Contract n°2014/352-852

EuropeAid/135600/DH/SER/MULTI

EU Technical Assistance Facility for the Sustainable Energy for All Initiative (SE4ALL)

Neighbourhood (East and South), Asia (including Central Asia), Latin America, Caribbean and Pacific

Providing Technical Support to EU Delegation to Trinidad and Tobago to organise and implement the Clean Energy Conference aiming at providing EU Expertise in the field of Sustainable Energy

Caribbean – GT#31/CSEE-EUDT&T (Trinidad and Tobago)

Sustainable Energy Roadmap 2021/2030 for Trinidad and Tobago
Final

13 July 2017

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Sustainable Energy Roadmap 2021/2030 for Trinidad and Tobago
Final

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Ioannis Stefanou – Senior Expert in Renewable Energy & Development Cooperation - NKE

Date: 13 July 2017

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List of Acronyms

CAPEX	Capital Expenditure
CCGT	Closed Cycle Gas Turbine
EDAB	Economic Development Advisory Board
ESCO	Energy Service Company
DSM	Demand Side Management
FiT	Feed in Tariff
GoRTT	Government of the Republic of Trinidad and Tobago
IDB	Inter-American Development Bank
IEA	International Energy Agency
IMF	International Monetary Fund
IPP	Independent Power Producers
IRENA	International Renewable Energy Association
MoEEI	Ministry of Energy and Energy Industries
MPD	Ministry of Planning and Development
MPU	Ministry of Public Utilities
MRV	Monitoring, Reporting and Verification
NDC	National Development Contributions
NGC	National Gas Company
OCGT	Opean Cycle Gas Turbine
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
RES	Renewable Energy Sources
RIC	Regulated Industries Commission
SWH	Solar Water Heaters
SWOT	Strengths Weaknesses Opportunities Threats
TAF	Technical Assistance Facility
T&T	Trinidad and Tobago
T&TEC	Trinidad and Tobago Electricity Commission
TGU	Trinidad Generation Unlimited
UNDP	United Nations Development Programme
UWI	University of West Indies
WB	World Bank

List of units

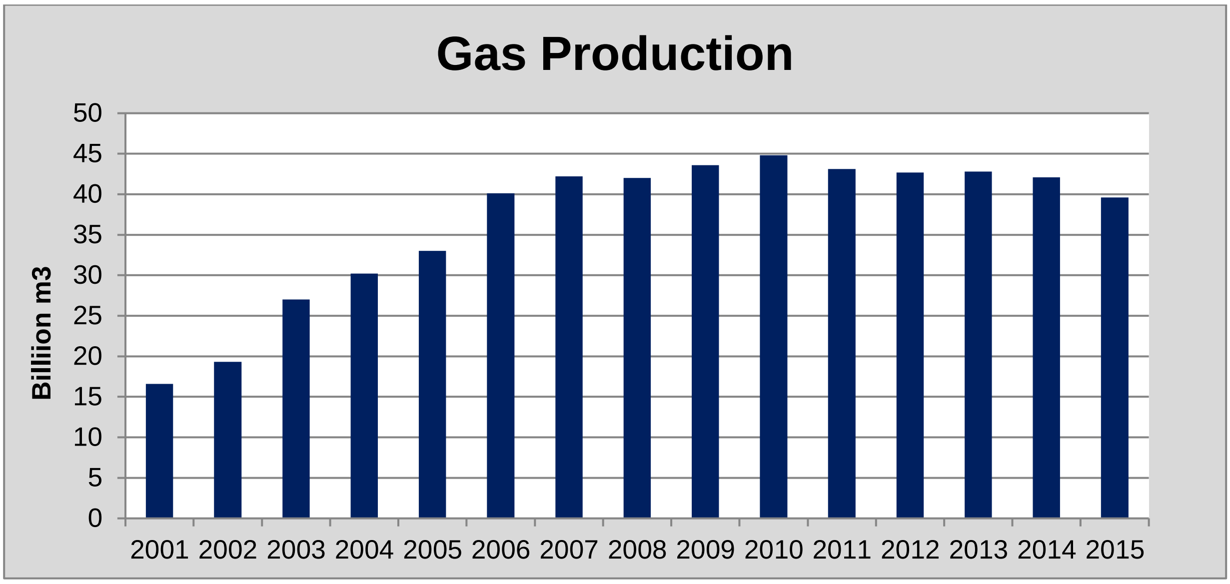
tcf	Trillion cubic feet
kW	Kilo-watt
kWh/ sq m	Kilowatt-hours per square meter
kWh/kwp	Kilowatt-hours per installed kilo-watt peak
MW	Mega-watt
USD/mmbtu	United States dollars per million British thermal units

1. Overview of the Energy Sector

T&T's economy is heavily reliant on oil and gas. Approximately 40% of GDP and 80% of total exports account for energy and energy products. Without going into further details, these figures frame the general context of a country that is enormously based on oil and gas. The energy sector of the country in general suffers from some structural in-efficiencies that fossil fuel-based countries suffer from, as well as lack of economic diversification despite the high level of industrialization. Furthermore, the 2015 Natural Gas Reserves Audit showed a reduction of proved gas reserves from 11.5 tcf to 10.6 tcf, while the probable and possible reserves have decreased to 3.24 tcf and 1.15 tcf respectively.

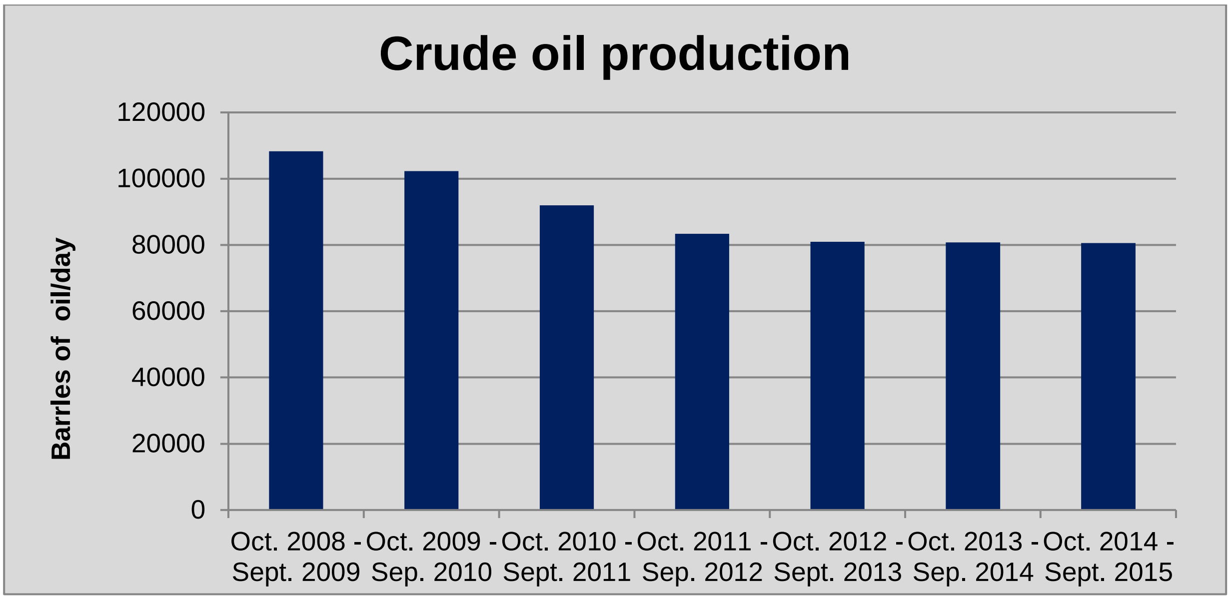
As it can be obtained from Figure 1.1 and Figure 1.2 the oil and gas production in T&T is steadily decreasing since 2010. Specifically, natural gas reserves have been steadily decreasing by around 1 tcf annually. This decline poses significant challenges for an economy heavily reliant on oil and gas like TT. In addition, high energy consumption depletes rapidly country's fossil fuel reserves to the detriment of the economy and the society.

