of about 4% contribution to electricity production by 2020 (already discounting a reduced consumption due to energy saving measures).

## Long-term Scenarios

In this Chapter, data available from desk studies is incorporated into the analysis of baseline data to identify trends and assume future projections in order to simulate the likely evolution of key indicators up to 2032. In order to do so, an initial "*Business-as-Usual Scenario*" is modified in order to estimate the evolution of key factors such as GDP, oil and natural gas production and consumption, electricity generation, and its effect on $CO_2$ emissions.

Based on the detailed analysis of the potential of each RE technology in T&T, the following policy measures, programs and other relevant next steps are being recommended:

| RE Technology | Potential | Financial, fiscal and regulatory requirements | Suggested programs | Other relevant activities |
|---|---|---|---|---|
| **Solar PV** | High | Introduction of fixed feed-in-tariffs for grid-connected small-scale generation and implementation of reimbursement scheme<br><br>Introduction of non-bureaucratic permission schemes for small-scale generation (RIC and T&TEC)<br><br>Establish cost-sharing structure for connection to the grid<br><br>Establish details to provide priority for self-consumption of RE, easy grid access and priority dispatch of excess power<br><br>Tender schemes for large-scale solar farms (RIC) and design of adequate Power Purchase Agreements<br><br>Possibly update or revise wiring code to incorporate standards for grid-connection and clarify responsibilities among stakeholders<br><br>Reduce or abolish import duties and taxes on all core parts of solar equipment (in particular panels and inverters) | Establishment of an introductory limited 100-Roof Program with capital subsidies of the Government<br><br>Establishment of a solar PV programme for public buildings using financial means of the Green Fund<br><br>Setting of annual portfolio targets for T&TEC to either generate solar electricity on its own or purchase such power from third-parties | Development and provision of solar radiation data by the Meteorological Service of T&T to reflect local conditions on both coast lines.<br><br>Training of electricians and electrical inspectors and introduction of certificates for qualified installers.<br><br>Providing information on international standards and labels for solar equipment to installers and end-users<br><br>Establish register for PV generation facilities to keep track of existing installations |

(*continued on next page*)

(*continued*)

| RE Technology | Potential | Financial, fiscal and regulatory requirements | Suggested programs | Other relevant activities |
|---|---|---|---|---|
| **Wind Power** | High | Establishment of feed in tariffs in case of small-scale wind turbines<br><br>Address the need for priority grid access legislation and the use of tax incentives<br><br>Establish Power Purchase Agreements for the case of third-party generation<br><br>Design grid codes for interconnection and operation of individual wind turbines or wind farms<br><br>Establish a cost-sharing structure for interconnection of wind turbines and possible strengthening of existing grids<br><br>Reduce or abolish all import duties and taxes on wind energy related equipment<br><br>Consider further fiscal incentives for private investors to reduce costs and come on par with conventional power generation | Establishment of a support scheme for wind farms, as long as subsidies for conventional power have not been removed<br><br>Setting of mandatory annual portfolio targets for wind power generation to be fulfilled by either T&TEC's own facilities or through purchasing from independent producers<br><br>Start tender schemes for large-scale wind farms, unless T&TEC prefers to invest and operate on its own | Perform detailed wind measurements at potential concrete sites, based on the national wind resource assessment<br><br>Design technical guidelines for grid connection and operation of wind turbines<br><br>Assess impact on grid stability and capacity if relevant levels of wind energy are fed into distribution or transmission lines<br><br>Analysis of a first evaluation of potential sites for potential offshore wind power (including wind assessments)<br><br>Introduce know-how on wind energy in university and college courses and start training of technicians for construction, operation and maintenance<br><br>Harmonize further grid extension with potential wind turbine locations |
| **Solar Water Heating** | High | Improve the current inadequate incentives (25% tax credit/0% VAT, 150% Wear and Tear allowance, conditional duty exemptions) to a long-term fiscal and regulatory framework for both manufacturers and consumers.<br><br>Develop a 100% tax credit for the first five years | Use SWH for retrofitting of social housing and in case of new constructions<br><br>Collaboration between government and manufacturers to reach high, quality products, certified and labelled by TTBS | Establish a system to collect data on SWH installations, and to analyse effects on GHG reductions, deployment and usage<br><br>Include SWH into technical/vocational training to create critical mass of artisans for installation and maintenance and increase consumer confidence<br><br>Institutionalize certification of SWH installation companies |

(*continued on next page*)

(*continued*)

| RE Technology | Potential | Financial, fiscal and regulatory requirements | Suggested programs | Other relevant activities |
|---|---|---|---|---|
| **Solar Water Heating** (*continued*) | High | Establish legal mandatory requirements of SWH installations for all establishments with high water consumption, such as hotels, hospitals, restaurants<br><br>Introduce higher taxes/penalties for electric water heaters | Provide incentives for the establishment of a local manufacturing industry as to lower costs and create employment<br><br>Establish a demand-side-management in cooperation between Government and T&TEC for substitution of electric boilers by SWH<br><br>Provide specific budgets (or the Green Fund) for the installation of SWH in public buildings with hot water consumption | Development of a sensitization and awareness raising campaign |
| **WtE** | High | Development of emission standards for exhaust gas and effluents from MSW incinerators by making reference to international examples<br><br>Development of technical specifications for MSW incineration power plants | Establish a long-term strategy and program on waste treatment<br><br>Provide budget and payment schemes for incineration of waste and reimbursement of electric power fed into the public grid or thermal energy extracted for productive purposes | Determination if existing treatment facilities are sufficient for safe disposal of fly and filter ashes<br><br>Implementation of a comprehensive waste characterization study<br><br>Implementation of a study analysing the composition and status of the existing waste at the three landfills to investigate co-incineration potential |

(*continued on next page*)

(*continued*)

| RE Technology | Potential | Financial, fiscal and regulatory requirements | Suggested programs | Other relevant activities |
|---|---|---|---|---|
| **WtE** (*continued*) | High | Establishment of a legal basis that redefines the treatment of waste and provides guidance for all types of waste material (starting from recycling to handling of contaminated ashes) | Elaborate tender documents for construction and possibly operation of an incineration facility | Calculation of economic potential (after implementation of studies), and analysis of local capacities to build an incinerator power plant<br>Elaboration of a full-scale feasibility study examining technical and economic viability of an incineration plant |
| **Bioenergy use** | Low | Examine if financial or fiscal incentives could stimulate the implementation of biogas facilities for local energy use | Potential development of four biogas demonstration projects at three large pig farms and the distillery | Investigate further biomass potentials, e.g. from organic domestic residues, if collected separately from other waste streams |
| **Ocean Energy** | High potential but no viable technology options for the moment | | | Implementation of a detailed feasibility study to analyse a quantitative assessment of the technological potential<br>Data collection on wave heights and periods off the North and East Coast of Tobago<br>Follow-up on international developments and share knowledge at R&D level |
| **Concentrated Solar Power** | Not existing | | | |

This translates into the following action and national budget plan for those measures that are identified as having a high potential:

| Solar PV and Wind Energy | | | | |
|---|---|---|---|---|
| **Summary of objectives** | **Summary of Targets** | | | **Budget Responsibility or Funding Source** |
| | **Short Term** | **Medium Term** | **Long Term** | |
| | **2014–2020** | **2020–2025** | **2026–2032** | |
| The overall objectives for RE interventions:<br>• Reach 4% of electricity generation in 2020 and 16% by 2032 | Reach 4% of electricity generation through Renewable Energy (100 MW of Wind and 60.3 MW of solar PV) | 16% of electricity generation through Renewable Energy | | |
| | **Specific Activities & 5-yr National Budget to meet Targets** | | | |
| | Development of an appropriate legal and regulatory framework to allow for large-scale implementation of RE<br>**Budget US$ 100,000** | Continue, review and appropriately modify the regulatory framework | | GoRTT |
| | Establishment of an introductory 100-Roof PV Program with capital subsidies of the Government<br>**Budget US$ 600,000** | Implement, continue and widen the programme | | GoRTT |
| | Establishment of a solar PV programme for public buildings using financial means of the Green Fund<br>**Budget US$ 800,000** | Implement, continue and widen the programme | | GoRTT/Green Fund |
| | Setting and monitoring of annual portfolio targets for T&TEC to either generate renewable electricity on its own or purchase such power from third-parties<br>**Budget US$ 50,000** | Continuously increase portfolio targets to be able to reach 16% of electricity generation through RE and installation of registration and monitoring system | | GoRTT/T&TEC/RIC |
| | Development and provision of country-wide solar radiation data by the Meteorological Service of T&T to reflect local conditions on both islands.<br>**Budget US$ 50,000** | – | – | Meteorological Service |

(*continued on next page*)

(*continued*)

| Solar PV and Wind Energy | | | | |
|---|---|---|---|---|
| | Training of electricians and electrical inspectors for Solar PV installations<br>**Budget US$ 200,000** | Introduction of certificates for qualified installers. | — | GoRTT/ TTBS/T&TEC/ Technical training institutions |
| | Perform detailed wind measurements at potential concrete sites, based on the national wind resource assessment<br>**Budget US$ 500,000** | To be continued, but preferably at the cost of investors | — | GoRTT/donor funding |
| | Design technical guidelines for grid connection and operation of wind turbines and PV systems<br>**Budget US$ 100,000** | Adaptation of guidelines depending on experiences and technical innovations | | GoRTT |
| | Assess impact on grid stability and capacity if relevant levels of wind or solar energy are fed into distribution or transmission lines<br>**Budget US$ 100,000** | Could become even more relevant in this phase due to concentration of wind and solar farms at certain locations— | | GoRTT |
| | Pre-feasibility analysis of potential sites for offshore wind power (including wind assessments)<br>**Budget US$ 300,000** | If assessment is favourable, followed by feasibility study and preparation of tender procedure for offshore wind power | | GoRTT |
| | Introduce know-how on wind energy in university and college courses and start training of technicians for construction, operation and maintenance<br>**Budget US$ 250,000** | — | — | GoRTT/UTT and UWI/ Technical training institutions |
| **5-YEAR BUDGET, US$** | **3,050,000** | | | |
| **AVAILABLE RE CAPACITY, MW** | **160.3** | | | |
| **$CO_2$ EMISSIONS AVOIDED, kt** | **278.565** | | | |

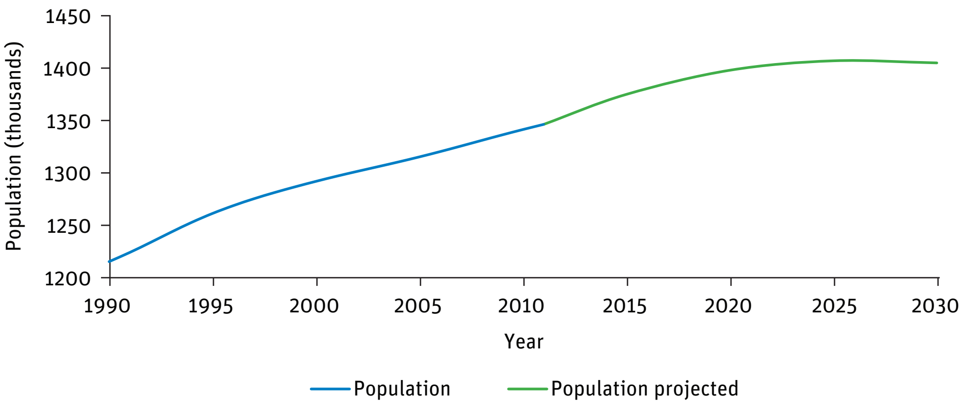
**Waste-to-Energy**

| Summary of objectives | Summary of Targets: Short Term 2014–2020 | Summary of Targets: Medium Term 2020–2025 | Summary of Targets: Long Term 2026–2032 | Budget Responsibility or Funding Source |
|---|---|---|---|---|
| The overall objectives for RE interventions:<br>• Reach 4% of electricity generation at 4% in 2020 and 16% by 2032 | Reach 4% of electricity generation through Renewable Energy | Reach 16% of electricity generation through Renewable Energy | | |
| | **Specific Activities & 5-yr National Budget to meet Targets** | | | |
| | Development of appropriate standards and regulatory framework for WtE<br>**Budget US$ 200,000** | Continue, review and appropriately modify the regulatory framework | | GoRTT |
| | Establish a long-term strategy and program on waste treatment<br>**Budget US$ 300,000** | Implement, continue and fine tune the programme | | GoRTT |
| | Implementation of a comprehensive waste characterization study<br>**Budget US$ 500,000** | Implement, continue and widen the programme | | GoRTT |
| | Elaboration of a pre-feasibility study on the realisation of a WtE plant<br>**Budget US$ 200,000** | | | GoRTT |
| | Elaboration of a full-scale feasibility study examining technical and economic viability of an incineration plant<br>**Budget US$ 400,000** | Tendering and construction of an incineration plant | – | GoRTT |
| **5-YEAR BUDGET, US$** | **1,600,000** | | | |

| Solar Water Heating | | | | |
|---|---|---|---|---|
| **Summary of objectives** | **Summary of Targets** | | | **Budget Responsibility or Funding Source** |
| | **Short Term** | **Medium Term** | **Long Term** | |
| | **2014–2020** | **2020–2025** | **2026–2032** | |
| The overall objectives for RE interventions:<br><br>• Equip about 50% of T%T households with Solar Water Heaters by 2032 | Reach 60,000 units of Solar Water Heaters | Reach 150,000 units of Solar Water Heaters | Reach 200,000 units of Solar Water Heaters | |
| | **Specific Activities & 5-yr National Budget to meet Targets** | | | |
| | Development of an appropriate legal and regulatory framework to kick start SWH (Including 100% tax allowance)<br>**Budget US$ 1,000,000** | Continue, review and appropriately modify the regulatory framework | | GoRTT |
| | Use SWH for retrofitting of social housing and in case of new constructions<br>**Budget US$ 300,000** | Make SWH mandatory in Social Housing | | HDC |
| | Establish a system to collect data on SWH installations, and to analyse effects on GHG reductions, deployment and usage<br>**Budget US$ 50,000** | – | | GoRTT |
| | Include SWH into technical/vocational training to create critical mass of artisans for installation and maintenance and increase consumer confidence<br>**Budget US$ 100,000** | Introduction of certificates for qualified installers. | | GoRTT/ Vocational training schools |
| | Establish a demand-side-management programme in cooperation between Government and T&TEC for substitution of electric boilers by SWH<br>**Budget US$ 300,000** | – | – | GoRTT/T&TEC |
| | Provide specific budgets (or the Green Fund) for the installation of SWH in public buildings with hot water consumption<br>**Budget US$ 200,000** | | – | GoRTT/TTBS/ Green Fund |
| **5-YEAR BUDGET, US$** | 1,950,000 | | | |
| **$CO_2$ EMISSIONS AVOIDED, kt** | 120,000 | | | |

**FIGURE 62**

**Population figures for Trinidad and Tobago from 1990 to 2030**




*Source*: UNDESA, 2013.[a]

[a] The Central Statistical Office was not operational when the data for the Report were required. Therefore data from UNDESA have been used.

Different trends are simulated to evaluate the likely impact these different Scenarios may have on key indicators. The resulting trends have been compared against the "*Business-as-Usual*" projections in order to gauge the impact of the proposed Scenario. The five (5) Scenarios assessed and discussed in this chapter are the following:

- Scenario 1: Introduction of EE measures
- Scenario 2: Introduction of RE covering 2.5% of generated power by 2020
- Scenario 3: Introduction of RE covering 4.0% of generated power by 2020
- Scenario 4: Combination of Scenarios 1&2
- Scenario 5: Combination of Scenarios 1&3.

## Projections for Population and GDP Growth

### *Population Figures and Projections*

The population growth estimates up to 2030 have been based on data obtained from the United Nations Department of Economic and Social Affairs (UNDESA), which provides projections on a 5-year period basis.[34]

[34] Population growth rates for 2010–2015: 0.28%; 2015–2020: 0.03%; 2020–2025: -0.24%; 2025–2030: -0,38% (Source: http://esa.un.org/wpp/unpp/panel_population.htm).