Figure 1.1: Gas Production History



Source: BP Statistical Review of World Energy 2016

Figure 1.2: Crude Oil Production History

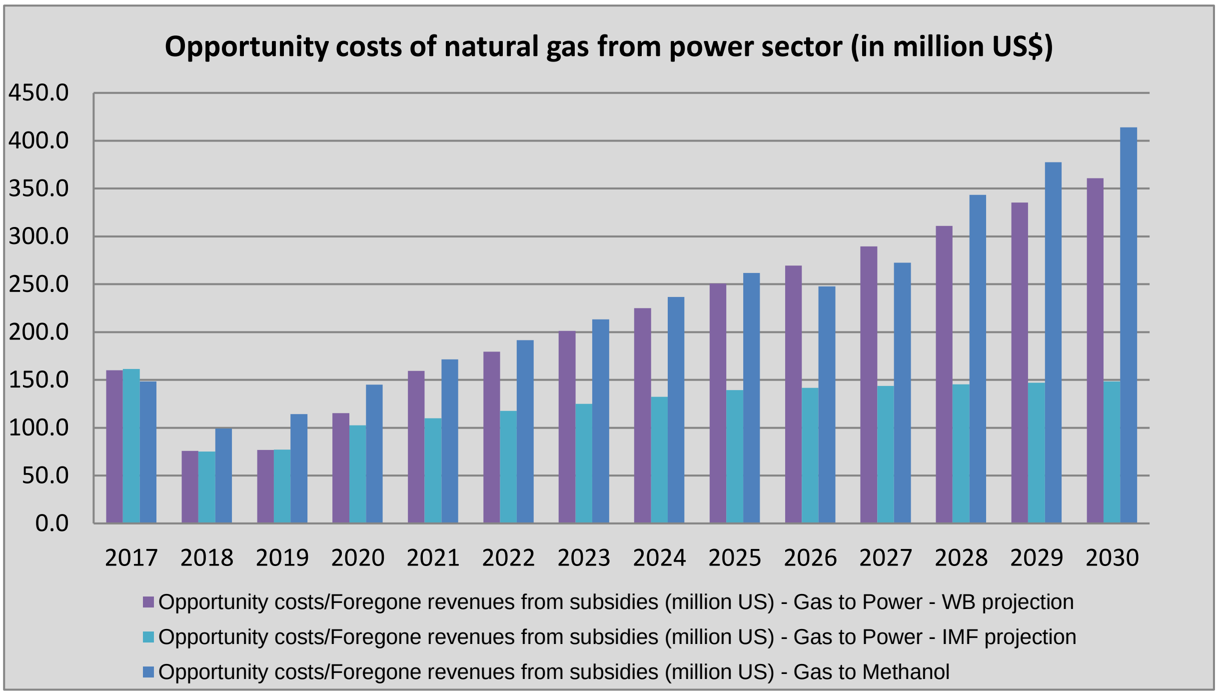


Source: Ministry of Energy and Energy Industries, 2016

The lack of efficiency in demand and supply as well as the low energy tariffs have as result the consumption of large amounts of NG for electricity generation, while this amount of natural gas could be channeled internally for methanol production or to the international market at higher prices. The opportunity costs as a result of this mode of utilization are ranging from 1.7 to 3.2 US billion up to 2030.

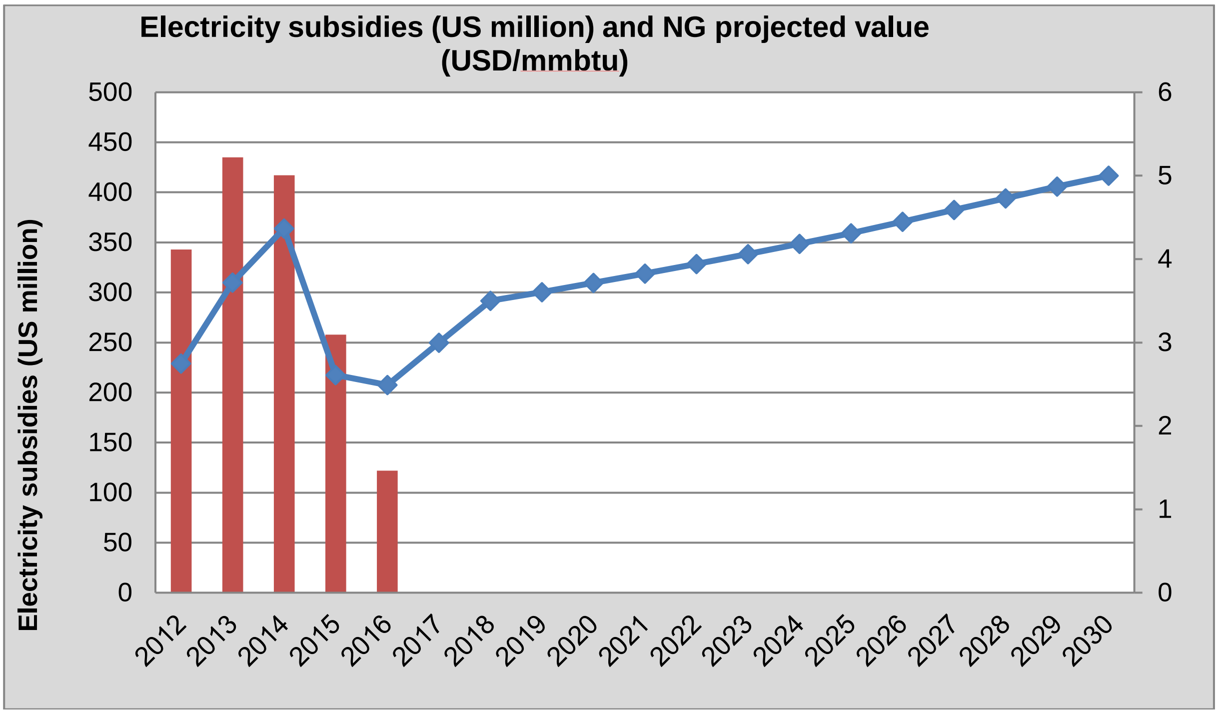
Moreover, electricity sector subsidies have led to a huge deficit of T&TEC standing at 516 million US$ by the end of 2016. The two effects combined have an impact of at least 1% of GDP implying that there is a large room for more optimum utilization of indigenous resources. These considerations pose significant challenges which are important for the energy sector but also for the formulation of the sustainable energy policy.

Figure 0.1: Opportunity Costs of Natural Gas in Trinidad and Tobago



Source: Prepared by the author of the present report, June 2017

Figure 0.2: Electricity Subsidies and NG Price in Trinidad and Tobago



Sources: Energy Chamber and the World Bank for natural gas projected values, 2017

Additional observations regarding the energy sector of T&T can be summarized as following:

- Lack of effective regulation of the energy sector by the Regulator (RIC).

- Widespread perception among some policymakers that low electricity and fuel prices can tackle energy poverty.
- Low efficiency at electricity production (mainly OCGTs) and end-use side (EE in buildings and industrial sector is not a common practice).
- Lack of incentives for the major players in the energy market to be more efficient.
- Lack of consistent legislative and regulatory framework concerning energy and especially for the fostering of EE and RES.
- Fragmentation of responsibilities and approaches among key institutional stakeholders.
- Protective economic mentality and some reluctance to open the market to foreign competition.

1.1 Renewables and Energy Efficiency

The Consultant performed an SWOT analysis concerning the RES and EE in energy sector of Trinidad and Tobago and the relevant table is presented below:

Table 0.1: SWOT Analysis for RES and EE in the Energy Sector of Trinidad and Tobago

Strengths	Weaknesses
• Excellent solar and good wind energy potential • The generation cost of RES electricity is directly competitive to fossil fuel technologies in TT. • Large part of existing conventional generation (OCGT) requires enormous investments which constitute RES as a very feasible option for TT. • Country's energy utility	• Abundancy oil and gas energy sources and low electricity prices till present • The existing legal and regulatory framework requires changes • Limited land availability calls for careful spatial planning and land usage.
Opportunities	**Threats**
• Energy subsidy costs from T&TEC to NGC are accumulating as a result of non-reflecting true • Gradually depleting natural gas resources. • Considerable natural gas savings due to the introduction of RES and more optimum utilization of domestic natural resources • Political commitment by the government through the commitment for 10% RES in the generation sector by 2021. • Government strategy for economic diversification in which RES could play a major role. • Fast growing electricity demand allowing for a smooth transitional path for RES • Significant diffused effected from the large penetration of renewables in various economic sectors • Combination of RES with social policy programmes and support of less benefitted parts of the population.	• Widespread belief that fossil fuels are an abundant and cheap energy source • Complex institutional arrangements in the energy sector that could require low to medium amendments in the market setting and legislation. • Despite political commitment to proceed a wider energy policy strategy that RES could be part is non-existent • RES and EE are a very low consideration among large parts of the population.

Source*: Prepared by the author of the present report, June 2017*

Currently, there are some measures for the support of EE and RES which in general have produced very insignificant effects. These are summarized in the Table 1.2 below:

Table 0.2: Measures for the Launch of RES in Trinidad and Tobago

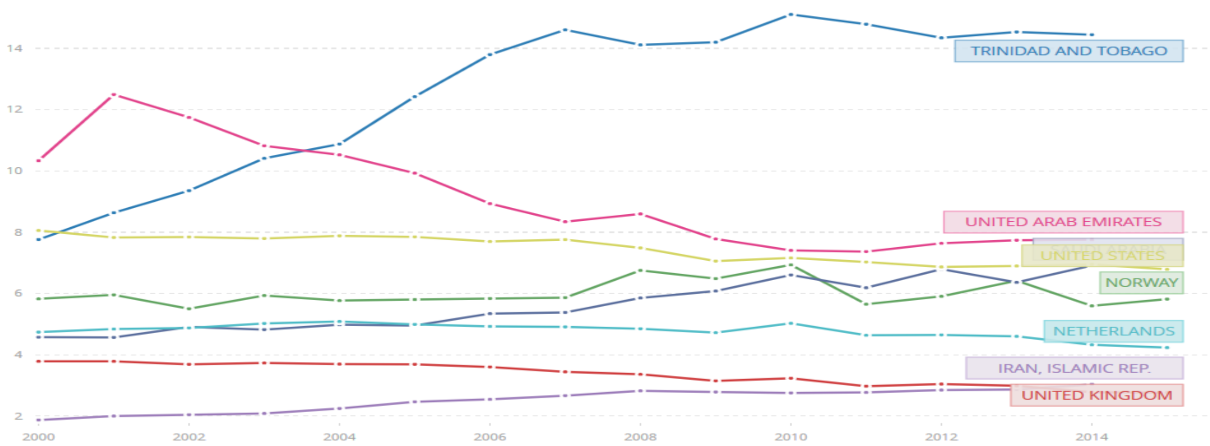
Measure	Description
Import Duty Exemptions	Granted for "machinery, equipment materials and parts for the manufacture or assembly of solar water heaters".
Zero Rated VAT	Granted for solar water heaters, solar PV panels and wind turbines
Tax Credit for Solar Water Heaters:	Where an individual, in a year of income commencing 1st January, 2011, purchases solar water heating equipment for household use, that individual shall be entitled to a tax credit of twenty-five per cent of the cost of the solar water heating equipment up to a maximum of ten thousand dollars (maximum tax credit of TT $2500.00).
Wear and Tear Allowance on	150% of expenditure incurred on: • The acquisition of plant, machinery, parts and materials for use in the manufacture of solar water heaters • The acquisition of wind turbines and supporting equipments; solar Photovoltaic systems & supporting equipments; and solar water heaters.

75% Accelerated Depreciation	Where a certified ESCO has acquired plant and machinery for the purpose of conducting energy audits there shall be allowed an amount of seventy- five per cent of the cost incurred in the year of acquisition, and this amount shall be the only allowance on this expenditure for that year.
150% Tax Allowance (Company that engages an ESCO)	Allowance of 150% of the expenditure incurred by a company that engages another company certified as an Energy Service Company by the Minister with responsibility for energy, for the: • Design of energy saving systems, and • Installation of the energy saving systems in the company

Source: *MoEEI's webpage 2017*

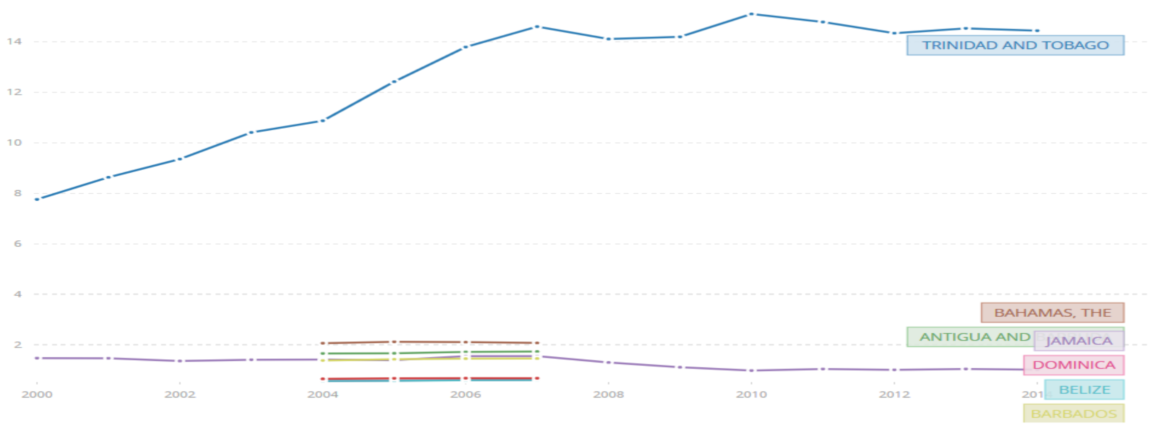
With respect to Energy Efficiency the main challenge of the country is the high energy intensity compared to several other countries. As it can be seen in Figure 1.5 and Figure 1.6 Trinidad and Tobago has the by far the highest energy intensity comparing against other countries in the Caribbean or other oil producing countries such as the UAE, Iran or Norway. This could be allegedly attributed to the high degree of industrialization of the country, which is in fact partially true. However, from the above rough benchmarking it can be derived that significant opportunities exist for implementing energy efficiency measures in all sectors of the economy

Figure 0.3: Energy intensity in Advanced Economies and Oil Producing Countries (in tonnes oil equivalent per capita)



Source: *World Bank Statistics 2016*

Figure 0.4: Energy Intensity in Caribbean Region **(in tonnes oil equivalent per capita)**