### *Expected Contribution of Energy Sector to GDP*

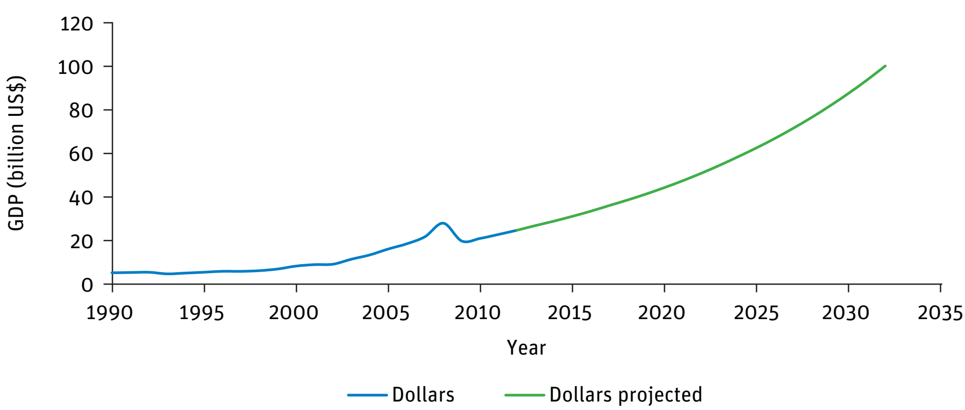
The International Monetary Fund (IMF) forecasts up to 2017, and the United States Department of Agriculture (USDA) thereafter, providing the necessary data to draw the GDP Forecast for T&T up to 2032 as illustrated in **Figure 68** The adjusted line, takes into account the reduction in production of oil and an increase in natural gas production, with a net reduction in fossil fuel production in T&T over the coming years. As such, the contribution of the combined oil and natural gas production to the country´s GDP will down spiral from the current 40% to approximately 14% in 2032.

USDA´s data is a continuation of the figures presented by the IMF, and as such, provides the continuity required to establish an appropriate projection up to 2032. However, this Report questions these estimates on the basis of the current gas and oil reserves. Currently the gas and oil sector are responsible for as much as 43% of the GDP shown in **Figure 68** With the current best reserves estimates, the energy sector´s share of the GDP will experience a drop. This drop is attributed to the reduction in Crude Oil reserves and the inability of NG Production to compensate for it. However, there are many factors that are also likely to affect the GDP growth, another key element being the population increase, which has been addressed in the previous section.

The effects of the Energy Sector´s share depletion are further evaluated in further chapters.

**FIGURE 63**

**Gross Domestic Product (GDP) in real values for Trinidad & Tobago, 1990–2032**




*Source*: IMF 2012 up to 2017, and USDA, 2012.

### *Business-as-Usual Projection till 2032*

This Scenario uses baseline data to establish the current trends, and projects them. Where appropriate, new considerations are taken into account in order to assume a projection up to 2032. These considerations include the following assumptions:

- Crude oil production will continue its declining trend for the entire study period unless the initiatives to arrest the decline proof successful.[35] While consumption will continue to increase at a similar rate following the tendency of the past decades.
- Natural gas production will continue to increase at a rate experienced in recent years, as new exploration Blocks have been awarded as of 2013, providing sufficient sources to continue production during the study period. Gas consumption will experience a similar trend as oil consumption, and follow the same tendency as in the past decade.
- Electricity generation will continue to increase at a constant 4.4% annually within the study period. Similarly, improvements in energy generation efficiency have been taken into account, and as such, a 1% annual efficiency improvement has been integrated.
- For comparison purposes, this is considered a "Do-Nothing" Scenario in terms of energy efficiency, renewable energy and electricity demand, GDP and population growth trends.

## Projected Oil Production & Consumption

When assessing the projected estimates, the simulations anticipate that the current demand will overtake the production capacity within the period until 2032. With the "Business-as-Usual" Scenario, the major implications are that T&T will turn into oil importing country and that to maintain estimated GDP growth rates, the natural gas production will need to increase.

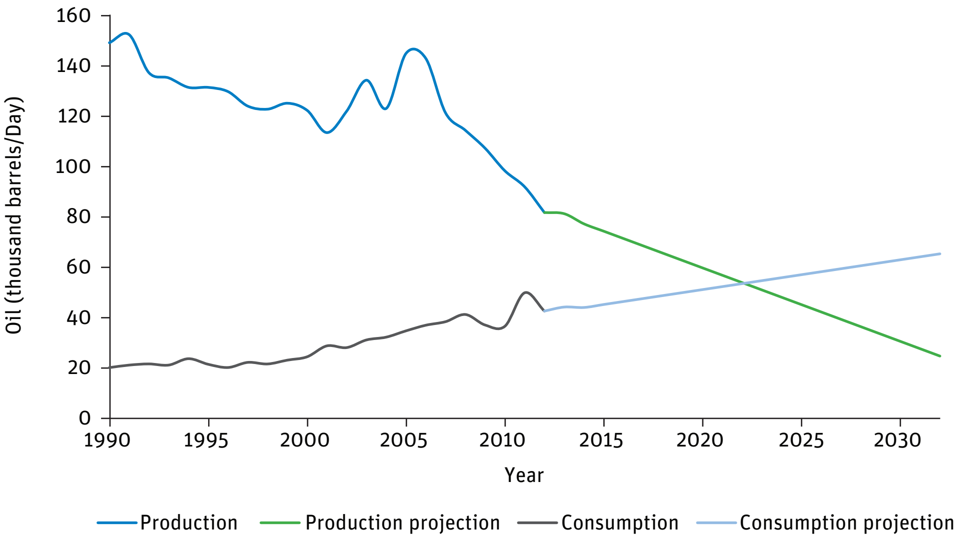
## Projected Natural Gas Production & Consumption

The projection from 2013 to 2032 has been carried out considering the tendency that natural gas production and consumption have shown in previous years. GoRTT awarded new exploration and extraction licenses for natural gas, which may raise the country´s reserves to nearly 50 tcf. The simulation indicates that although these reserves may be sufficient, they will be at a minimum by 2032. Moreover, should the relation between GDP and domestic energy production be used at the current 40% share, the recorded reserves will not suffice. Therefore, this Report has explored the adjusted GDP growth and maximum energy generation from current reserves.

[35] There are reported initiatives by MEEA to arrest the decline in Crude Oil production. This is intended to stimulate the exploration activities and for the development of "small oil pools" which had been discovered but were apparently not regarded by the companies as worth commercialising. There is uncertainty over the quantifiable impact of these initiatives and therefore not sufficiently indicative for the purpose of this study.

**FIGURE 64**

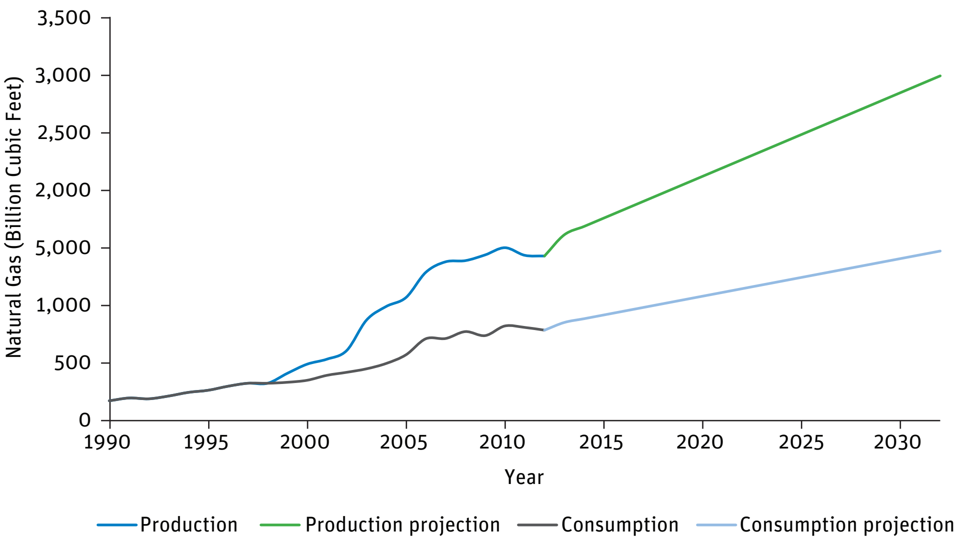
**Projected crude oil production & consumption up to 2032**




*Source*: Own elaboration.

**FIGURE 65**

**Projected natural gas production and consumption**




*Source*: Own elaboration.

## Adjusted GDP Projection for recorded Natural Gas Reserves and decline in Crude Oil Production

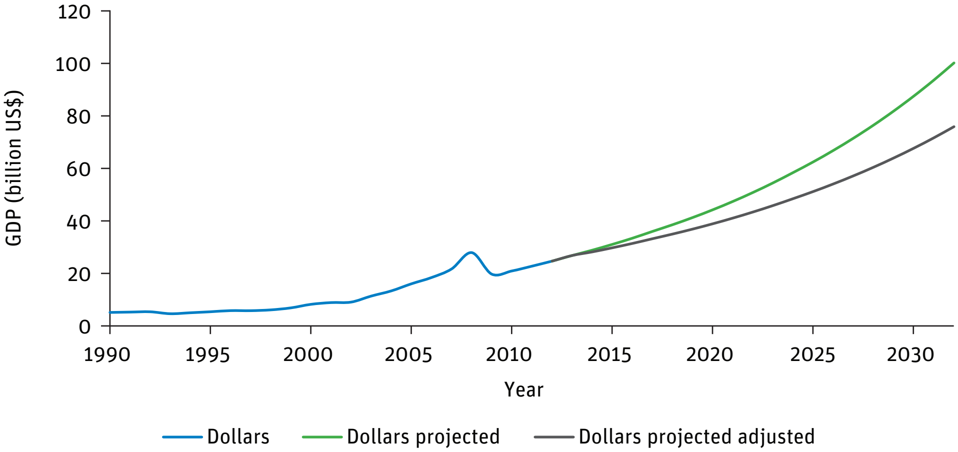
As previously mentioned, the production of crude oil and natural gas has been a large contributor to T&T´s GDP, with a share of over 40% in 2013. However, GDP share is projected to decrease, as crude oil production continues to fall, and the increase in natural gas is not sufficient to compensate this drop.

The current GDP estimates provided by IMF and the USDA, do not indicate any change with regard to the limits of crude oil and natural gas reserves. Assuming that the referenced GDP projections have not taken into account this effect, the GDP estimates need to be adjusted, as illustrated in **Figure 71**.

By 2032, the contribution of conventional energy production (crude oil & natural gas) is expected to decrease to 14% of GDP, from the current US$ 100.2 billion to the adjusted US$ 75,9 billion in 2032.[36]

**FIGURE 66**

**GDP projection and adjustment for decline in crude oil and natural gas production**




*Source*: Own elaboration.

[36] For future projections regarding crude oil and natural gas prices, the lack of information regarding the increase or fall of prices, legitimatizes the adoption of a flat price of US$ 107 per barrel of oil and US$ 4.35 per cubic feet of natural gas for the 20 years that this Report projects.

## Projected Electricity Demand ("Business-as-usual")

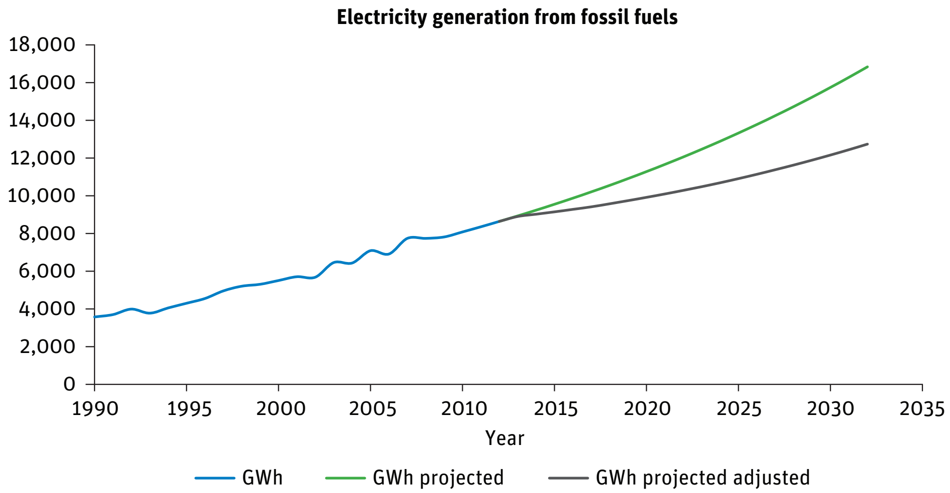
As the current situation implies, electricity generation matches electricity demand, given that Trinidad & Tobago does not import electricity from neighboring countries.

With regard to electricity generation in the baseline study, the projected line was established considering that conventional energy production will continue to grow at the same rate as in recent years. However, the current best estimates for the oil and gas reserves assume that the current growth rate is not replicable in the future and should be adjusted. The adjusted assumption therefore, includes the most recently available public data.

The impact of these simulations on the estimated future GDP has already been introduced in the previous chapter. The energy generation capacity in the future contradicts the estimated GDP growth under the current share. Simulated data obtained consider the adjusted projections of crude oil and natural gas production and revenues. This assumed trend was adjusted to consider a drop in the GDP share, which the study indicates will be approximately 14% from the current 43% of GDP. Therefore, the adjusted simulation indicates that Trinidad & Tobago´s GDP will not increase as in the past, due to lower revenues from oil and gas, and that this lower GDP may also affect demand for electricity. Hence, considering all of these factors, T&T's electricity demand projections may experience a drop, which by 2032 will be down from the projected 16.8 TWh to the adjusted 12.7 TWh.

**FIGURE 67**

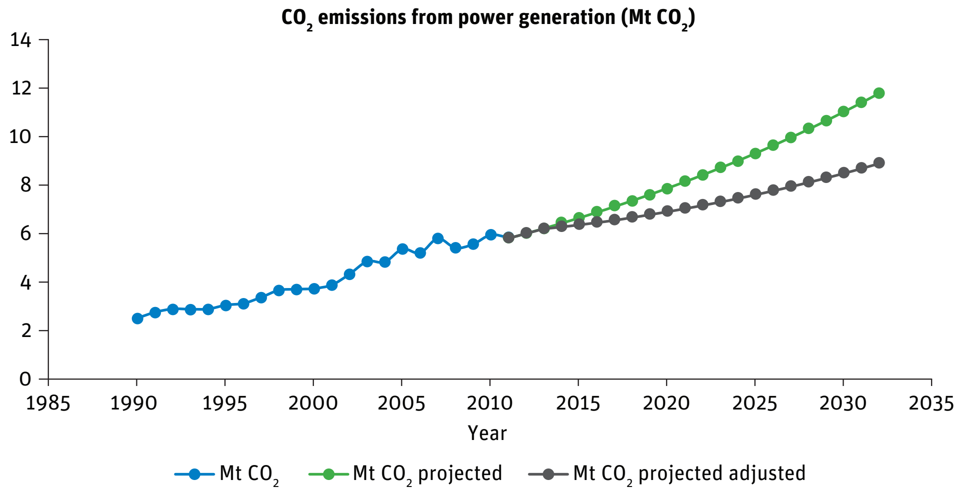
**Projected electricity demand – "Business-as-Usual"**




*Source*: Own elaboration.

**FIGURE 68**

**Projected $CO_2$ emissions from power generation – "Business-as-usual"**




*Source*: Own elaboration.

## Projected $CO_2$ Emissions from Power Generation

With regard to $CO_2$ emissions from power generation, the baseline study has used the findings of a study that links GDP to population and energy generation.[37] Using this relationship, $CO_2$ emissions can be determined. The Scenario was developed using electricity generation from GDP projections up to 2032 and using IMF and USDA data for population growth estimates. The simulation concludes, that under this Scenario the assumed $CO_2$ emissions in 2032 will increase from 6.04 Mt in 2012 to 11.78 Mt under the projected situation, and to 8.92 Mt under the adjusted situation.