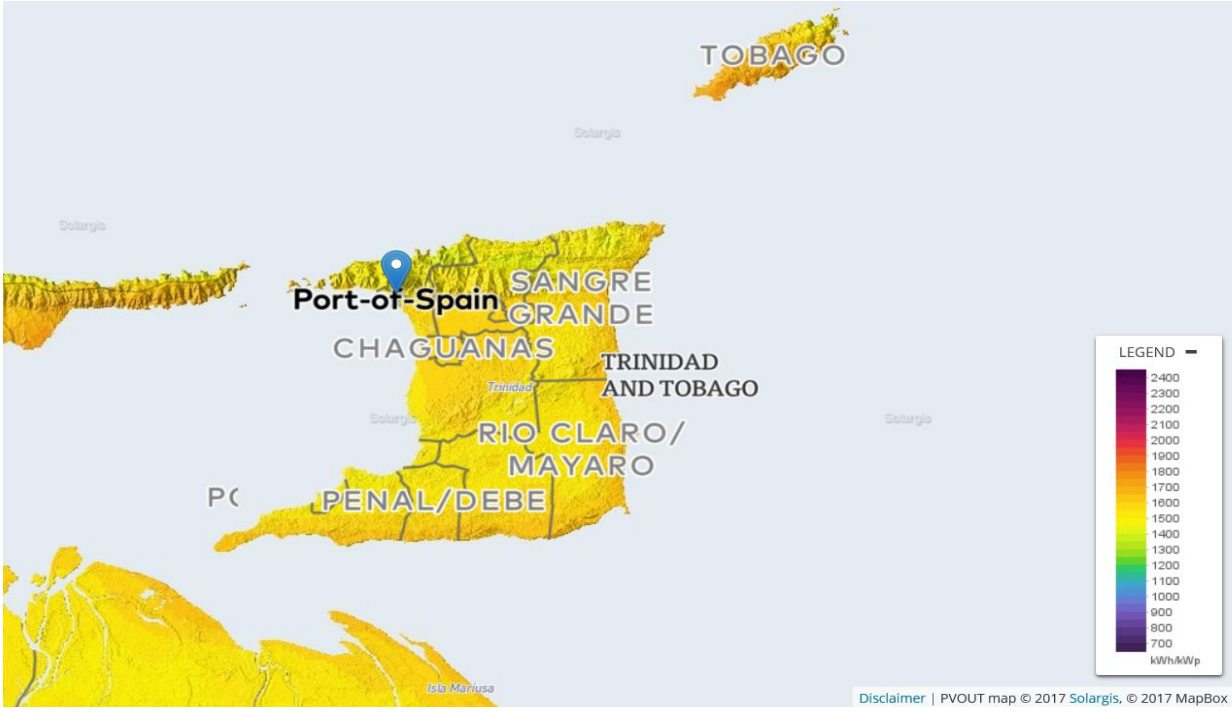


Source: *World Bank Statistics 2016*

1.2 Resource Assessment

Trinidad and Tobago is located in an area with excellent solar resources as can be seen in Figure 1.7. From that figure it is concluded that excellent opportunities exist for the launch of PVs in the country.

Figure 0.5: Solar Resource Assessment in Trinidad and Tobago



Source: *World Bank SolarGIS* http://globalsolaratlas.info/

In that framework, the Consultant performed a study in order to estimate the PV output for 3 categories of systems, namely (residential, small scale and utility scale). The results of this analysis is presented in Table 0.1 and it is deduced that the power output is excellent regardless of scale and ranges from 4.3 GWh/year to 14,5 GWh/year for utility scale installations.

Table 0.3: PV Power Output for 3 Categories of PV Systems

PHOTOVOLTAIC POWER OUTPUT for 3 categories of grid-connected PV systems with modules facing 180° tilted at 12°		
Photovoltaic system of size 100 kWp	144,925 kWh per year	Global tilted irradiation [kWh/sq m]: 1,989 per year (5,448 per day)
Photovoltaic system of size 3 kWp	4,348 kWh per year	Global tilted irradiation [kWh/sq m]: 1,970 per year (5,397 per day)
Photovoltaic system of size 10 MWp	14,492,453 kWh per	1,970 kWh/m^2 per year

Source: *World Bank SolarGIS 2017*

In order to investigate the influence of the PV site location in the power output of the plant the electricity output was calculated for a residential installation of 10 kWp located in several locations in T&T (see Table 0.4). From this table it is concluded that the electricity output ranges from 1,498 kWh/kWp/year to 1,707 kWh/kWp/year revealing a very good potential for electricity production from PV systems.

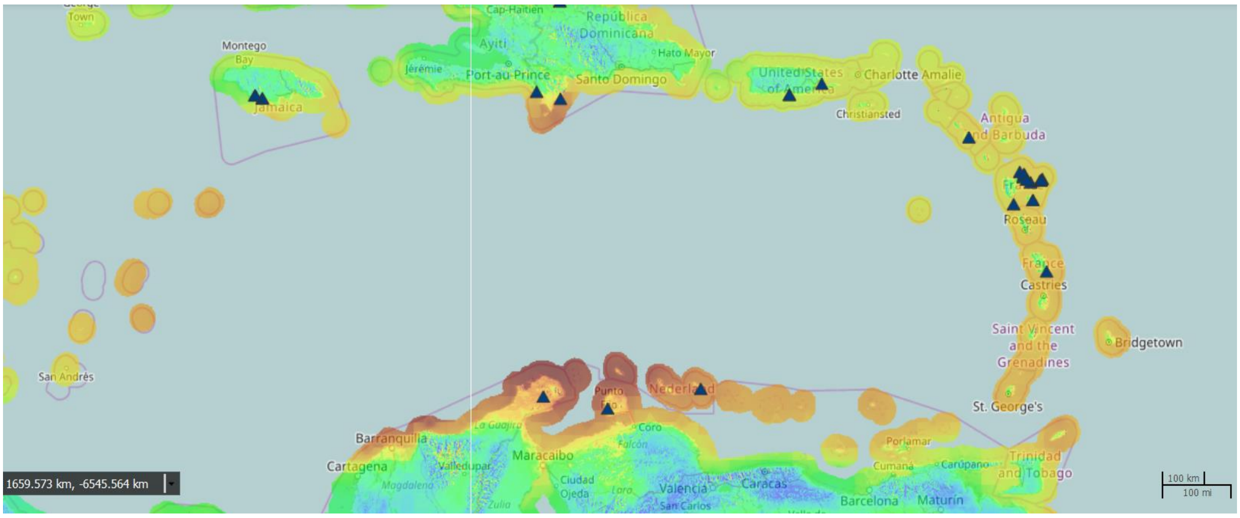
Table 0.4: Electricity Output of a PV 10kWp System in Various Locations in TT

Location	Geographical coordinates	Electricity output (10 kWp typical system, optimum tilt)	Global Horizontal Irradation
St. Andrew, Western Tobago, Trinidad and Tobago	11°11'11", -60°44'04"	1,700 kWh/kWp per year	2,151 kWh/m2 per year
Port of Spain, Port of Spain, Trinidad and Tobago	10°40'00", -61°31'00"	1,529 kWh/kWp per year	1,937 kWh/m^2 per year
Castries, Castries, Saint Lucia	14°01'00", -60°59'00"	1,613 kWh/kWp per year	2,016 kWh/m^2 per year
Bridgetown, Saint Michael, Barbados	13°05'46", -59°36'30"	1,707 kWh/kWp per year	2,140 kWh/m^2 per year
Clarendon, Clarendon, Jamaica	18°09'05", -77°19'09"	1,498 kWh/kWp per yeat	1,850 kWh/m^2 per year
Guanabacoa, Havana, Cuba	23°07'27", -82°19'07"	1,610 kWh/kWp per year	1,958 kWh/m^2 per year