The improvements on the generation side, which include the use of combined-cycle technologies (chapter 3.4) have been incorporated in all of the Scenarios, as the purpose of this exercise is to compare the improvements achieved in each Scenario with the "Do nothing" situation that is the adjusted trend. It is also estimated that these improvements are some of the measures that will have the biggest impact in the reduction of $CO_2$ emissions.

a. This Report has identified referenced projections for GDP to 2032 as well as population figures. Following the findings from a referenced study[38] that correlates relation-

[37] Tverberg, Gail, 2012: "An Energy/GDP Forecast to 2050" (ourfiniteworld.com), July 26, 2012.
[38] Tverberg, Gail, 2012: "An Energy/GDP Forecast to 2050" (ourfiniteworld.com), July 26, 2012.

ship between GDP, population growth and the energy sector, the future electricity demand can be calculated.

b. Currently documented fossil fuel reserves are considerably lower than required to maintain the referenced GDP ratio and growth rate. Having this consideration in mind, the adjusted growth rate takes into account the change in the share of the energy sector with regard to overall GDP, which shall drop from 40% to 14%. This is based on the historical trends of the GDP reliance on the Fossil fuel reserves.[39]
c. Under the simulated projections, the current oil demand will overtake the oil production within the period until 2032. With the *"Business-as-Usual"* Scenario, the major implications are that T&T will turn into an oil importing country.[40]
d. The simulation indicates that although the natural gas reserves may be sufficient for the period at such rate, the reserves will be at a minimum by 2032.
e. The limitations of the current energy sector to ensure the referenced GDP growth in the projections demonstrate the need to diversify the energy matrix and reduce national demand as well as to diversify the industrial sector to maintain GDP growth.

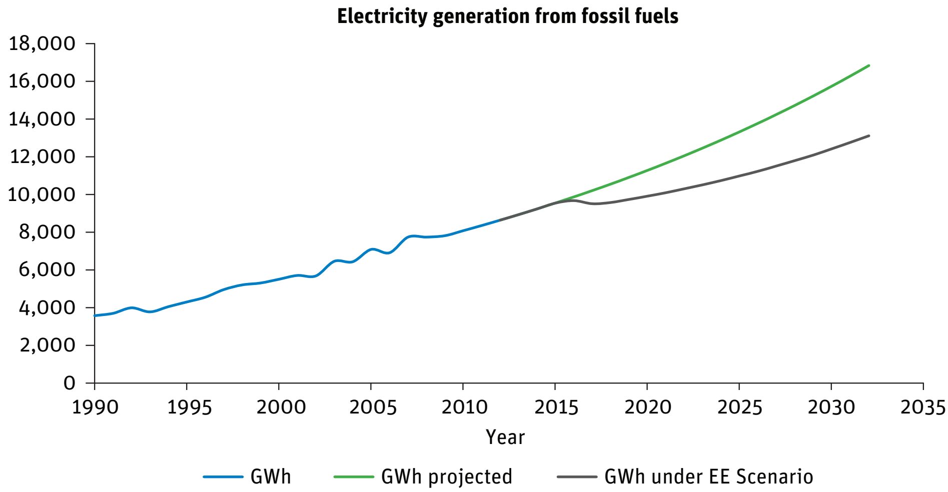
## Scenario 1: Introduction of Energy Efficiency Measures

Scenario 1 takes into consideration new energy efficiency measures applicable within the residential, hotel and the commercial/industrial sector, which would result in a reduction of approximately 973.3 GWh by 2020 (see chapter 5.3). This represents over 9% of the estimated electricity demand for that year. Additionally, the Scenario also includes the improvements in the power stations, with combined-cycle processes being introduced to all plants. This would save an additional 12% of the fossil fuel used for electricity generation required to meet the demand from 2020 and thereafter. For the following period, the Scenario assumes that the trend is to continue until 2032. Should these conditions be met, the proposed EE measures could potentially save over 21%[41] (see chapter 6.2) of the estimated electricity production required under the *"Business-as-Usual"*, or 3.7 TWh of the 16.8 TWh of the projected original electricity generation.

[39] Other factors, such as developments in the non-oil and gas sectors, could also result in lower comparative oil and gas GDP contribution. Oil and gas percentage GDP may not always be a factor of significance but the study has based its findings in the historical trends of the key factors of significance which have been studied and published (Tverberg, Gail, 2012).
[40] Importing oil not only under processing agreements to keep the refineries operating.
[41] Savings in the Residential, Hotel and Commercial/Industrial sector yield 9.2% of the estimated energy demand, while savings derived from the improvements introduced in the power stations would yield a 12% savings by upgrading to Combined Cycle. Therefore, the actual savings due to EE would be 21.2% (see chapter 6.2)

**FIGURE 69**

**Fossil fuel based electricity generation – Scenario 1**




*Source*: Own elaboration.

**Figure 69** illustrates the simulated trend, which is assumed to kick-start when the EE measures are introduced in 2016, assuming that most measures will be introduced in the first 3–4 years.

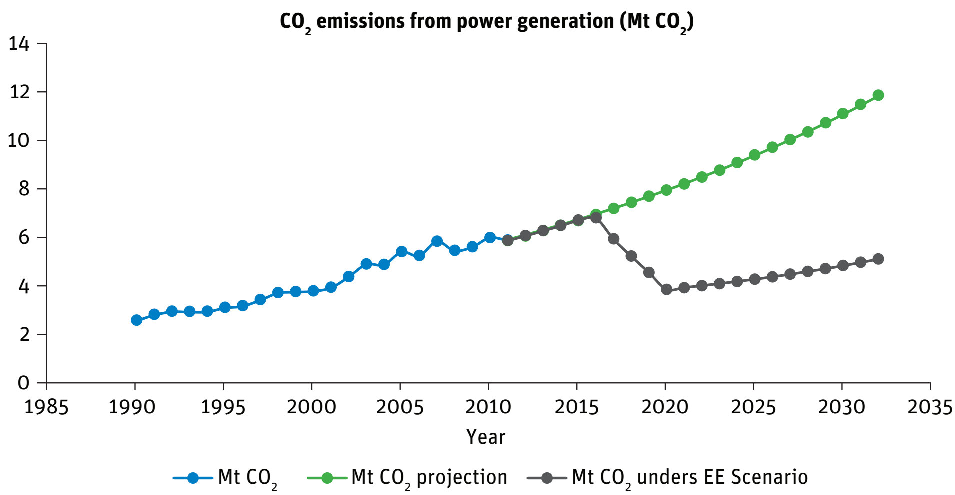
Under this Scenario, energy efficiency measures, which have a direct impact on electricity consumption in the residential, hotel and commercial/industrial sectors, are accounted for. These measures, which would start to take effect in 2017 will account for a 973.3 GWh reduction of annual electricity demand by 2020. The combined-cycle technology replacing about 50% of all simple-cycle gas turbines (see chapter 3.3) would also account for an additional 12% drop, given that the current efficiency level of 26.6% would increase to 38.5%.

These measures will consequently reduce $CO_2$ emissions from power generation. Furthermore, the improved efficiency of the combined-cycle plants, which would be introduced between 2017 and 2020, will have a sizeable impact in terms of $CO_2$ emissions per kWh generated nationally.

The simulation demonstrates that this first batch of measures could have a great impact on $CO_2$ per kWh. This is illustrated by the steep inclination experienced in the first years. This is be-

**FIGURE 70**

**Projected $CO_2$ emissions from power generation**




*Source*: Own elaboration.

cause improvements in the power generation stations will lower the emission factor from 700 g of $CO_2$ per kWh currently to 387 g of $CO_2$ per kWh in 2020 and onwards (see chapter 3.7).

As a result of these assumptions, $CO_2$ emissions will be reduced to 4.30 Mt in 2032, as opposed to 11.78 Mt, if no measures are introduced.

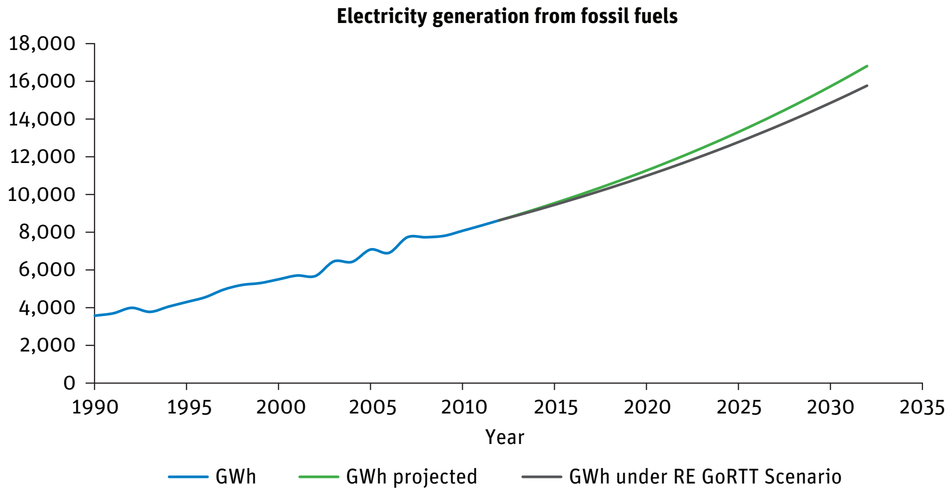
## Scenario 2: Introduction of RE covering 2.5% of Generated Power by 2020

As of 2013, the GoRTT is looking at introducing RE generation technologies, which could potentially provide 2.5% of the electricity generated by 2020. Keeping this consideration in mind, this Scenario simulates the assumed impact that such measure would have on the electricity generation from fossil fuels, as well as the effects on the $CO_2$ emission produced.

In this Scenario, RE is introduced at 2.5 % of generated power by 2020 and projected to further escalate thereafter at a continuous 0.3% annual increase (see chapter 4). The assumed results are compared with the projected data in the "*Business–as-Usual*" Scenario**. Figure 71** illustrates the results of the simulation and compares the projected electricity generation up to 2020, which would be entirely based on natural gas, with the Scenario, in which the RE share will be 2.5% as of 2020 and up to 6.3% as of 2032. This Scenario has been calculated

**FIGURE 71**

**Fossil fuel based electricity generation – Scenario 2**




*Source*: Own elaboration.

to lower the fossil fuel based electricity to 15.8 TWh by 2032, as opposed to the 16.8 TWh under the "*Business as Usual*" Scenario.

The measures introduced in this scenario include the following RE installed capacity by 2020:

- 100 MW from Wind Power
- 60 MW from Solar PV

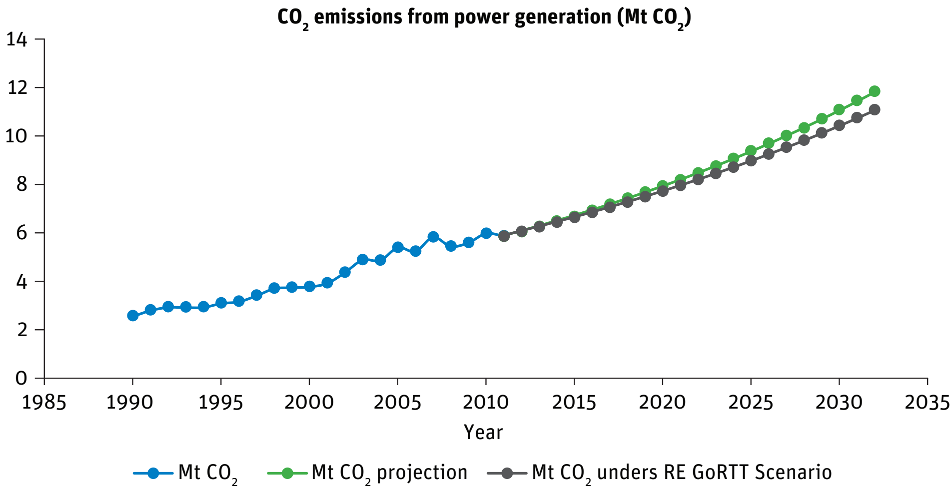
RE sources do not emit $CO_2$ when generating electricity (or release as much $CO_2$ as they have previously absorbed in the case of biomass energy). As such, the $CO_2$ emissions from power generation will be reduced at the same ratio as the renewable based power generation share of the total power generated. **Figure 72** shows the difference in emissions between the projected baseline and Scenario 2 situations, which would be at 11.78 and 11.04 Mt respectively in 2032.

## Scenario 3: Introduction of RE covering 4.0% of power generation by 2020

Considering the introduction of RE in T&T, the consultants considered which would be the ratio of introduction in order to generate a sizable market share and opportunities for local business. As such, it has been estimated that a 4% contribution to electricity generation by

**FIGURE 72**

**$CO_2$ emissions from power generation – Scenario 2**




*Source*: Own elaboration.

2020 would meet this requirement. This situation, if further escalated, would lead to the generation of approximately 2.7 TWh or 16% of the total 16.8 TWh in 2032 from RE sources.

**Figure 73** below illustrates the difference between this Scenario, and the baseline.

With regard to $CO_2$ emissions, the amount of $CO_2$ produced through power generation would fall from 11.78 Mt in 2032 to 9.90 Mt (refer to Figure 79 below).

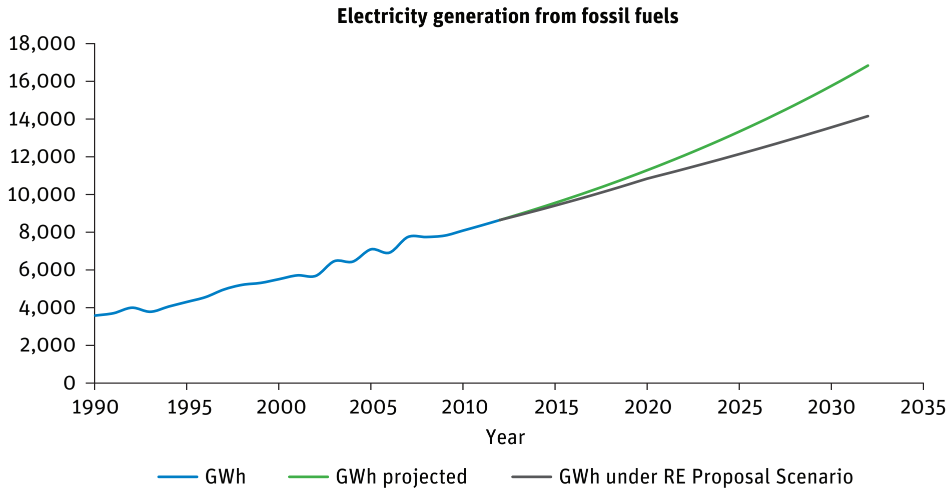
## Scenario 4: Combination of Scenarios 1&2

Under this Scenario, energy efficiency measures will be introduced, combined with the introduction of renewable energies at 2.5% of the electricity generated in 2020, increasing to 6.3 % by 2032. This Scenario would combine the positive effects of Scenarios 1 & 2, therefore reducing electricity generated from natural gas to about 12.08 TWh from 16.8 TWh in 2032 as shown in **Figure 75**.

Similarly, given that the share of electricity generated from fossil fuels will decrease, the amount of $CO_2$ emissions will experience a fall due to the energy efficiency and renewable energy introduction and consolidation. **Figure 76** illustrates the difference in $CO_2$ emissions

## FIGURE 73

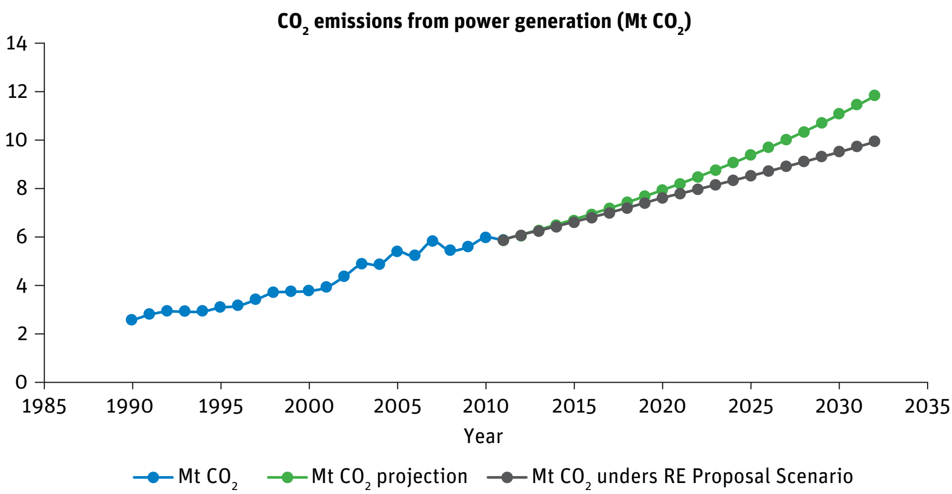
### Fossil fuel based electricity generation – Scenario 3




*Source*: Own elaboration.

## FIGURE 74

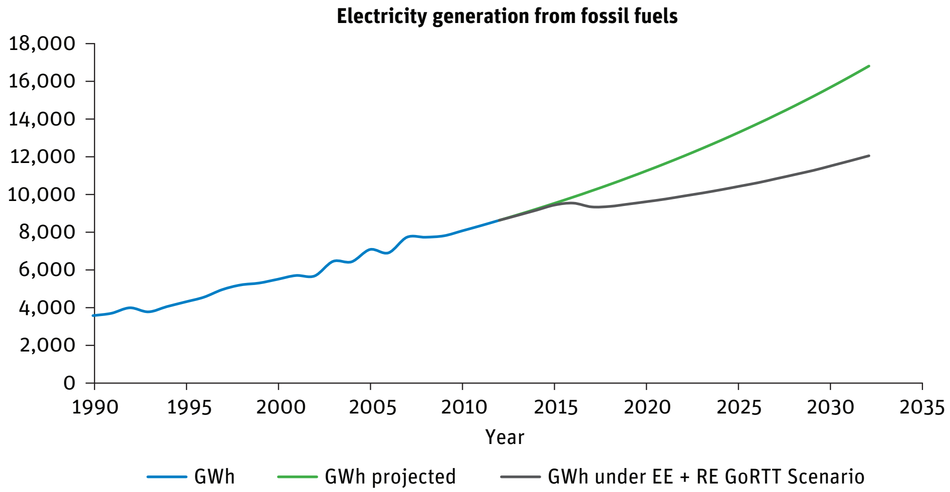
### $CO_2$ emissions from power generation – Scenario 3




*Source*: Own elaboration.

**FIGURE 75**

**Fossil fuel based electricity generation – Scenario 4**




*Source*: Own elaboration.

under this Scenario, and the baseline, with a difference in emissions of 11.78 Mt under the baseline conditions to 3.89 Mt of emissions under Scenario 4 conditions.

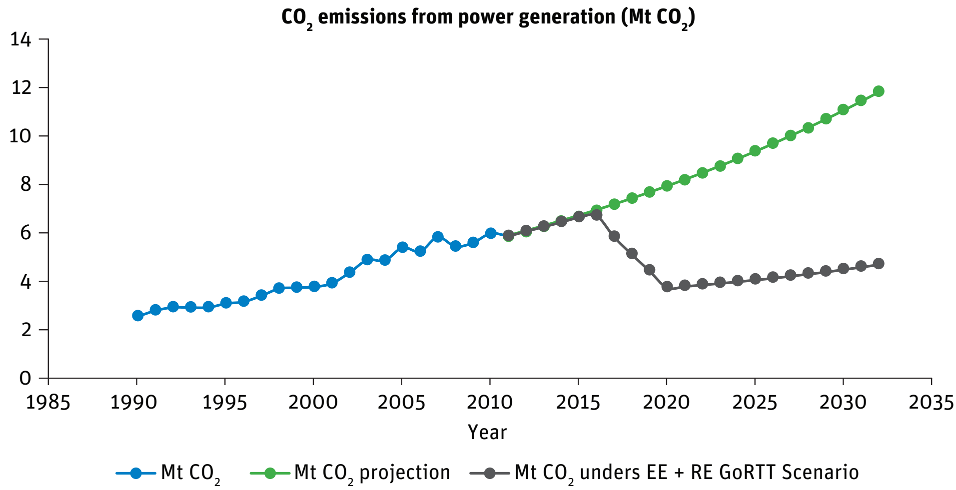
## Scenario 5: Combination of Scenarios 1&3

Similar to Scenario 4, the Scenario presented in this section takes into account the potential results obtained from combining EE and RE. The difference is that Scenario 5 takes into account the consultants´ proposed 4.0% of Renewable Energy generation by 2020, and 16% by 2032. Initially, the annual growth in RE generation to be 0.5%, while after achieving 4% in 2020, the annual growth will increase to 1%. This would enable the creation of sufficient market size that will reciprocally lead to lower specific costs and strengthen experience in new business sectors. By increasing the annual rate from 2020 to 2032, it is technically and economically feasible through the use of wind and solar resources. **Figure 77** clearly illustrates the difference between the baseline and Scenario 5 with regard to electricity generation from fossil fuels, which would be reduced from the total of 16.8 TWh to 10.4 TWh in 2032.

When considering $CO_2$ emissions, the trend will follow a similar pattern as that shown under Scenario 4; however, given the increased amount of RE, the difference in $CO_2$ emissions

## FIGURE 76

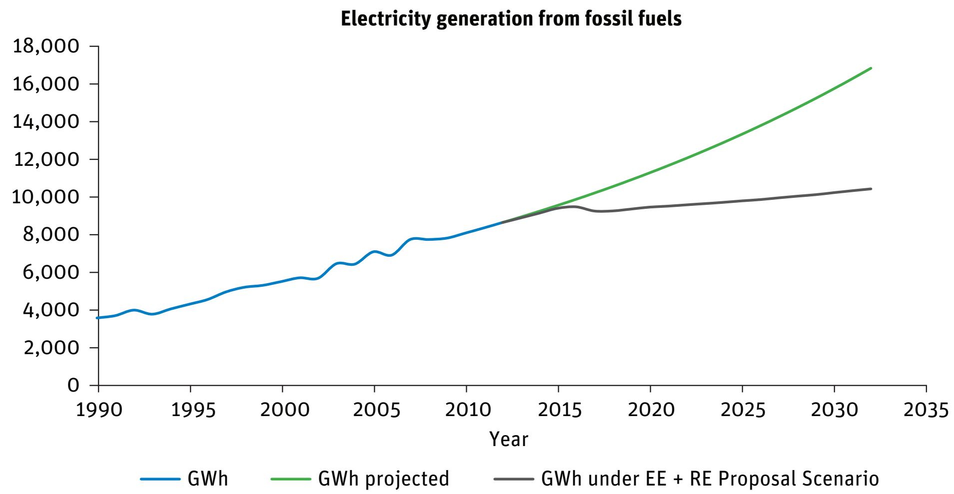
### $CO_2$ emissions from power generation – Scenario 4




*Source*: Own elaboration.

## FIGURE 77

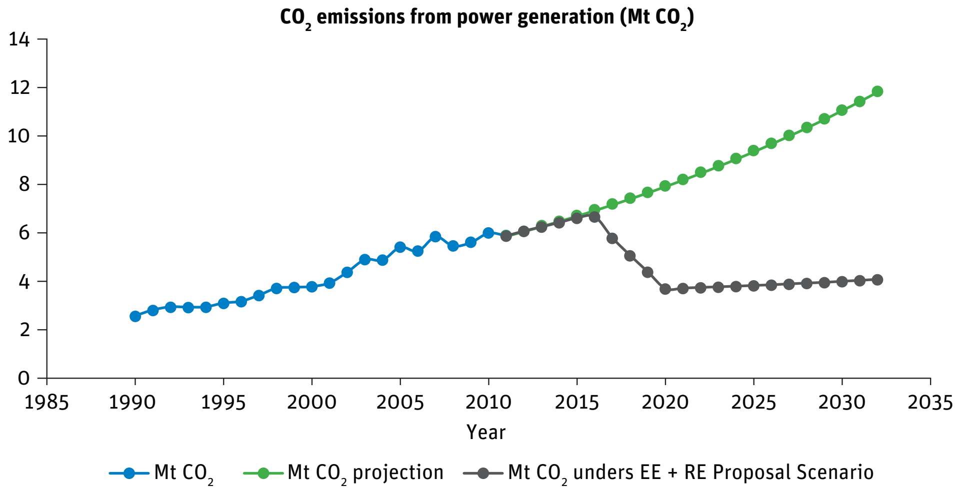
### Fossil fuel based electricity generation – Scenario 5




*Source*: Own elaboration.

**FIGURE 78**

**$CO_2$ emissions from power generation – Scenario 5**




*Source*: Own elaboration.

between the baseline and Scenario 5 will be 11.78 Mt and 3.26 Mt respectively, as shown in **Figure 78**.

While EE measures proposed under Scenario 1 are more efficient in terms of electricity generation and $CO_2$ emissions in comparison to the RE Scenarios, Scenarios 4 and 5, which combine the EE measures with a 2.5 % RE by 2020 and 4.0% RE by 2020, are the ones to favour. More specifically, the Scenario 5 indicates that as much as 6.4 TWh of electricity generated could be either saved with EE measures or produced through the use of RE technologies by 2032. This would generate $CO_2$ emissions at a rate of 3.26 Mt as opposed to the 11.78 Mt, if no additional measures are introduced to reduce the dependency on fossil fuels for the generation of electricity.

7

# Conclusions

The different chapters of the report contain detailed recommendations on the next steps that the GoRTT could undertake to strengthen its policy and legal framework, as well as to promote EE and RE.

The following chapter is summarizing some of the recommendations and proposed measures and provides an overview on those activities that the GoRTT could undertake to promote a Sustainable Energy future for T&T.

## Policy and Regulatory Framework

- Establish clear and measurable targets for RE, with a binding mandate for T&TEC to incorporate RE electricity from own or third-party generation facilities.
- Raise the RE target to at least a contribution of 4% in electricity consumption by 2020 in order to create sufficient market size that will reciprocally lead to lower specific costs and strengthen experience in new business sectors. In the medium term until 2032, a RE share of 16% in electricity consumption is technically and economically feasible by using primarily wind and solar resources.
- Amend the T&TEC Act to allow access to the grid for operators of RE generation facilities, although the extent and scope should be controlled by T&TEC in line with the Regulated Industries Commission and made dependent on capacity demand and technical circumstances.
- Simplify the permission process for operators of small distributed generation and do not request any lengthy licensing procedure. A simple registration procedure and control by the electrical inspectorate should be sufficient.
- Develop a feed- in- tariff for small-scale wind and solar electricity and publish guidelines around all steps of the permission process, the technical requirements for grid integration, payment schemes, requirements of the grid operator, etc.
- Use bidding schemes (auctions) for large-scale wind and solar electricity financed and operated by private investors, unless T&TEC is installing sufficient capacity with own resources.
- The initial uptake of residential PV systems should be stimulated with a 100-roofs programme (up to 5 kWp each) as a starting point for the development of a PV market.

- Revise eligibility criteria for the Green Fund to allow for investment coverage of pilot and demonstration programmes.
- Ban incandescent light bulbs by setting minimum performance standards.
- Lead the initiative at CARICOM level for a harmonized approach on minimum efficiency standards and labelling for domestic electrical appliances.
- Apply energy-related minimum building standards—in a first step for social housing and public government buildings.
- Improve internal information exchange and learning at the MEEA through the development of knowledge management.
- Clearly define roles and responsibilities with regards to EE and RE within the MEEA.

## Energy Efficiency

In the area of EE, the data situation has been especially complicated. Current uptake of EE is low, especially due to the low cost of energy. The government has started a comprehensive awareness raising campaign that has started at the end of 2012 and is providing a number of incentives such as the ESCO/150% tax allowance for energy audits. The Consultants have extensively advised with regards to the ESCO/tax allowance and provided detailed recommendations. Guidelines for energy audits have been developed and an extensive capacity building process for local audit firms, as well as the implementation of energy audits in public buildings has taken place. The energy audits resulted in possible improvements in energy consumption of over 25% with an estimated payback time of under 5 years in all selected buildings. At the same time, lessons learnt such as the need for capacity building for auditors or the need for further capacities with regards to passive solutions could be derived from the audits. Both, the committee and the MEEA should support these findings by providing guidelines, training and programs that guarantee an understanding of the benefits of energy audits, support in expanding technical capacity to carry out complete audits and implement the identified measures.

The Consultants propose the development of specific programs that spur the uptake of EE in T&T. Some of the proposals are:

- Promote residential EE programs related to
  - Reducing the use of electricity for water heating;
  - Encouraging the use of energy-efficient appliances and lighting;
  - Reducing energy consumption in the social housing sector;
  - Engaging and motivating consumers to adopt no-cost, durable energy savings behaviours.
- Promote EE in the hotel sector through:
  - Improving air-conditioning efficiency;

- Using more efficient lighting and controls;
- Using more efficient equipment and appliances in rooms and back-of-house
- Encouraging green hotel certification.
- Promotion of Energy management for public institutions.

Additionally, a GEF-financed project has been developed that should improve the uptake of EE in the housing sector, especially with regards to social housing. Clear leadership from the HDC will be necessary to make this proposed GEF project a success.

## Renewable Energy

All potential existing technologies for RE in T&T have been assessed. PV, SWH and onshore wind energy are the most promising technologies. To support a generous uptake of these technologies, detailed technical studies, such as local wind measurements to assess the expected energy yields at concrete sites, are necessary.

At the same time, it will be important to accompany the promotion of RE technologies with appropriate legislation to ease their uptake. As, technologies such as PV are competitive in T&T in the medium to long term, no time should be wasted to put those measures in place.

In the case of SWH, a relevant penetration in the T&T market is necessary. A supporting scheme such as in Barbados, enrolling a program that contains different elements from incentives, capacity building, awareness raising to standards and testing, could lead to an uptake that would result in relevant amounts of avoided costs of electricity. At the same time, it is perceived that T&T could also have market potential for the local manufacturing of SWH.

WtE is an interesting technology for T&T, as it can solve some of the waste disposal problems of T&T; as well as provide an additional source of energy for the T&T energy mix. However, to move forward, it has to be studied whether the existing treatment facilities are sufficient for the safe disposal of fly and filter ashes from the incinerators. Emission standards for exhaust gas and effluents from MSW Incinerators have to be established. Based on the recommendations of the Consultants, the Government has foreseen the development of a comprehensive waste characterization study in its budget for 2013–2014.

Potential for biogas is limited; the most promising projects are the development of a biogas plant in the distillery of Trinidad, as well as in one of the large pig farms. Other technologies, such as ocean wave energy would need further detailed assessment to define their exact potential. However, given the status of these technologies, it seems more relevant to focus on PV, SWH and onshore wind energy for the near future.

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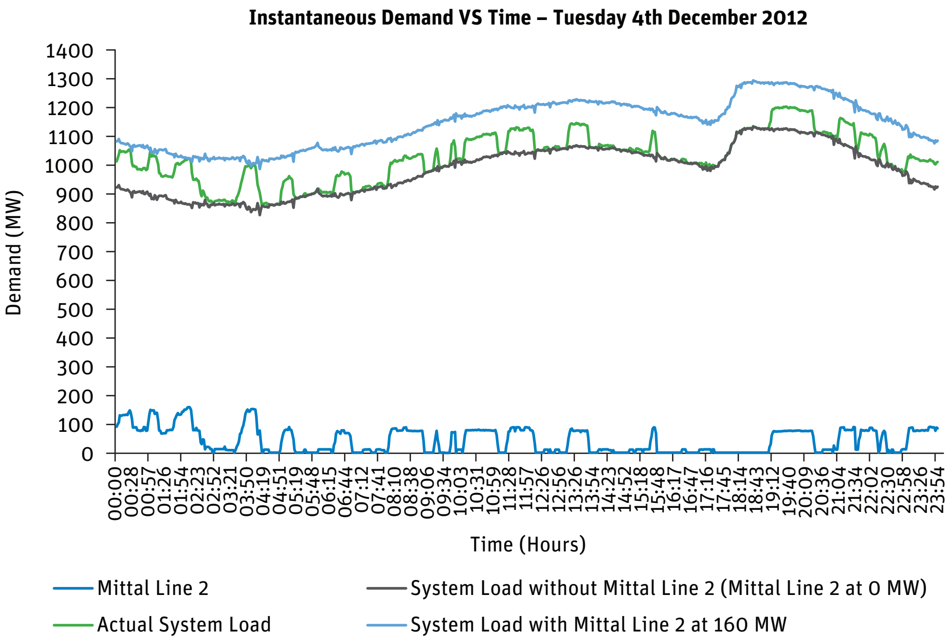
Infographic_World_map_2.ipg.