Source: *World Bank SolarGIS 2017*

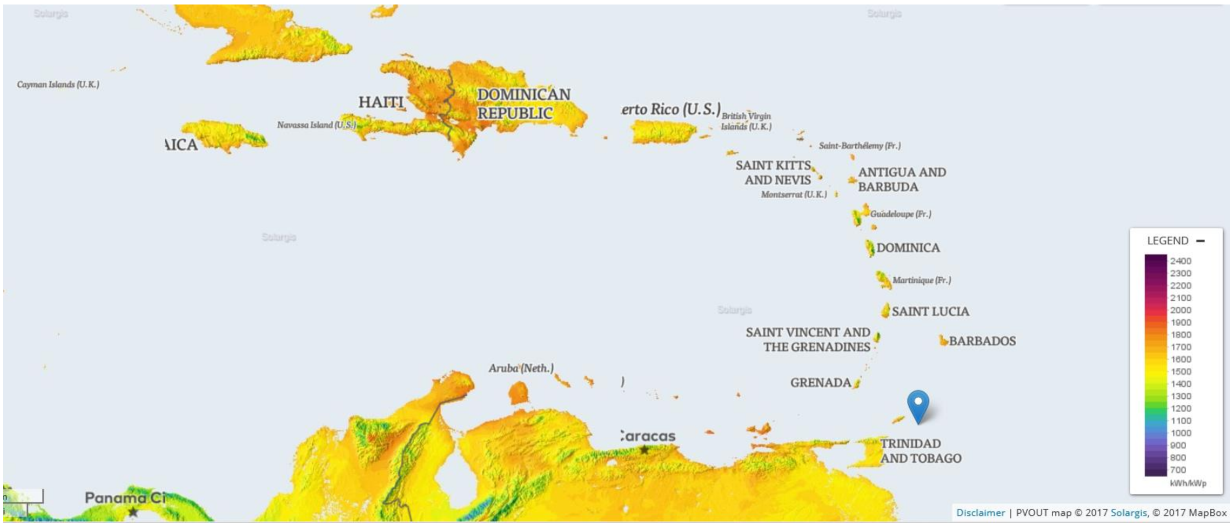
As concerns wind energy the analysis of already existed data revealed that the resource of the country isn't among the best (see Figure 1.8). However other countries in the Caribbean region with same or worst wind resource have implemented several wind projects in their countries proving the feasibility of such investments (see Figure 1.8).

Figure 0.6: Wind Resource in Trinidad and Tobago



Source: *Global Atlas for Renewable Energy-Danish Technical University Global Wind Energy Atlas, 2017*

Figure 0.7: Wind Resources in the Caribbean Region



Source: *World Bank SolarGIS 2017*

1.3 Regional Perspective

As concerns the policy mechanisms and compensation structures for the launch of PV in the residential sector established in several countries Caribbean a study was performed and the results are depicted in Table 0.5. The research revealed that there is a diversity of policy measures range from net metering and feed-in tariff to core tariff and renewable standard offer and as it was expected the compensation structure varies significant among the countries as well. However, in the majority of the cases the on-site consumption was the practice.

Table 0.5: Policy Mechanisms and Compensation Structures for the Lunch of Residential PV in the Caribbean

Country	Policy Mechanism	On-site Consumption	System size cap	Program cap	Compensation structure	Compensation amount (USD)
Barbados	Renewable Energy Rider	Yes**	1.5x the customer's current avg. usage up to a max. capacity of 150kW	9 MW	Under 2kW: Cash payment for metered output of system. Over 2 kW: Cash payment for 100% of power	1.6 x the Fuel Clause Adjustment

Cayman Islands	CORE Tariff	Yes*	Residential: 20 kW, or peak load	2 MW	Cash payment for 100% of power	~USD $0.47/kWh for 20 years
Grenada	Renewable Standard Offer	No	Commercial: 100 kW, or peak load	2.5% of annual electricity demand	Cash payment for 100% of power	USD $0.17/kWh for 10 years, or avg. avoided fuel cost for previous 12 months
Jamaica	Net Billing Standard Offer Contract	Yes	Resid.: 10kW, Comm.: 100kW	2% of JPS' Highest system peak	Cash payment for metered output of system	Short-run avoided cost of generation
St. Vincent & the Grenadines	VINLEC Net Billing/FIT policy	Yes***	Single Phase: 17kW Three Phases: 50kW	Max. of 5% of peak demand on certain islands	Residential: Cash payment for metered output of system. Commercial: Cash payment for 100% of power	EC $0.45/kWh
USVI	Feed-In Tariff	No	10 – 500kw	15MW (both programs in total)	Cash payment for 100% of power	Percentage discount to the avoided cost of the Utility
	Net Metering	Yes	Residential: 20kW Commercial: 100kW Public Facility: 500kW		Generation credited to the customer-generator's utility account	Retail rate
	* Power can be consumed on-site but it does not offset retail electricity purchases. Customer pays the utility retail rate for all electricity consumed. ** Systems up to 2kW may choose whether to use a Buy All/Sell All or a Sale of Excess arrangement; system owners over 2kW may only enter into a Buy All/Sell All agreement *** Residential systems may consume on-site; commercial systems must utilize a Buy All/Sell All arrangement					

Source*: GTM Research and Meister Consulting Group 2016*

1.4 Sustainable Targets of Trinidad and Tobago

Despite Trinidad and Tobago's long lasting reliance on fossil fuels, there is a clear commitment to diversify into renewable sources of energy and decrease GHG emissions in various economic sectors. This commitment is condensed in ambitious, but fully achievable energy and environmental targets:

- Target for 10% of electricity generation coming from Renewables by 2021;
- Trinidad and Tobago's Nationally Determined contributions (NDCs) and Strategy for the Reduction of Carbon Emissions in Trinidad and Tobago from the three sectors (power generation, transportation and industrial sectors) by 15% by 2030 with the aim of achieving emissions reductions of 30% in the public transportation sector by December 31, 2030.

The RES target stems naturally - apart from climate change considerations - from the acknowledgement of the fact that electricity subsidies and artificially low electricity prices in fact:

- Impose a fiscal burden on public budget;
- Promote inefficient use of natural resources and foregone revenues;
- Hinder the deployment of new cost-efficient generation capacity;
- Deprive the country of the opportunity of attracting new investments and creating growth.

In order to achieve the aforementioned targets the country - among others - has to create an enabling environment and implement a series of actions that will facilitate the deployment of renewables. Strenuous efforts are required in order to create a robust regulatory framework that will allow to existing and new market players to invest in the RES sector. The creation of an enabling environment will require the amendment of certain parts of primary and secondary legislation. More specifically, regulatory instruments such as Feed in Tariffs and competitive tendering will have to be employed.

RES targets are usually set as a percentage (%) of final energy consumption, so as to include all economic sectors. Onwards, they are further decomposed to sectoral targets such as power generation, heating/cooling, transport, etc. Moreover, renewable energy targets are set for a long term time period. In this context, the EU set in 2009 issuing the Renewable Energy Directive the 2020 RES target of equal to 20% of the final energy consumption of the EU Member States. By this Directive an overall policy for the production and promotion of energy from RES in the EU was established in order to achieve the 2020 RES target. Furthermore, the EU countries have agreed on a new 2030 Framework for climate and energy setting a target of at least 27% share of RES in the total EU energy needs.

With respect to T&T, the exact content of the 10% RES target by 2021 is not clear. More specifically, there were considerations on whether this target refers to nominal generation capacity or peak capacity.

According to the international practice, RES targets at the electricity sector are usually linked to generation capacity as this is a figure which exhibits less fluctuation over time. In this context, it is clear that the RES target should be linked to nominal generation capacity. Thus, based on 2016 installed generation capacity in 2016 (1,950.8 MW), the renewable energy target should be that being **195 MW of installed power generation capacity by RES by 2021**. Nonetheless, it should be highlighted that this figure does not actually reflect the easiness or difficulty of achieving the target and does not assess whether it has been correctly set at that level.

According to the Trinidad and Tobago's Nationally Determined Contributions (NDCs) and Strategy for the Reduction of Carbon Emissions the target is to achieve emission reductions from the three sectors (power generation, transportation and industrial sectors) by 15% by 2030. Nonetheless, three major issues can be identified with respect to RES as presented in Table 0.6. In the same table are also presented the advices on these issues according to TAF and Consultant's experience.

Table 0.6: Issues and Recommendations Regarding the RES Targets in TT

Issues	Considerations
• **Issue 1:** The target of 15% GHG emission reduction in the power generation sector by 2030 should be translated to a RES target. • **Issue 2:** Preliminary analysis indicates that the GHG reduction target for the power sector until 2030 will be achieved and probably relatively easy. In this context, the 2030 GHG does provide for a large incentive/stimulation for RES and by extension to translating this target in a RES target. • **Issue 3:** The RES target of 10% refers only to the power generation sector. Nonetheless, RES in principle cover all sectors (e.g. transportation – biofuels). Is there an intention for considering sectoral RES targets beyond 2021.	Ideally the RES target should: • refer to all sectors • cover the period up to 2030 • be stated as a percentage of the total final energy consumption • Specific sub-targets exist for each sector (power generation is one of them). In the absence of the above and with respect to the preparation of the Roadmap: • The RES roadmap for the short term (2017-2021) will be developed on the basis of the 10% RES by 2021. • The RES Roadmap for the medium term (2021 - 2025) and the long term (2025 - 2030) will be developed on the basis of targets (only for the power generation sector) developed by the Consultant taking into consideration feedback to the maximum possible extent by line Ministries and trying to provide provisional targets for other sectors.

Source*: Prepared by the author of the present report, June 2017*

As regards Energy Efficiency the country so far has not established EE targets neither at the supply nor the generation side. It is strongly advised that concrete EE targets are set and RES is seen in conjunction with EE as joint policies in order to decrease carbon emissions. It should be noted that increased EE considerations accompanied by solid actions taken would result in decreased needs for deploying new generation capacity. The analysis that has been conducted indicates that a 10% of savings can be achieved at the generation side through the upgrade of the OCGT to CCGT, while another 10% of savings compared to existing levels can be achieved at the demand side by 2030.

2. Methodology for the Development of the Roadmap

2.1 Problem Definition

As discussed, the Sustainable Energy Roadmap for the short term (2017-2021) will be developed on the basis of the 10% target RES by 2021. The Roadmap for the medium term (2021 - 2025) and the long term (2025 - 2030) will be developed on the basis of targets (only for the power generation sector) developed by the Consultant taking into consideration various economic considerations and the feedback to the maximum possible extent by line Ministries and trying to provide cost efficient targets for other sectors.

Thus, in the context of decreasing oil and gas reserves, sub-optimal utilization of natural resources taking also in account the projected energy demand policymakers are called to answer the following basic questions:

- When and what extent introduce Energy Efficiency?
- When and what extent introduce Renewables?
- What is the optimum mix of RES, EE and natural gas?
- Upgrade existing OCGT to CCGT?

Apparently there is no straightforward answer and a combination of policy options and technological solutions will be required in order to ensure the optimized solution with respect to energy production and energy end-use. Thus a series of policy decisions have to be made soon so that a long-term energy planning will be available.

2.2 Situation Analysis and Baseline Setting

The first action to be implemented is the analysis of the current situation with respect to energy production and energy end-use in order to set the baseline. Having in mind that effective and accurate technical analysis requires robust data the Consultant incorporated into the analyses previously completed feasibility studies, resource assessments, strategy documents, and infrastructure expansion plans, as those were collected by various stakeholders. These studies provided the analytical team with an understanding of the energy vision for TT and essential baseline data. The accuracy of the resulting outputs is directly proportional to the level of detail and precision of these inputs.

2.3 Stakeholder Consultation

The main challenge for the promotion of RES and EE at this stage is not to design legal frameworks, draft regulations, etc, but to effectively engage and convince major stakeholders that RES and EE in the longer run will:

- Drive down real electricity costs;
- Help diversify the economy;
- Save gas and eventually avoid foregone revenues, etc.

In response, an extensive consultation process was implemented to obtain the views of main stakeholders and policymakers. These included:

1. Economic and Development Advisory Board (EDAB)
2. Ministry of Public Utilities (MPU)
3. Ministry of Planning and Development (MPD) - Environmental Policy and Planning Division
4. Ministry of Energy and Energy Affairs (MoEEI)
5. Regulated Industries Commission (RIC)
6. Trinidad and Tobago Electricity Commission (T&TEC)
7. Energy Chamber (EC)

Apart from the policymaking and basic institutional stakeholders a series of other actors was also consulted to obtain their views. These include:

1. University of Trinidad and Tobago (UT&T)
2. University of West Indies (UWI)
3. Inter-American Development Bank (IDB)
4. United Nations Development Programme (UNDP)
5. Carbon Zero Initiative of Trinidad and Tobago
6. European Business Chamber in Trinidad and Tobago (EUROCHAMT&T)

2.4 Development of Policy Scenarios

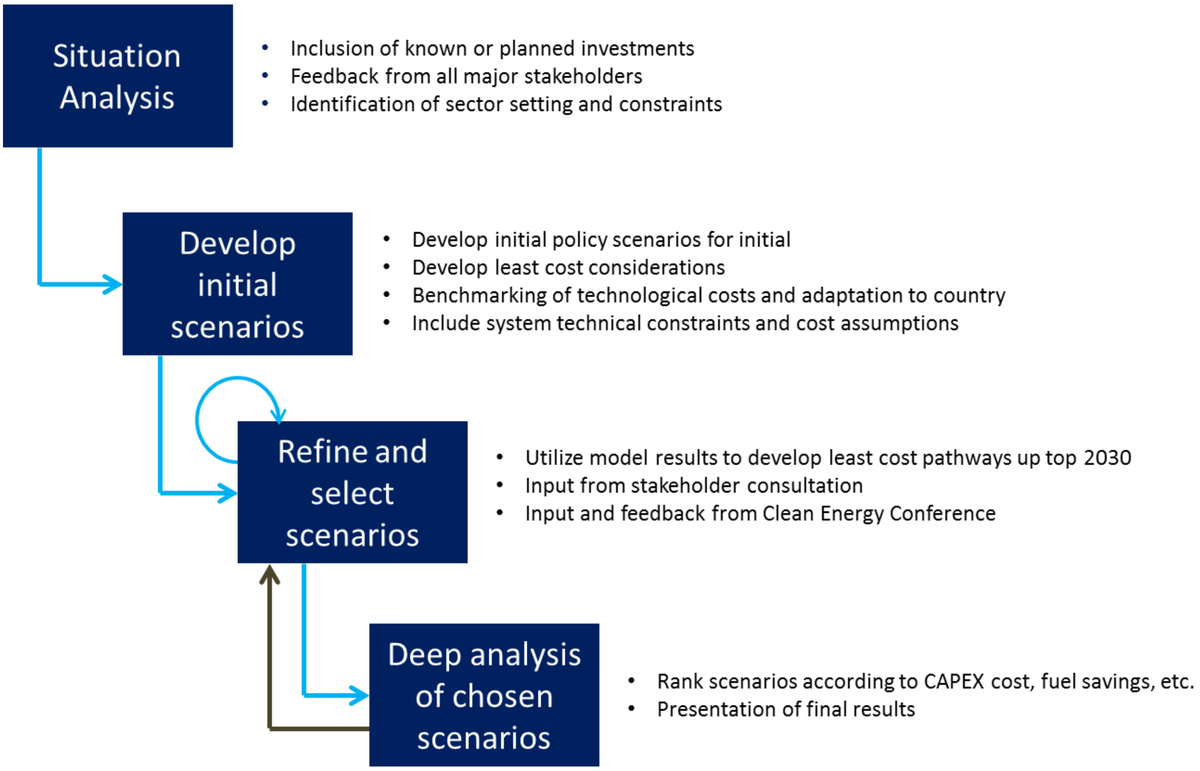
The Roadmap is organized in three time periods. The rationale for the development of the Roadmap with respect to the time horizon is pretty straightforward. The following time periods are foreseen:

- Short-term horizon (2017-2021)
- Medium Term Horizon (2021-2025)
- Long term Horizon (2025-2030)

For the assessment of various policy options and the identification of the optimum path for the promotion of RES and EE in T&T a specific quantitative analysis was developed taking into consideration various aspects and variables. It has to be stated that this is not an optimization model but the analysis is indeed based on least-cost considerations. The main steps of the methodology are presented in Figure 2.1 and include the following:

- Situation analysis: In this step the baseline is calculated taking into account the existing situation as well as the inclusion of known or planned investments;
- Development of initial scenarios: In this step are developed the initial scenarios with respect to RES and EE deployment taking into account all possible costs and constraints;
- Refining and selection of scenarios: On the basis of model results, the input from the stakeholder Consultation and the Clean Energy Conference the most appropriate scenarios are selected;
- Deep analysis of chosen scenarios: The scenarios are ranked according to CAPEX, OPEX and fuel savings and the presentation of the final results is taking place.

Figure 2.1: Methodology for the Quantitative Analysis



Source*: Prepared by the author of the present report, June 2017*

The major inputs and outputs of this model are included in the following Table:

Table 2.1: Inputs and Outputs of the Quantitative Analysis

Inputs	Outputs
• Demand Forecast	• Optimum Generation Mix (MW)
• Load Forecast	• Optimum RES Technological Mix (MW)
• Policy Targets - RES Electricity Target	• Cost to serve for each scenario (US Million)
• Policy Targets - EE	• RES CAPEX (US Million)
• New Conventional Capacity	• Total System CAPEX (US Million)
• System Adequacy Margin	• Fuel Savings (MMbtu)
• Natural Gas capital costs	• Foregone Revenues from Natural Gas (US Million)
• Projected PV CAPEX costs	• LCOE (US/kWh)
• Projected Wind CAPEX costs	

• Projected W2E Installation CAPEX costs • RES integration costs • Retail Electricity Tariff level • EE investment costs • Fuel costs • Emission factors	

Source*: Prepared by the author of the present report, June 2017*

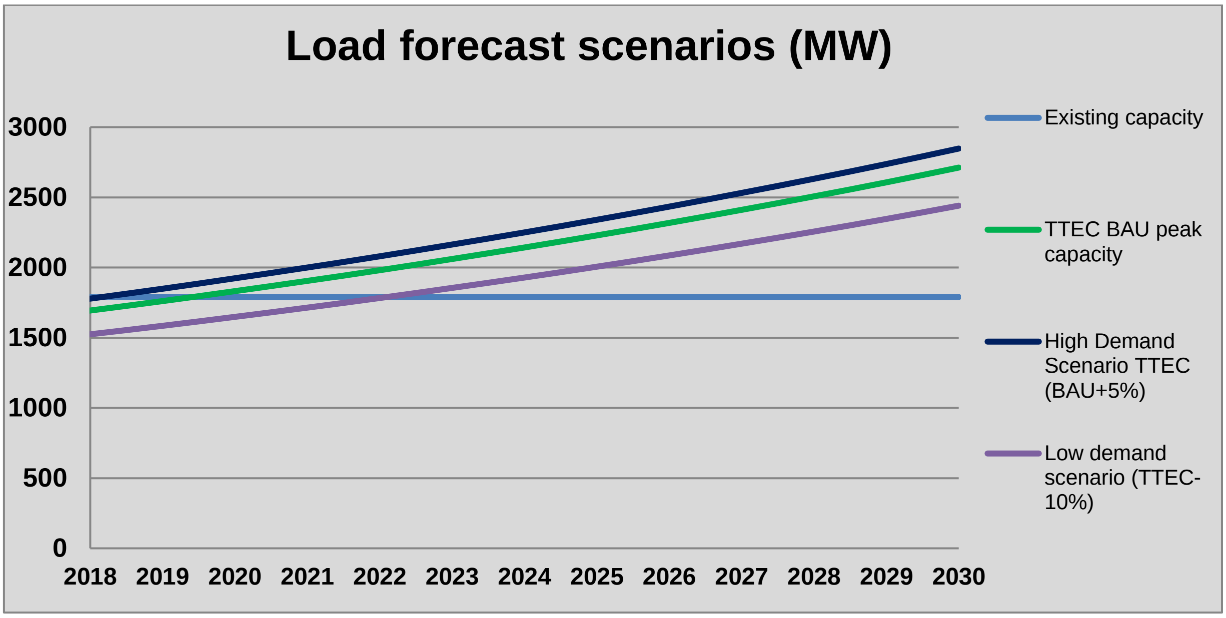
2.5 Technical and Financial Analysis of Policy Options

In this section are presented the main pillars of the analysis that were carried out and as follows:

Load Forecasting:

It provides the foundation of all long-term utility-planning efforts and identifies the magnitude of the demand from today through the next 15-20 years while providing a multi-aspect characterization of the load profile. Forecasts present the total energy or the number of customer-purchased kilowatt-hours and project annual peak demand. Projections are traditionally the responsibility of the Utility to meet these peaks when they are expected to occur in the future; thus, predicting the peak ensures proper planning for future procurement of adequate generation capacity (i.e., the total power of the generating assets). Load forecasts, based on both near-term developments (such as hotels and large commercial buildings) and long-term economic growth projections, show a steady increase in electricity usage and peak demand with a total projected increase of 33% in the coming 20 years. The load forecasting for the T&T according to various sources and scenarios is presented in Figure 2.2. As it can be seen, the projected annual growth rate is in the range of 3-5 % annually. This requires the deployment of significant new capacity.

Figure 2.2: Load Forecasting for T&T



Source: T&TEC, IDB and author's estimates (June 2017)

Demand Side Modeling:

Demand Side Management (DSM) is a widespread tool used by Regulators and Utilities in order to reduce the peak demand, defer generation, transmission and distribution (T&D) investments, and benefit consumers by reducing electricity consumption. The most common practices of DSM are:

- Energy efficiency: Using less energy to perform the same task;
- Demand response: Reducing demand on the customer side in order to respond to an event or condition within the electricity system;
- Load shifting: Not reducing overall energy use, but shifting the time of use to an off-peak period.

The method adopted for T&T focused on end-use energy efficiency namely thermal retrofitting and amelioration of coefficients for technical building systems in residential and tertiary sector of the Country. Having in mind that EE is generally considered as "low-hanging fruit" because of its availability at lower costs than the installation of any kind of power plants a rough potential for energy savings was identified and relevant calculations were performed.

Supply-Side Management:

This method is based on the selection of the most appropriate energy resources and operating them in the most cost-effective manner. In small and large scale grids, stakeholders increasingly assess a range of generation sources spanning from Thermal Power Plants to RES installations. All generation options taking into account existing ownership status and assets as well as fossil fuel expansion plans.