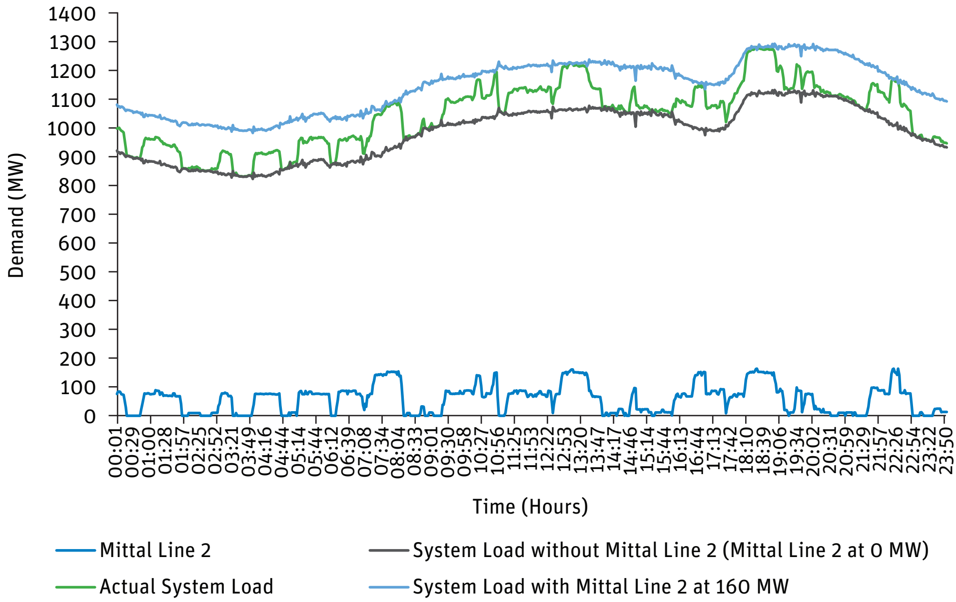
# Appendices

## Appendix A:
## Load Curves of T&TEC

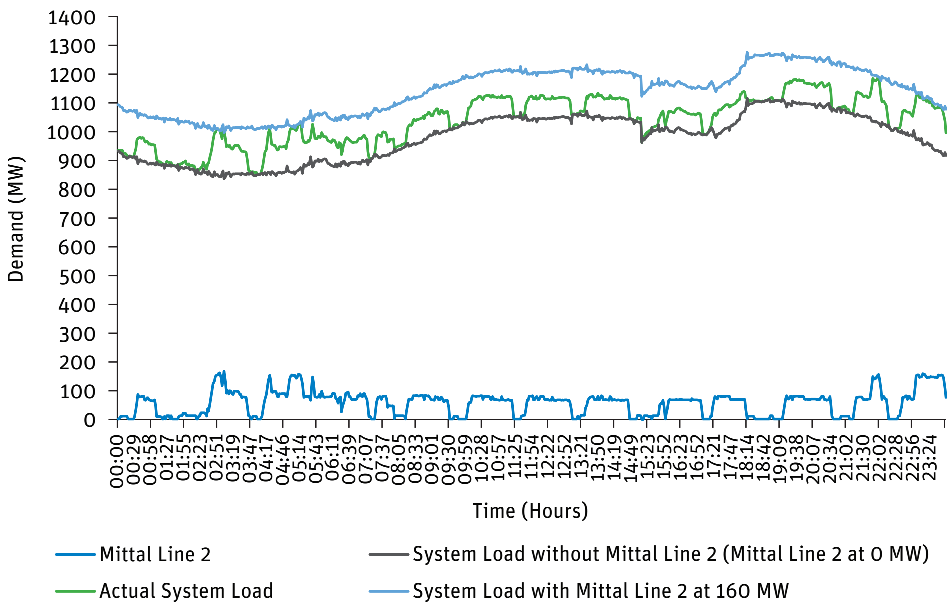
Daily load curves Tue, 4th Dec 2012 – Sat, 8th Dec 2012:



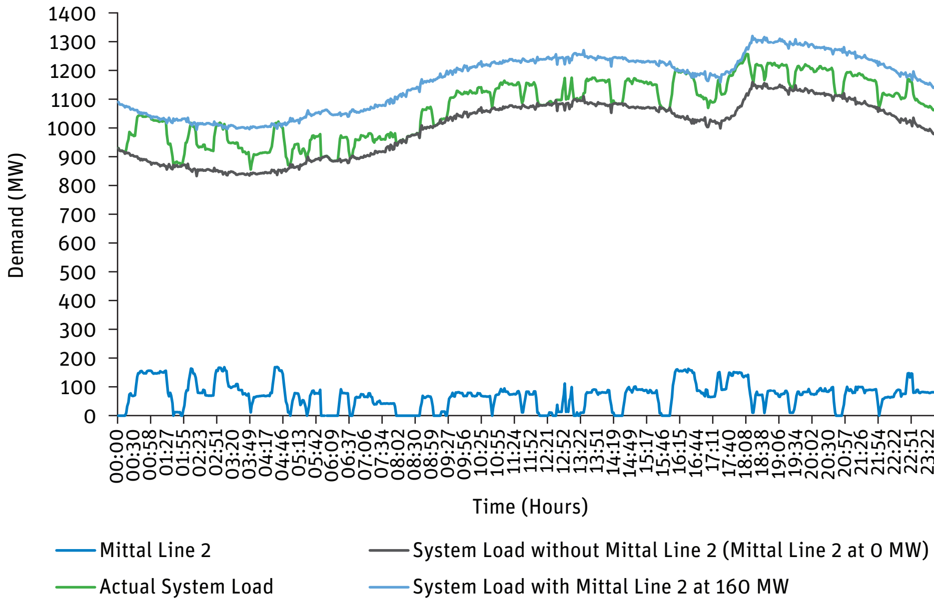
**Instantaneous Demand VS Time – Wednesday 5th December 2012**



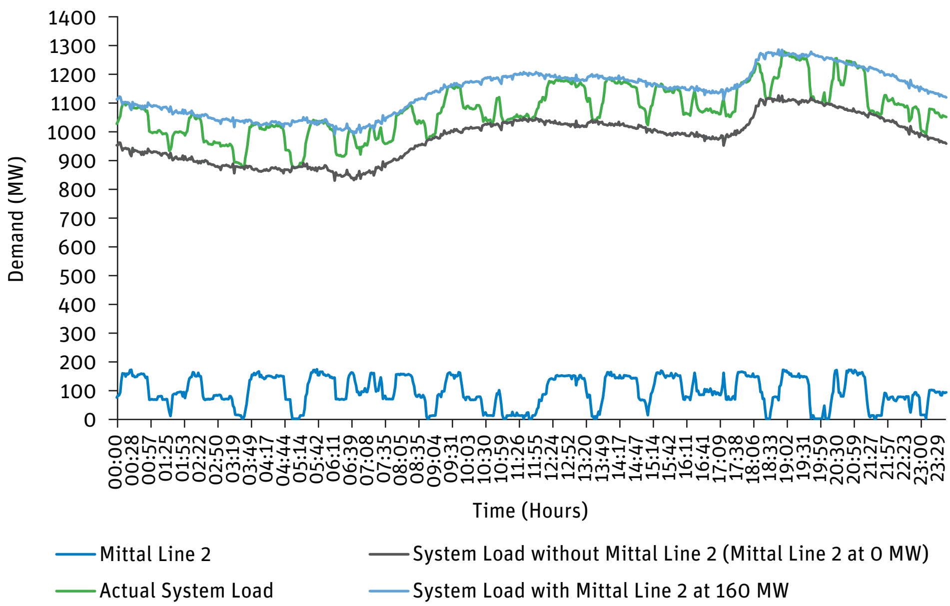

**Instantaneous Demand VS Time – Thursday 6th December 2012**



**Instantaneous Demand VS Time – Friday 7th December 2012**

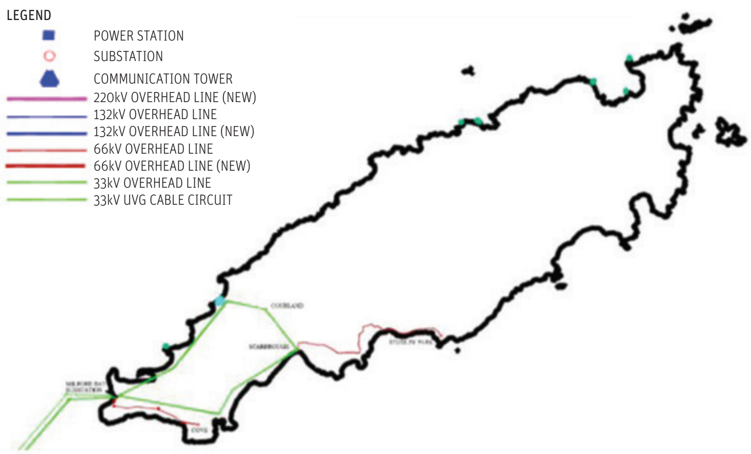



**Instantaneous Demand VS Time – Saturday 8th December 2012**



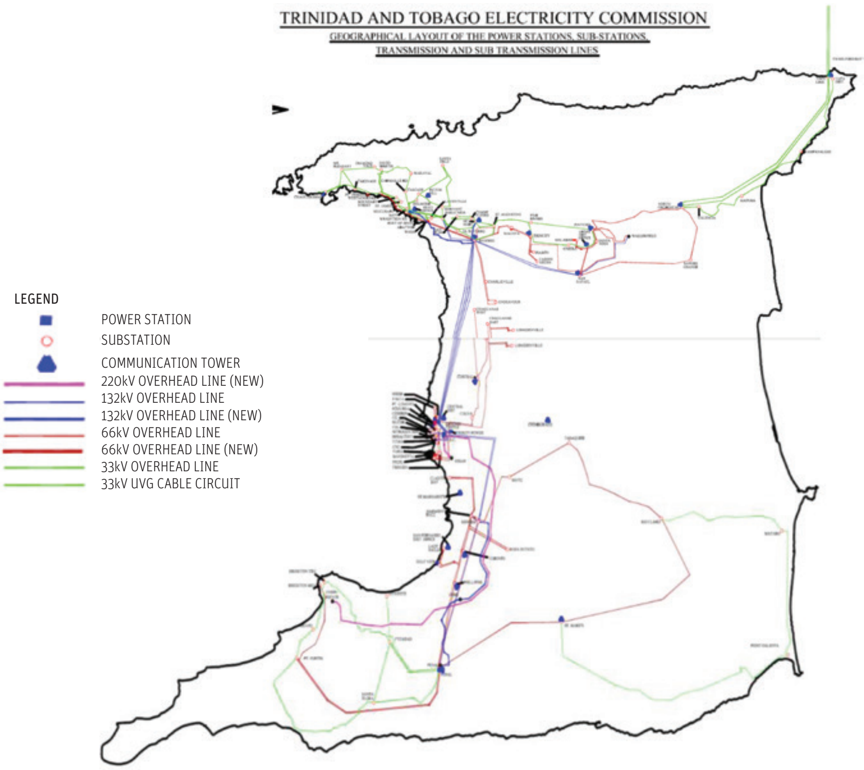
# Appendix B:
## Maps of Transmission and Distribution Grids

### Tobago




*Source*: T&TEC.

## Trinidad




*Source*: T&TEC.

# Appendix C:
## Methodology for Residential Baseline and Savings Estimates

We have few data on the usage of lighting and appliances in T&T, but we do have (i) actual data for the Eastern Caribbean[1] where electricity prices are several times higher and incomes and purchasing power lower than in T&T and (ii) some information for Barbados which is a similar economy to T&T in relation to GDP at Purchasing Power Parity (PPP).[2]

In the Eastern Caribbean (high electricity prices and relatively low incomes) we would expect the uptake of CFLs and energy efficient appliances to be low to moderate. In Barbados (high electricity prices and incomes on par with T&T) we would expect uptake to be better than in the Eastern Caribbean, since customers dissatisfied with their bills would be better able to afford the necessary investments to reduce them. In T&T, with very low electricity prices and high incomes, we would expect uptake to be low.

**Lighting**

Survey results from Grenada and St Lucia indicate that half or more of households use CFLs to satisfy some portion of their lighting needs; on the other hand, a recent IDB study[3] suggests that uptake of CFLs in Barbados is very low (5%). Accordingly, we estimate that CFL uptake in T&T is likely to be low or even very low.

**Air-conditioning**

In 2010, air-conditioning was used in only 5.2% of total households in St. Lucia (Saint Lucia Preliminary Census Report 2010).

In 2000, air-conditioning was used in only 5.9% of households in T&T (2000 National Census Report). Even allowing for increased incomes between 2000 and 2011 (per capita GDP in constant 2000 Dollars rose from $6,311 to $10,329), it is not likely that the penetration

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1 Survey results from the *Eastern Caribbean Energy Labelling Project (ECELP)*, CREDP/GIZ, (2012), http://www.oecs.org/ecelp/downloads/doc_download/5-ecelp-activities-results-jc-20120903.

2 See http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?order=wbapi_data_value_2013+wbapi_data_value+wbapi_data_value-last&sort=desc.

3 *Sustainable Energy Framework for Barbados, Final Report Volume 1*, performed by Castalia and Stantec for Government of Barbados/Inter-American Development Bank, June 2010.

rate is now over 50%. We therefore initially assumed that the average household does not use air-conditioning.

We estimate that about 18% of residential customers now use air-conditioning (see below).

## Residential sector estimates

Residential sector estimates were made with data from the following sources:

- T&TEC residential sales data (kWh sold and number of customers) for 2009 and 2010
- T&TEC appliance usage guide (published in 2008 based on 2007 data)
- T&TEC Business Plan 2011–2016
- T&T 2000 National Census Report.

**Estimation of residential electricity baseline**

We started with the average residential electricity consumption in 2009 of 938 kWh per two months (469 kWh per month) from the T&TEC sales data.

We then looked at the appliance usage guide, a T&TEC list of residential device kWh consumption per two months (T&TEC's billing period) and made a determination, based on information from the 2000 national census (sections on housing stocks & living arrangements, and **Table 7.16**—access to durable goods & services) along with local knowledge, of what appliances might be used by the 'average' household in T&T. In this way, we arrived at a listing of lighting, devices and appliances that had a total usage of 920 kWh per two months, matching the reference value of 938 kWh per two months.

We then categorised the items in this list and totalled the consumption of the items in each category, which provided the initial baseline numbers in **Table 2**, for the 'average' household.

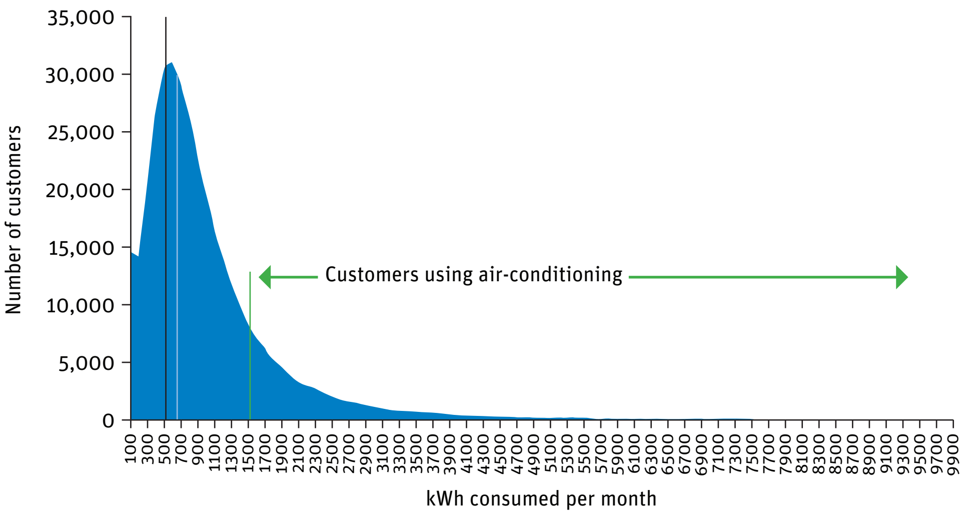
## Air-conditioning

A special consideration then needed to be made for air-conditioning, which does not contribute to consumption of the average household but contributes at higher incomes. Some proportion of electricity is used for air-conditioning in T&T and we needed to estimate what that was in the context of the overall picture. The methodology was as follows:

The T&TEC Business Plan 2011–2016 presents (in Appendix III – Residential Consumption Analysis for 2010) a customer consumption distribution table, which shows the numbers of

**FIGURE 79**

**T&TEC Residential Customer Distribution Curve, 2010**




*Source*: T&TEC.

residential customers using 0–100 kWh a month, 101–200 kWh a month, and so on, across their entire residential customer base. We graphed the distribution up to customers using 10,000 kWh per month (**Figure 79**).

The data show that the mean (arithmetical average) and the median consumption are in adjacent bands. We already have the average; what we are interested in is, what happens above that. Going back to the appliance guide, we make some assumptions about HHs that use air-conditioning. First, we take a single 12,000 BTU/h unit as the average quantum of air-conditioning. We then assume that a HH that uses this unit of a/c is also likely to have a tank-type water heater, some additional lighting and appliances, a better (i.e.: bigger) TV in the living room, and so on. Using such assumptions, we arrive at a consumption figure for the nominal 'air-conditioned' HH of 1,583 kWh per month. We assume that all HHs with consumption above that value on the distribution curve (and some below) will have a/c.

This estimated consumption falls at the top end of the 1501–1600 kWh consumption band. The number of HHs including and above that band is 68,173 or 18.5% of the total HHs.

Based on the above, we conclude that about 18% of households in T&T use air-conditioning in 2010 (compared to 5.9% in 2000, per the census data).

## Estimation of savings

We calculated the potential savings in each of the two residential cases: the households without air-conditioning (based on the 'average' household) and the households with air-conditioning. To calculate potential savings, we simply varied the numbers in the baseline lists based on various assumptions and noted the reduction in consumption that resulted.

### Lighting

To determine lighting savings we assumed all incandescent lamps would be changed to CFLs, so we changed the baseline from $x$ CFLs + $y$ incandescent lamps to $x + y$ CFLs and 0 incandescent lamps and noted the difference.

### Water heating and pumping

We assumed a target penetration of solar water heating of 10% across the board. With appropriate incentives this penetration should be achievable within 3 to 5 years.

### Cooking

Most cooking in T&T is done by LPG (93% of households in 2000) and we assume no significant electricity savings potential exists.

### Refrigeration

The baseline (T&TEC) figures for energy consumption of fridges and freezers are very high; such high figures can be assumed to be due to an existing stock of highly inefficient units coupled with very poor consumer behaviour in using them. We assume that baseline figures of this magnitude are amenable to savings on the order of 60%. We assume that on average, 25% of all refrigeration units in use by 2015 will be energy-efficient units (to Energy Star certification standard or better), with a 60% lower energy consumption than the baseline consumption.

### Laundry

Savings can be achieved by the use of more efficient washers and by changing behaviour—hanging clothes out to dry instead of using dryers. According to the Energy Star website, Energy Star certified, front-loading washers use about 20% less energy (and 35% less water) than regular washers. Hanging clothes out to dry uses 100% less electricity than using a dryer. We assume that 25% of washers will be replaced by efficient units (20% less energy use) over the next 5 years. We assume that average energy savings due to these washers will be 25% per washer, since the reduced water use will save energy on water pumping, and the larger capacity of front load machines means fewer loads to do the laundry. We also assume that households with clothes dryers already use natural drying (which is a Caribbean tradition), but perhaps not as often as possible, so we assume a potential 10% reduction overall in dryer use for these HHs.

### Cooling & Ventilation

The only savings here in households without air-conditioning will come from changes in behaviour (turning off fans in unoccupied bedrooms, for example). We assume a 29% reduction here.

For air-conditioned households, significant savings are available from the replacement of older, inefficient a/c units with newer, higher efficiency units. For the purposes of the estimate, we assume that a 2.1 kW unit replaces a 3.6 kW unit and provides an average 38% savings per year[4]. The problem however with projecting residential air-conditioning savings is that, unlike other significant household devices such as fridges and washing machines, few households have them at the moment—but most households aspire to have them. Based on current data and our estimates, we expect continued growth in the proportion of households that use air-conditioning. Depending on this rate of growth, any savings to be achieved through better efficiency can be entirely offset by new installations.

Our estimate is that about 68,000 households, which are 18% of the total in 2010, are air-conditioned, up from 6% in 2000. If that estimate is correct and if growth continues at the same rate, a further 67,000 air-conditioned households will enter the sector over the next five years. Such an outcome will entirely overwhelm any potential savings from the existing or new installations. Based on this consideration, we estimate no net savings from air-conditioning efficiency in the residential sector over the short to medium term.

### Appliances

To estimate the potential savings available from this wide-ranging category, we looked at each item on the list in terms of its potential for savings based on replacement with a more efficient model and/or consumer behaviour. We assumed the following:

- Laptops – 30% potential saving based on behaviour
- Computers – 40% (behaviour)
- Alarm clock – none
- Vacuum cleaner – none
- Blow dryer – none
- Curling iron – 10 % (behaviour)
- Shaver – none
- DVD player – 3% (phantom load)
- Music stereo system – 3% (phantom load)
- TV – 3% (phantom load)

[4] These savings are proposed for similar unit replacements in Barbados, see *Sustainable Energy Framework for Barbados*, Castalia & Stantec, IDB & Government of Barbados, June 2010.

**Table 47 Energy Saving Cost of EE Technologies**

| Sector Detail | Unit | Residential CFL | Res., Comm. T8 with Electronic Ballast |
|---|---|---|---|
| Tariff rate | US$ | 0.048 | 0.05 |
| Capacity | kW | 0.015 | 0.025 |
| Baseline capacity replaced | kW | 0.06 | 0.04 |
| Energy saved per hr | kWh | 0.045 | 0.015 |
| Investment cost | US$ | 4.38 | 25.78 |
| O&M costs | US$ | 0.00 | 0.00 |
| Operating hours | Hrs. | 8,000 | 30,000 |
| Lifetime energy savings | kWh | 360 | 450 |
| Annual financial savings | US$ | 17.28 | 22.50 |
| Simple Payback period | Years | 0.3 | 1.1 |
| Energy saving cost | US$ per kWh | 0.012 | 0.057 |
| Energy saving cost | US$ per MMBTU | 3.56 | 16.79 |

**Table 48** Estimated Lighting Consumption, Cost & Savings for HDC Houses

| Number of Bulbs in: | House Model | | | Average | Bulbs | | | Average Hours run | | Saved kWh |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | Baseline | Replacement | Saved Watts | Day | Year | Year |
| Bedroom 1 | 1 | 1 | 1 | 1.0 | 60 | 15 | 45 | 3 | 1095 | 49 |
| Bedroom 2 | 0 | 1 | 1 | 0.7 | 60 | 15 | 45 | 3 | 1095 | 49 |
| Bedroom 3 | 0 | 0 | 1 | 0.3 | 60 | 15 | 45 | 3 | 1095 | 49 |
| Kitchen | 1 | 1 | 1 | 1.0 | 60 | 15 | 45 | 3 | 1095 | 49 |
| Living room | 1 | 1 | 1 | 1.0 | 60 | 15 | 45 | 3 | 1095 | 49 |
| Bathroom 1 | 1 | 1 | 1 | 1.0 | 60 | 15 | 45 | 1 | 365 | 16 |
| Bathroom 2 | 0 | 0 | 1 | 0.3 | 60 | 15 | 45 | 1 | 365 | 16 |
| Porch | 1 | 1 | 1 | 1.0 | 60 | 15 | 45 | 8 | 2920 | 131 |
| Back entrance | 1 | 1 | 1 | 1.0 | 60 | 15 | 45 | 8 | 2920 | 131 |
| Total | 6 | 7 | 9 | 7.3 | | | | | | 542 |

| No of homes | 6,500 |
|---|---|
| Cost per bulb | TT$ 28/ US$ 4.37 |
| Total cost of bulbs | 208,542 |
| Total savings, kWh | 3,523,163 |
| Value of Savings, US$ | 169,112 |
| Simple Payback period, years | 1.2 |

# Appendix D: Highlights of the “My Energy, My Responsibility” Campaign

(Information supplied by MEEA Community Liaison Officer, August 2013)

## Campaign Overview

The local energy sector contributes the largest percentage to our Gross Domestic Product but, based on a recent survey commissioned by the MEEA, it is clear that the average citizen is unaware of even basic information about this sector that affects their lives in significant ways. This informational campaign is ground-breaking in that no prior attempts have been made on such a large scale to inform our citizenry about how the energy sector powerfully impacts upon their quality of life. In one sense, this campaign aims to rectify this information gap while also promoting EE and encouraging use of renewable forms of energy in ways that are both practical and expenditure-reducing for our population. This has become especially important within the context of declining traditional energy sources, the partial removal of the subsidy from premium gasoline and the opening up of Renewable Energy usage. Bridging this information gap is especially important for our young people who, given adequate information, may now view the energy sector as a potential employer, whereas before, they may have found it cloaked in mystery and therefore inaccessible.

The campaign is a useful resource across the energy sectors’ corporate social responsibility programs as the information provided broadly covers the entire sector and also targets key audiences, primary and secondary school students. The program also generates additional goodwill among peripheral audiences of teachers, school principals and parents of participating students by way of the branded tokens and the interest generated in the energy sector via the state-of-the-art, interactive website, that serves as an informational hub for the campaign.

The educational campaign will be rolled out in three phases and will target school-aged children between eleven (11) and twelve (12) years old throughout the country. Each phase will run for a three-month period during which time, the Ministry expects to visit twenty-five (25) schools across T&T, complemented by the communication campaign featured via the print and electronic media.

## Phase 1:

### My Energy: From where does it come?

The first phase of the campaign seeks to make the public aware about the importance of our local energy sector in their everyday lives. A recently conducted omnibus survey indicated that most people knew little of how our oil and gas sectors affect their quality of life in basic and significant ways. This phase features thought-provoking statements that link our everyday usage of energy with our energy sources as well as their contribution to our economy, thus sensitizing the population to the significance of the local energy sector. The campaign's theme, "My Energy, My Responsibility" seeks to introduce the idea that each individual is responsible for the wise usage of our resources with campaign materials directing audiences to the informational hub, www.myenergytt.com.

Supplementing the media communication campaign, some eighty teachers in T&T were trained in the delivery of lessons on Renewable Energy and Energy Efficiency, so as to further sensitize their students on energy issues. These teacher-training sessions, which were held over one week, were facilitated by UWI, UTT and MIC.

## Phase 2:

### Energy Efficiency begins with me

Having educated the public about the significance of the local energy sector in their daily living, the second phase seeks to encourage more energy-efficient practices among the population. T&T has been labelled as one of the least energy efficient countries in the world. Due to the availability and relatively low cost of electricity, our energy is often taken for granted by our population. This campaign segment makes the individual directly responsible for conservation of energy. It focuses on the fact that the population generally takes our energy for granted, resulting in energy inefficiency, and takes into account that our energy comes largely from finite resources that are heavily subsidized by the State. The campaign seeks to empower individuals by demonstrating how small actions can make a big difference when approached collectively. In addition to the media communication campaign, this phase will also be highly interactive and activity based; it will be complemented by the schools' outreach campaign.

## Phase 3:

### Renewable Energy: Share the Power of Nature

The third phase of our campaign highlights the benefits and importance of using renewable forms of energy locally, specifically solar and wind energy. This phase not only highlights the Government’s initiatives and tax incentives for both users and investors in Renewable Energy but also seeks to educate and inspire public participation in a national move towards Renewable Energy as a viable source. This phase also incorporates a media communication component and interactive events reinforced by the schools’ outreach programme.

*Teaching/Tools*

The MEEA has already partnered with the National Energy Corporation (NEC) to present the campaign to seven schools in their fence-line communities of La Brea, Rousillac, Mayaro and Guayaguayare.

During the interactive sessions, the participating students are engaged via PowerPoint presentations, video clips, and mini quizzes. They are directed to the core website, www.myenergytt.com, for more detailed information and are also given the opportunity to ask questions directly and leave their comments, for which they are rewarded with branded MEEA tokens. During the school visits, students also have the opportunity to view the Toyota Prius, an energy-efficient vehicle purchased by the Ministry.

# Appendix E:
## Estimate of Costs & Benefits of 150% Tax Allowance Program

Our estimation of the likely costs and benefits of the 150% tax allowance program starts with a review of the electricity sales to the various tariff categories, from Commercial B through to Very Large Industrial E5. These sales are then categorized in accordance with the customer categories used in the tax allowance program (**Table 49**).

We then estimate the likely uptake of the program by its prospective customers. We assume that, over the first five years, no uptake will occur in the smallest commercial group (i.e.: commercial customers having a demand of up to 50 kVA); 200 customers in the second group (having a power demand of 51 to 4,000 kVA), and so on, up to a total of 224 customers. This is a modest rate of uptake and it is considered to be achievable under the local circumstances (very low electricity prices with corresponding low financial incentive for implementing EE audits). These estimates are shown in **Table 50**.

**Table 51** shows the costs (in foregone tax revenues) of the program, based on an estimated expenditure per customer, for procurement of the ESCO and implementation of the recommended energy saving intervention.

Table 52 then shows the benefits in energy, cost saved and $CO_2$ emissions avoided, assuming 15% savings in the first year, followed by savings of 5%, 3%, 2% and 1% (compared to baseline) in subsequent years.

**Table 49** **Commercial and Industrial Tariff Categories and Sales (2011)**

| Category | | Demand Range, kVA | | Consumption Range, kWh | | Customers | | 150% Allowance Category | Sales, GWh by | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min Demand | Max Demand | Minimum | Maximum | Number | % | | Tariff Category | 150% Allowance |
| Commercial | B | | 50 | | | 38,336 | 92% | | 773 | 773 |
| Commercial | B1 | 50 | 350 | | | 35 | 0% | | 2 | 1,882 |
| Small Industrial | D1 | 50 | 350 | | | 2,320 | 6% | | 512 | |
| Medium Industrial | D2 | 350 | 4,000 | | | 772 | 2% | | 1,368 | |
| Large Industrial | D3 | 4,000 | 25,000 | | | 14 | 0% | | 460 | 1,353 |
| Large Industrial | D4 | 4,000 | 25,000 | | | 19 | 0% | | 892 | |
| Large Industrial – Standby | D5 | 4,000 | | | | 1 | 0% | | 1 | |
| Very Large Load | E1 | 25,000 | | | 25,000,000 | 3 | 0% | | 321 | 1,592 |
| Very Large Load | E2 | 25,000 | | 25,000,000 | 50,000,000 | 0 | 0% | | 401 | |
| Very Large Industrial | E3 | 25,000 | | 50,000,000 | 75,000,000 | 0 | 0% | | 0 | |
| Very Large Industrial | E4 | 25,000 | | 75,000,000 | 100,000,000 | 0 | 0% | | 0 | |
| Very Large Industrial | E5 | 25,000 | | 100,000,000 | | 1 | 0% | | 870 | |
| | | | | | | 41,501 | 100% | | 5,600 | 5,600 |

*Source*: T&TEC.

**Table 50** **Estimates of customer uptake and expenditure on the 150% Tax allowance Program**

| Programme Activity | Commercial (B)<br>Up to 50 kVA | Commercial, Small & Medium Industrial<br>51 to 4,000 kVA | Large Industrial<br>4,001 to 25,000 kVA | Very Large Industrial<br>25,000+ kVA |
|---|---|---|---|---|
| **Typical Business Description** | **Small enterprise, family-owned & operated** | **Small - medium hotel or other commercial enterprise** | **Commercial/ manufacturing enterprise** | **Large oil & gas sector production company** |
| **Expenditure Estimates:** | | | | |
| Level 3 Energy Audit | 5,000 | 5,000 | 10,000 | 25,000 |
| Purchase of equipment on approved list | 35,000 | 60,000 | 100,000 | 500,000 |
| Installation of equipment on approved list | 20,000 | 40,000 | 75,000 | 250,000 |
| Consulting/Technical assistance for project implementation | 7,000 | 10,000 | 17,500 | 60,000 |
| **Total Estimated Expenditure, US$** | **$67,000** | **$115,000** | **$202,500** | **$835,000** |
| **Total Allowable Expenditure, US$*** | **$156,000** | **$313,000** | **$313,000** | **$1,560,000** |
| Estimated 150% Allowance Amount, US$ | 100,500 | 172,500 | 303,750 | 1,252,500 |
| Total number of customers in the sector | 38,336 | 3,127 | 34 | 4 |
| Estimated No of Customers taking up the Allowance: | | | | |
| Number of customers in the programme year 1 | 0 | 10 | 3 | 0 |
| Number of customers in the programme year 2 | 0 | 15 | 4 | 1 |
| Number of customers in the programme year 3 | 0 | 25 | 5 | 1 |
| Number of customers in the programme year 4 | 0 | 50 | 5 | 0 |
| Number of customers in the programme year 5 | 0 | 100 | 5 | 0 |
| **Total Customers taking up** | **0** | **200** | **22** | **2** |
| | 0% | 6% | 65% | 50% |
| | 0.54% | | | |

* Based on expenditure cap proposed by the ESCO Certification Committee.

**Table 51** Cost (Taxes foregone) of Activity under 150% Tax Allowance Program

| Programme Activity | Commercial (B) Up to 50 kVA | Commercial, Small & Medium Industrial 51 to 4,000 kVA | Large Industrial 4,001 to 25,000 kVA | Very Large Industrial 25,000+ kVA | |
|---|---|---|---|---|---|
| Total # of businesses in the category | 38,336 | 3,127 | 34 | 4 | |
| Average expenditure per business | $67,000 | $115,000 | $202,500 | $835,000 | |
| **Programme Uptake & Costs (US$):** | | | | | |
| **Year 1** | | | | | |
| Customers | 0 | 10 | 3 | 0 | Total Cost Year 1 |
| Cost (Taxes foregone) | 0 | 287,500 | 151,875 | 0 | $439,375 |
| **Year 2** | | | | | |
| Customers | 0 | 15 | 4 | 1 | Total Cost Year 2 |
| Cost (Taxes foregone) | 0 | 431,250 | 202,500 | 208,750 | $842,500 |
| **Year 3** | | | | | |
| Customers | 0 | 25 | 5 | 1 | Total Cost Year 3 |
| Cost (Taxes foregone) | 0 | 862,500 | 329,063 | 208,750 | $1,400,313 |
| **Year 4** | | | | | |
| Customers | 0 | 50 | 5 | 0 | Total Cost Year 4 |
| Cost (Taxes foregone) | 0 | 1,653,125 | 354,375 | 104,375 | $2,111,875 |
| **Year 5** | | | | | |
| Customers | 0 | 100 | 5 | 0 | Total Cost Year 5 |
| Cost (Taxes foregone) | 0 | 3,306,250 | 417,656 | 104,375 | $3,828,281 |
| **Grand Total Cost Years 1–5** | | | | | **$8,622,344** |
| Total Corporate Tax Revenue 2011, US$ | | | | 1,340,140,054 | |
| | | | | | **0.64%** |

**Table 52** **Estimated Benefit of Activity under the 150% Tax Allowance Program**

| Programme Activity | Commercial (B) | Commercial, Small & Medium Industrial | Large Industrial | Very Large Industrial | |
|---|---|---|---|---|---|
| | Up to 50 kVA | 51 to 4,000 kVA | 4,001 to 25,000 kVA | 25,000+ kVA | |
| Total # of businesses in the category | 38,336 | 3,127 | 34 | 4 | |
| Baseline Annual kWh Consumption | 773,000,000 | 1,882,000,000 | 1,353,000,000 | 1,592,000,000 | |
| Baseline average annual kWh consumption per customer | 20,164 | 601,855 | 39,794,118 | 398,000,000 | |
| **Programme Customers & Benefits:** | | | | | |
| **Year 1** | | | | | |
| No of Customers | 0 | 10 | 3 | 0 | Total Benefit Year 1 |
| Baseline Average annual kWh consumption | 0 | 6,018,548 | 119,382,353 | 0 | |
| kWh Saved per annum (15%) | 0 | 902,782 | 17,907,353 | 0 | 18,810,135 |
| **Year 2** | | | | | |
| No of New Customers | 0 | 15 | 4 | 1 | Total Benefit Year 2 |
| Baseline Average annual kWh consumption | 0 | 6,018,548 | 119,382,353 | 0 | |
| kWh Saved per annum (5%) | 0 | 300,927 | 5,969,118 | 0 | 6,270,045 |
| **Year 3** | | | | | |
| No of New Customers | 0 | 25 | 5 | 1 | Total Benefit Year 3 |
| Baseline Average annual kWh consumption | 0 | 6,018,548 | 119,382,353 | 0 | |

(*continued on next page*)

**Table 52 Estimated Benefit of Activity under the 150% Tax Allowance Program** *(continued)*

| Programme Activity | Commercial (B) Up to 50 kVA | Commercial, Small & Medium Industrial 51 to 4,000 kVA | Large Industrial 4,001 to 25,000 kVA | Very Large Industrial 25,000+ kVA | |
|---|---|---|---|---|---|
| kWh Saved per annum (3%) | 0 | 180,556 | 3,581,471 | 0 | 3,762,027 |
| **Year 4** | | | | | |
| No of New Customers | 0 | 50 | 5 | 0 | Total Benefit Year 4 |
| Baseline Average annual kWh consumption | 0 | 6,018,548 | 119,382,353 | 0 | |
| kWh Saved per annum (2%) | 0 | 120,371 | 2,387,647 | 0 | 2,508,018 |
| **Year 5** | | | | | |
| No of New Customers | 0 | 100 | 5 | 0 | Total Benefit Year 5 |
| Baseline Average annual kWh consumption | 0 | 6,018,548 | 119,382,353 | 0 | |
| kWh Saved per annum (1%) | 0 | 60,185 | 1,193,824 | 0 | 1,254,009 |
| **Grand Total kWh Savings Years 1–5** | | | | | **32,604,234** |
| **Savings US$** | | | | | **1,630,212** |
| Savings TT$ | | | | | 10,433,355 |

# Appendix F:
# Street Lighting Pilot Project

A 2012 study of the economics of various street lighting types (ceramic metal halide, magnetic induction and LED) vs. the default type (high pressure sodium) for street lighting in Portland, Oregon[1] indicates that although LED lighting products provide the greatest annual cost savings, their high initial cost result in payback periods of up to 23 years (the payback period of the induction lamps was over 30 years). The electricity price used in the analysis was 9 US$ cents per kWh, which is much higher than the street lighting rate in T&T.

Using this example and factoring in T&TEC's lower tariff rate (which will increase the payback period) and a higher total cost of ownership for T&TEC's existing lighting stock of low pressure sodium lamps[2] (which will make payback more attractive), we are still left with an unattractive financial investment. In such a situation, it is difficult to recommend the wholesale replacement by T&TEC of the existing low-pressure sodium lamps with LEDs, in the absence of specific financial subsidies for same.

[1] *Demonstration Assessment of LED Roadway Lighting Host Site: NE Cully Boulevard, Portland, Oregon* June 2012. Prepared by: Pacific Northwest National Laboratory for Solid-State Lighting Program Building Technologies Program Office of Energy Efficiency and US Department of Energy.

[2] Ninety five percent of street lighting in T&T is low pressure sodium (LPS). LPS lighting is 18% to 33% more efficient than HPS, but only last about two thirds as long. Based on the data presented in the Portland study the total cost of operation of HPS is estimated to be approximately 15% lower than LPS.

# Appendix G:
# Guidelines for Energy Audits

## Background & Introduction

The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) defines three levels of energy audits having increasing complexity.[1] This document refers to the performance of *Level 2 audits*, with the specified component activities:

- Energy end-use breakdown;
- Detailed analysis;
- Costs & savings for energy efficiency measures;
- Operations & maintenance changes.

## Process and scope of the energy audit

The auditor is encouraged to be guided by the ISO 50001 energy management standard where applicable in the performance of the audit. The auditor will:

- Conduct a preliminary energy analysis;
- Conduct the walk-through survey;
- Measure key plant & equipment operating parameters (where applicable);
- Identify low-cost/no-cost recommendations;
- Identify capital improvements and their estimated costs;
- Analyze capital measures (costs, savings and payback);
- Meet with owner/operator to review recommendations.

The **scope of the analysis** includes the following:

a. *Data collection*
   The auditor will collect the relevant information and data on the building's characteristics and energy use. Where appropriate, the auditor will install appropriate instrumentation to measure and monitor the performance of specific systems, if possible during typical operating conditions. Information to be collected and/or reviewed includes:

[1] The reference document is: Procedures for Commercial Building Energy Audits. Second Edition, ASHRAE.

- Monthly utility or supplier billing data (electricity, gas, water) for the most recent 24 months if available;
- List of energy-consuming appliances and equipment, their load capacity ratings, an estimate of their typical duration of use and their energy consumption;
- Building area, with a distinction between air-conditioned and non-air-conditioned areas. As-built drawings or direct measurement should be used to provide this information;
- Building shape, orientation, location and building envelope details and condition;
- Description of main electrical, electronic and mechanical equipment and systems and their condition and performance;
- Description of controls and automation types, condition and status;
- Process operating procedures if applicable;
- Building occupant characteristics (what groups of people occupy the building—internal staff, external customers, etc.) and building functions (time of use, number of beds, occupancy rate, etc.);
- Records of building systems' changes and problems in overall operation, including increasing electrical loads, alterations, additions or use changes and concerns over power or environmental quality.

The auditor will liaise as necessary with building owners, operators and service & support personnel (including equipment suppliers) to obtain specific information where necessary on system operations and interfacing with proposed retrofits.

b. *Deliverables*
The auditor will provide:

- A description of the building, building systems and operation;
- A description of the main energy-using equipment in the building (age, model type, capacity, hours of use etc., where applicable);
- A building energy performance index (BEPI)—equivalent kilowatt-hours per square meter per year, for each building in the facility if applicable and possible;
- A building energy cost index (BECI) for all energy types in dollars per square meter per year;
- An end-use breakdown of all energy consumption;
- A consumption profile for each energy type (for the most recent 24 months if available), with an analysis of peaks and variations based on occupancy, usage mode or other variation factors;
- A list of energy conservation opportunities (ECOs) based on typical retrofits and the technologies known to be readily available on the market. These ECOs shall be characterized as:

    - Opportunities to reduce the energy demand: passive solutions such as reduction of solar gain through external protection, insulations, reorganization of internal uses, etc.;
    - Opportunities to reduce energy consumption through improvements in the technical efficiency of the building's energy systems, equipment and appliances;
    - Opportunities to reduce energy consumption through changes in occupant behaviour;
  - Recommendations for substituting energy sources (e.g.: solar instead of electric water heating);
  - Estimates of investment costs, calculations of energy savings and a simple payback analysis for all ECOs, recommended combinations of ECOs and energy source substitution;
  - Suggestions for improvements in operating procedures and establishment of an Energy Management System in appropriate cases.

## Suggested structure of the energy audit report

The report should include:

### Title page according to the attached format

### Table of contents

**Executive summary** (see table formats below)

Information drawn from the more detailed information in the full report, preferably in plain non-technical language, including:

- Summary of baseline energy consumption;
- Summary of results:
  - Assessment of energy-consuming systems;
  - Identification of Energy Conservation Opportunities (ECOs) and the estimated energy and cost savings associated with each option, along with the related cost of implementing the measures and the expected payback period;
- Recommendations summarized in table form.

## Introduction

The Introduction should include:

- Audit Objectives: a clear statement that defines the scope of the energy audit in clear and measurable terms;

- Background Information: a description of the location of the facility where the audit has been conducted, as well as information regarding facility layout, products/services provided or produced, operating hours including seasonal variations (if applicable), number of permanent staff working in the building and relevant results of previous energy-saving initiatives.

## Audit activity and results

This section should make reference to:

- Description of the audit methodology and execution (techniques—e.g.: inspection, measurements, calculations, analyses and assumptions);
- Observations on the general condition of the facility and equipment;
- Identification of an energy consumption baseline in terms of energy types, units and costs for the facility/system being assessed;
- Results of the audit including identification of ECOs, the estimated energy and cost savings associated with each measure as well as the required investment and payback period associated with each of the ECOs identified.

## Recommendations

This section should list and describe the recommendations that flow from the identification of ECOs and may include details concerning implementation (e.g. need for major intervention in the building envelope in case of new installations). An explanation should be provided for recommending or not recommending each ECO identified in the results.

## Appendices

Appendices will include background material essential for understanding the methodology, calculations and recommendations and may include:

- Facility layout diagrams;
- Process diagrams (in exceptional cases);
- Reference graphs used in calculations;
- Data sets too large to fit within the body of the report.

If requested, a draft monitoring & evaluation plan to guide the building owner in post-implementation monitoring and evaluation of the facility, is to be included.

## Sample Executive Summary Tables

**Table 1** Baseline Energy Use and Cost

| Audited System Description | Electricity | | LPG | | Other (Specify) | | Total Cost |
|---|---|---|---|---|---|---|---|
| | Units (kWh/yr) | Cost | Units (m³/yr) | Cost | Units | Cost | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| TOTAL | | | | | | | |

**Table 2** Energy end-use allocation

| End Use | kWh | BTU | % |
|---|---|---|---|
| Internal lighting | | | |
| External lighting | | | |
| Cooling (AC, refrigeration, etc.) | | | |
| Heating (specify process heat, hot water, etc.) | | | |
| Pumps | | | |
| Fans | | | |
| Office equipment & appliances | | | |
| Miscellaneous equipment | | | |
| TOTAL | | | |

**Table 3** Recommendations

| No | Description | Potential Savings | | | | Cost to implement ($) | Simple payback (yrs) |
|---|---|---|---|---|---|---|---|
| | | Electricity (kWh/yr) | LPG ($m^3$/yr) | Other energy (specify type and units) | Cost savings ($/yr) | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| TOTAL | | | | | | | |

# Appendix H: International Examples of Market-based Financial Mechanisms for EE and RE Measures in the Residential Sector

The following provides information on international programs that have been successful in facilitating the implementation of EE and RE measures in the residential sector.

Although most programs are orientated towards housing, this list can provide a source of ideas, which can be investigated at will, about finance options to accompany the 150% Tax Allowance already set up by the ESCO committee.

## Mexico

### Hipoteca Verde

*Green Mortgage is a housing finance scheme developed by the Institute for the National Workers' Housing Fund (INFONAVIT) to encourage the use of energy-efficient systems and technologies for lower-income households. Families purchasing homes with INFONAVIT are given an additional 'green' mortgage (a credit on top of the actual mortgage credit) of up to US$1,250, to cover the cost of additional eco-technologies. The initiative aims to encourage developers to build homes with energy-saving materials and technologies, and the low-rate mortgage given enables families to save more on their utility bills than the increase in their monthly mortgage payment. To date, over 900,000 Green Mortgage credits have been granted, benefiting over three million people*. (WORLDHABITATAWARDS).

http://www.cmic.org/mnsectores/vivienda/2008/infonavit/hipotecaverde.htm.

## USA

### Property Assessed Clean Energy (PACE) Programs

*In the Property Assessed Clean Energy (PACE) Programs, EE upgrades are financed through long-term loans that are repaid via an annual property tax assessment. Loans under PACE programs are* *secured by placing an additional lien on a property that is senior to the existing mortgage debt. PACE financing programs are particularly well suited for residential EE projects but are also applicable to commercial facilities.* (EU, 2010).

http://energycenter.org/policy/property-assessed-clean-energy-pace.

### Clean Energy Works Program

*In 2009, this model was introduced via the Clean Energy Works Program (CWEP) in Portland (Oregon). Under CWEP, single-family residential homeowners can receive 100% financing to implement a wide range of EE measures. Loans are provided at attractive levels of fixed interest rates and are amortized over a 20-year period. Customers repay loans through their regular utility bill.* (EU, 2010).

http://www.cleanenergyworksoregon.org/home/.

### San Diego Gas and Electric Program

*The utility can provide its customers with an unsecured loan that covers 100% of EE equipment and installation costs. The customer then pays the loan via an on-the-bill surcharge that is added on to the regular utility bill. Energy savings realized from the EE project typically equal or exceed the monthly loan repayment obligation. This is not a new concept, with utilities in California, Connecticut, Rhode Island, Massachusetts, and other states having offered different variations of on-the-bill repayment schemes for more than 10 years.*

http://www.sdge.com

### Rural Energy Savings Program

*Innovative idea developed by electric cooperatives in South Carolina to address the special challenges and opportunities facing rural communities to save energy, cut household utility bills, and reduce greenhouse gas emissions. The program supports stable, high-skilled jobs and keeps more dollars in the local economy. Through the program, residential EE improvements are financed with low-cost loans that are repaid through co-op members' electric bills (a process known as "on-bill financing"). The "Help My House" pilot for this program produced very encouraging results. Participants' energy bills were cut by 34 percent, saving an average of US$ 288 per home and year after loan payments.* (EESI).

http://www.eesi.org/projects/rural-energy-savings-program.

## TUNISIA

### PROSOL

*PROSOL program, launched in 2005, is based on an innovative mechanism designed to address key financial, technical and organizational barriers against the development of the market for solar water heater. Thanks to this mechanism, PROSOL has initiated a real market transformation of the SWH in Tunisia.* (ADEME, 2010).

http://climatepolicyinitiative.org/wp-content/uploads/2012/08/Prosol-Tunisia-SGG-Case-Study.pdf.

## PORTUGAL

### Efficiency Credit Scheme

*The Portuguese government has, as part of its National EE Action Plan 2015, set up the Efficiency Credit scheme. This scheme, set up in 2008, offers personal low-interest rate finance for households installing a variety of low-carbon measures. Loans need not be secured, but the interest rate on secured loans is half that for unsecured loans. The scheme is delivered through a number of banks with the Portuguese government supplying funds for interest subsidy. Furthermore, there is a programme to replace 1 million large electric appliances (white goods), providing a 50 Euro bonus for the replacement with an A+ appliance and 100 Euro for an A++ appliance; old appliances must be handed over for recycling.* (EU, 2010).

http://www.iea.org/policiesandmeasures/energyefficiency/?country=Portugal.

## IRELAND

### Better Energy Homes

*The Irish Government wishes to encourage people to improve the energy performance of their homes by incentivising the cost of installing various upgrade measures. The Better Energy Homes scheme provides assistance to homeowners to reduce energy use, costs and greenhouse gas emissions and improve the comfort levels within their home.*

*The objectives of the scheme are to:*

- *Support homeowners in making intelligent choices to improve the energy performance of their home;*
- *Reduce energy use, costs and greenhouse gas emissions*
- *Build market capacity and competence by driving contractor standards and quality*
- *Stimulating market innovation.*

*The incentive is in the form of a Cash Grant. Cash grants are fixed, irrespective of home size, though where actual expenditure is lower than the grant value only the lower amount will be paid. Payment is by Electronic Funds Transfer to the applicant's bank*.(EU, 2010).

http://www.seai.ie/Grants/Better_energy_homes.

### Better Energy Warmer Homes Scheme

*This scheme aims to improve the EE and comfort conditions of homes occupied by low-income households. It engages regional community-based organisations to acquire and apply the skills to carry out the work—which includes attic insulation, draught proofing, lagging jackets, energy efficient lighting, cavity wall insulation and energy advice*. (EU, 2010).

http://www.seai.ie/Grants/Warmer_Homes_Scheme.

## SPAIN

### Plan Renove de Electrodomésticos

*El Plan Renove de Electrodomésticos was one of the measures under the Second Action Plan for Energy Saving and EE 2008–2012. The objective of Plan Renove was to encourage the substitution of old domestic appliances which were produced before the energy labelling became mandatory with new energy-efficient ones*. (IDAE).

http://www.planrenove.info.

## UK

### Pay as You Save

*In early 2010, the UK government launched the "Warm homes, greener homes" initiative, which includes a new form of 'Green Finance' based on a Pay-as-You-Save model (PAYS). The government* *expects this to provide approximately one third of the financing for major insulation and support upfront payments for any energy saving eco-upgrade with pay-back through energy savings or micro-generation revenue. Instead of paying for the eco-upgrade upfront, householders will be able to get finance at term, such that householders will be able to cover the cost of the installation out of bill savings, and usually with a further monthly surplus as well.*

*The finance itself would come from the private sector, as banks and others provide funding for the eco-upgrade, secured against future savings on bills (EU, 2010).*

*Five partners, from both public and private sectors, were selected through a competitive tender process, to run pilot schemes.*[1] *Each proposed and implemented pilots, with different delivery approaches, broadly based on the following key principles being offered to householders:*

- *Pay-As-You-Save funding of up to £20,000 per property for energy saving measures.*
- *Free energy assessment to establish and recommend suitable measures and on-going advice to help householders reduce their energy consumption.*
- *Repayment periods up to a maximum of 25 years.*
- *Zero percent interest rate.*
- *Optional householder contribution.*
- *Feed-in Tariff (FIT) benefits when installing solar PV panels.*

http://www.energysavingtrust.org.uk

## Green Deal

*Green deal is a scheme that can help making energy-saving improvements to residential homes or businesses, for example:*

- *Insulation – e.g. solid wall, cavity wall or loft insulation*
- *Heating*
- *Draught-proofing*
- *Double glazing*
- *RE generation – e.g. solar panels or heat pumps*

*You can make energy-saving improvements to your home or business without having to pay all the costs in advance.*

[1] Department of Energy and Climate Change and the Energy Saving Trust, Home Energy Pay As You Save Pilot Review, September 2011

*You have to pay back the cost of the improvements over time because the Green Deal is a loan, not a grant. However, the savings on your energy bills after you've made the improvements should cover the repayment of the loan.*

*You can also choose to pay for improvements in advance using Green Deal providers and certified installers*. (Green Deal).

http://www.energysavingtrust.org.uk/Take-action/Find-a-grant/Green-Deal-and-ECO.

# Appendix I:
## Current Electricity Generation Costs for On-shore Wind Farms

### LCOE of on-shore wind energy

| | | Minimum | | Average | | Maximum | |
|---|---|---|---|---|---|---|---|
| | | 2010 US$ | 2012 TT$ | 2010 US$ | 2012 TT$ | 2010 US$ | 2012 TT$ |
| ICC | per kW | 1,800 | 12,211 | 2,000 | 13,568 | 2,200 | 14,925 |
| AOE | per MWh | 10 | 67.8 | 10 | 67.8 | 10 | 67.8 |
| Capacity factor | % | 38 | 38 | 38 | 38 | 38 | 38 |
| Discount rate | | 4.75 | 14.55 | 14.55 | 14.55 | 14.55 | 14.55 |
| Operational life | Years | 25 | 25 | 20 | 20 | 15 | 15 |
| CRF: | | 0.069 | 0.151 | 0.156 | 0.156 | 0.167 | 0.167 |
| Q | | 3,328.80 | 3,328.80 | 3,328.80 | 3,328.80 | 3,328.80 | 3,328.80 |
| LCOE 2012: | per MWh | 47.4 | 620 | 103.6 | 703 | 120.6 | 818 |
| LCOE 2015: | per MWh | 43.9 | 574 | 98.7 | 670 | 118.2 | 802 |
| LCOE 2017: | per MWh | 38.9 | 509 | 91.7 | 622 | 114.6 | 777 |
| Inflation | 9,36% | | | | | | |
| $d_n$ | 4,75% | Quoted by central bank | | | | | |
| $d_r$ | –4,22% | | | | | | |
| $d_n$ | 0,15 | (assume central bank quotes real value) | | | | | |

# Appendix J:
# Solar Water Heating

## The Barbados Case

Barbados has a successful SWH manufacturing industry since the 1970's. The pioneering company, Solar Dynamics Ltd, had numerous challenges, but was able to overcome these and develop a successful industry with high quality products.

Barbados is facing the issue of high fossil fuel costs and heavy reliance on imported fossil fuels. Through favourable Government incentives (described in **Table 53**), competition in the manufacturing business evolved with two other companies entering the market. **Figure 80** shows the graphical chronology of annual SWH installations in Barbados, highlighting significant economic landmarks, and demonstrating the effects of fiscal incentives introduction and also their removal on the growth.

In addition to the incentives listed above, the Government increased the duties on gas and electric water heaters. The oil crisis of 1973 sparked off the interest in and development of

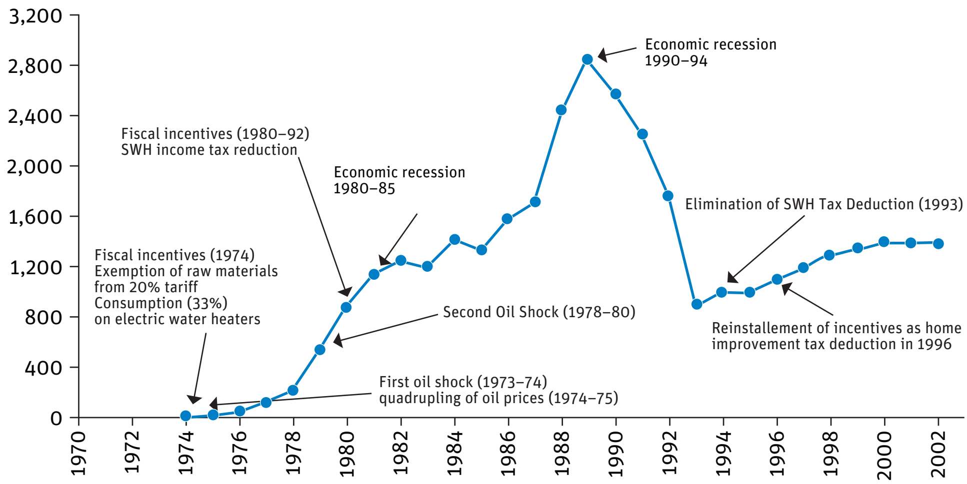
**Table 53 SWH incentives in Barbados**

| Government Incentives | Details |
|---|---|
| 1974<br>Fiscal Incentive Act of 1974 | 1. Elimination of import tariffs on raw materials used to manufacture solar water heaters<br>2. Imposition of 30% consumption tax on electric water heaters |
| 1980–1992<br>Homeowner Tax Benefit | 3. Deduction of full cost of SWH installation up to a maximum of up to $3500 Bds. |
| 1993<br>Elimination of Homeowner Tax Deduction | Elimination of income tax deduction |
| 1996<br>Re-Instalment of Homeowner Tax (amended) | Home improvement tax deduction (allowing homeowners an annual deduction up to 3500 BBD for mortgage interest, repairs, renovation, energy or water saving devices, solar water heaters, and water storage tanks) |
| In addition to Incentives | Government purchased a significant number of solar water heaters for housing development projects. Initially 80 units were purchased in the mid-1970s, and four other transactions in 1980s and 1990s |

*Source*: PERLACK, 2008, HEADLEY, 2001.

**FIGURE 80**

**Graphical chronology of annual SWH installations in Barbados**




*Source*: PERLACK, 2008.

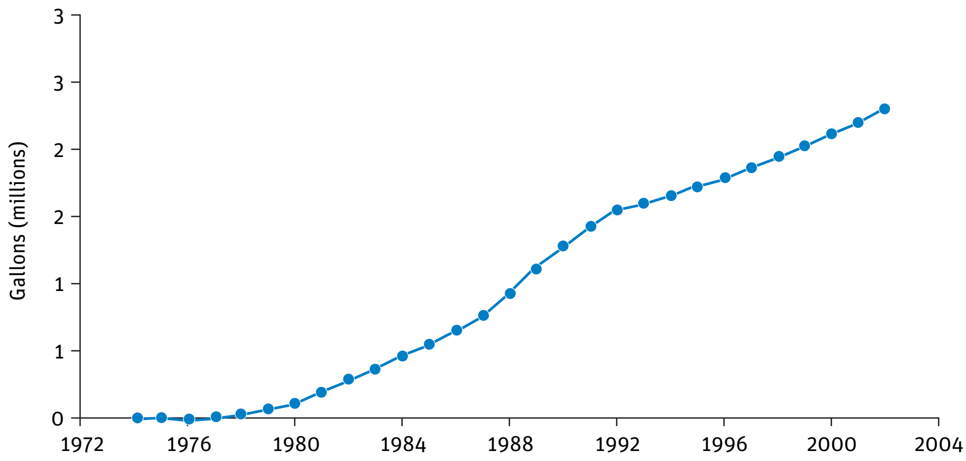
the SWH industry. Growth in the industry is shown post the 1974 incentives, and the sharp rise from 1980 to just prior to 1992 is a direct result of the income tax deduction. With the cut in 1993, the growth was slow, and with the re-instatement of the amended home-owner tax, the number of installations began to rise again.

Unfortunately, information post 2002 is not available. However, a large percentage of the solar water heaters are purchased by the Government of Barbados for housing developments. It is reported that today Barbados has approximately 55,000 SWHs installed, with an annual market volume of about 2,000 systems. The savings at today's cost per home is US$ 1,600 per year, cumulative consumer savings in the past more than three decades has been roughly US$ 0.5 billion. Barbados is saving about 185,000 barrels of oil equivalent in energy and has an abatement of 150,000 tons of carbon emissions per year (HUSBANDS, 2012).

**Figure 81** shows the cumulative installed SWHs expressed in storage volume in Barbados from 1974 to 2002. This graph also shows the effects that fiscal incentives had on the growth of the industry.

**FIGURE 81**

**Cumulative installed SWH storage in Barbados (1974–2002**




*Source*: PERLACK, 2008.

# Appendix K:
## Waste to Energy – Contacts

Companies and Government agencies interviewed and visited during the fact finding mission:

| Organization | Interviewed | Visited |
|---|---|---|
| **Ministry of Energy and Energy Affairs**<br>Levels 15 & 22–26, Energy Tower<br>International Waterfront Centre<br>#1 Wrightson Road<br>Port of Spain<br>Trinidad and Tobago<br>Phone: (868) 626-6334/ 623-6708<br>Fax: (868) 625-0306<br>www.energy.gov.tt | X | X |
| **The Environmental Management Authority**<br>Head Office<br>#8 Elizabeth Street, St. Clair<br>Port of Spain<br>Trinidad and Tobago<br>Phone: (868) 628-8042/8044-5<br>Fax: (868) 628-9122<br>www.ema.co.tt | X | |
| **SWMCOL**<br>**The Trinidad and Tobago Solid Waste Management Co. Ltd.**<br>34 Independence Square<br>Port of Spain<br>Trinidad and Tobago<br>Phone: (868) 625-6678<br>Fax: (868) 623-6534<br>www.swmcol.co.tt | X | X |
| **B.K. Holding Ltd.**<br>35 Preysal Crown Trace<br>Freeport<br>Trinidad and Tobago<br>Phone: (868) 673-0067<br>www.bkholdingslimited.com | X | |

| Organization | Interviewed | Visited |
|---|---|---|
| **Kaizen Environmental Services (Trinidad) Ltd**<br>Rajkumar Street, Mission Road<br>Freeport<br>Trinidad and Tobago, West Indies<br>Phone:(868)<br>kaizen-tt.com | X | |
| **Waste Disposal (2003) Ltd.**<br>9 Concessions Road, Sea Lots, Port of Spain,<br>Trinidad and Tobago, West Indies<br>Phone: (868) 625-6746/5546-7<br>Fax: (868) 625-6747<br>www.wastedisposalsltd.com | X | X |

# Appendix L:
## Power Output of the Pelamis System

**Table 54** **Power of the Pelamis System (in kW) and its influence by height and period of waves**

| | Period (T) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Height (H) | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1 | 0 | 0 | 0 | 0 | 0 | 29 | 37 | 38 | 35 | 29 | 23 | 0 | 0 |
| | 1.5 | 0 | 0 | 0 | 0 | 32 | 65 | 83 | 86 | 78 | 65 | 53 | 42 | 33 |
| | 2 | 0 | 0 | 0 | 0 | 57 | 115 | 148 | 152 | 138 | 116 | 93 | 74 | 59 |
| | 2.5 | 0 | 0 | 0 | 0 | 89 | 180 | 231 | 238 | 216 | 181 | 146 | 116 | 92 |
| | 3 | 0 | 0 | 0 | 0 | 129 | 260 | 332 | 332 | 292 | 240 | 210 | 167 | 132 |
| | 3.5 | 0 | 0 | 0 | 0 | 0 | 354 | 438 | 424 | 377 | 326 | 260 | 215 | 180 |
| | 4 | 0 | 0 | 0 | 0 | 0 | 462 | 540 | 530 | 475 | 384 | 339 | 267 | 213 |
| | 4.5 | 0 | 0 | 0 | 0 | 0 | 544 | 642 | 628 | 562 | 473 | 382 | 338 | 266 |
| | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 726 | 707 | 670 | 557 | 472 | 369 | 328 |
| | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 737 | 658 | 530 | 446 | 355 |
| | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 | 711 | 619 | 512 | 415 |
| | 6.5 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 | 750 | 658 | 579 | 481 |
| | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 | 750 | 613 | 525 |
| | 7.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 | 750 | 686 | 593 |

(*continued on next page*)

**Table 54 Power of the Pelamis System (in kW) and its influence by height and period of waves** (*continued*)

| | Period (T) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 | 750 | 625 |
| | 8.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 | 750 |
| | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 | 750 |
| | 9.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 750 |
| | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 |
| | 10.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 11.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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