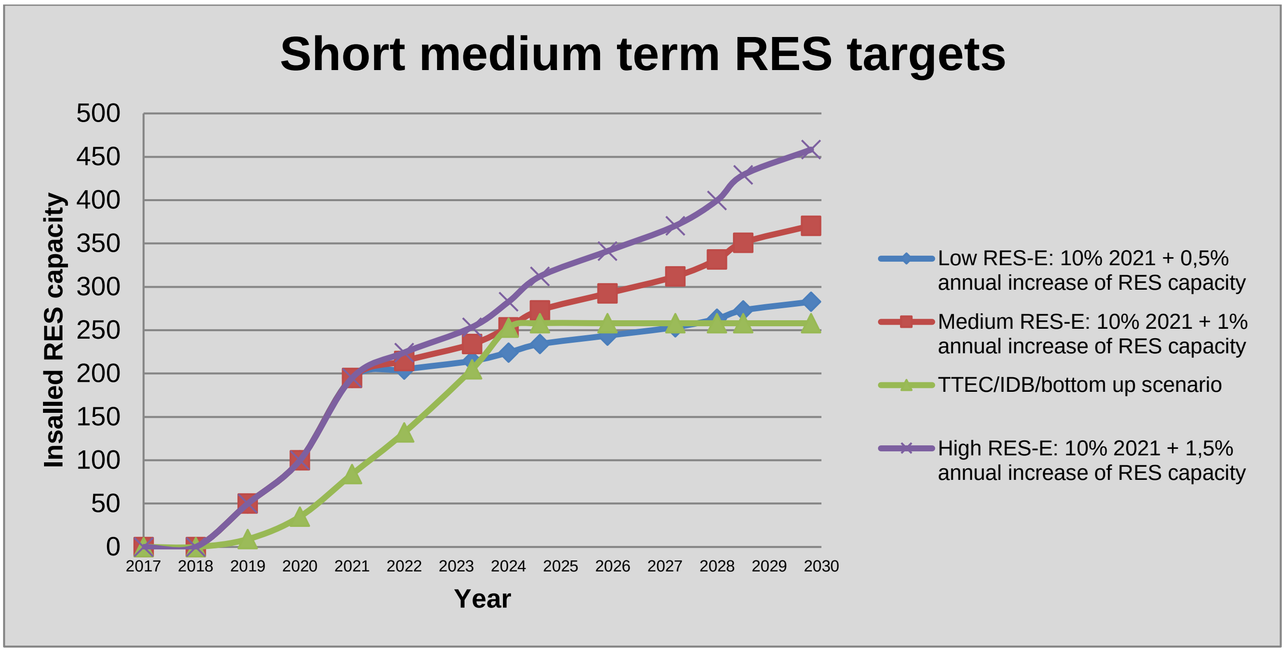
3. Results

3.1 RES Deployment

Four scenario categories were analyzed regarding in the energy system of TT and the evolution of the installed power is depicted in Figure 3.1 below:

- Low RES-E: 10% penetration until 2021 and 0.5% annual increase of RES capacity;
- Medium RES-E: 10% penetration until 2021 and 1% annual increase of RES capacity;
- High RES-E: 10% penetration until 2021 and 1.5% annual increase of RES capacity;
- T&TEC bottom-up scenario.

Figure 3.1: RES Targets in Trinidad and Tobago



Source*: Authors calculations, June 2017*

According to these scenarios the maximum installed RES capacity will be approximately around 458 MW (see Table 3.1). From the same graph it can be seen that the implementation of the bottom up scenario envisages the installation of 258 MW of RES and this figure is slightly lower than the 283 MW of Low-RES scenario. **The analysis performed concludes that a target of 15% RES installed capacity until 2030 seems to be both cost-efficient and fully feasible by TT.** This scenario category will be further analyzed to derive the optimum RES mix. The installed RES capacity for the time milestones (2021, 2025, and 2030) is illustrated in Table 3.1.

Table 3.1: RES Installed Capacity in Trinidad and Tobago according to the Scenarios Assessed

Target Sce-nario	Description	2017	2021	2025	2030
1	Low RES-E: 10% 2021 + 0,5% annual increase of RES capacity	**0**	**195**	**234**	**283**
2	Medium RES-E: 10% 2021 + 1% annual increase of RES capacity	0	195	273	371
3	High RES-E: 10% 2021 + 1,5% annual increase of RES capacity	0	195	312	458
4	TTEC/IDB/bottom up scenario	0	84	258	258

Source*: Authors calculations, June 2017*

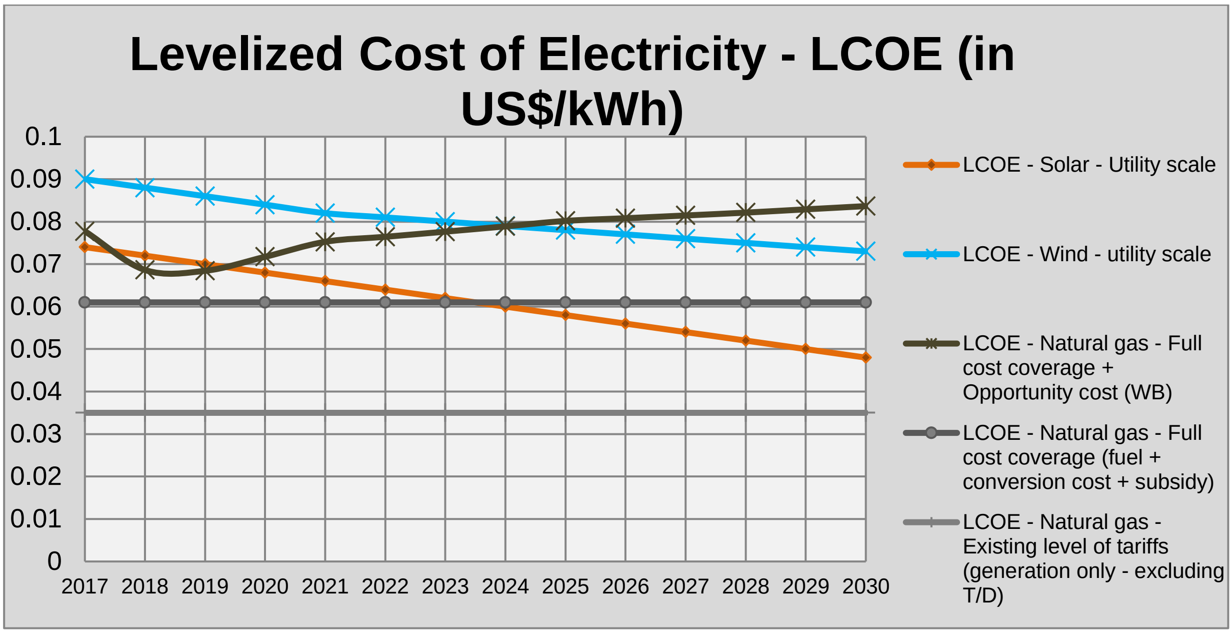
3.2 Levelized Cost of Electricity (LCOE)

A LCOE analysis and the results are presented in Figure 3.2. Wind and solar energy generation costs are compared against three levels:

- The existing level of electricity tariffs (generation segment only)

- The theoretical level of tariffs assuming full cost coverage by T&TEC (Weighted Average Cost of Capital of 8%)
- The theoretical case that full opportunity costs are charged (i.e. electricity is charged assuming that natural gas is purchased at international prices)

Figure 3.2: LCOE for 4 different Energy Sources



Source: *IRENA, IEA, Author's calculations June 2017*

According to this analysis the following conclusions are arising:

- LCOE for natural gas generation considering the existing level of tariffs is calculated equal to 0.035 US$/kWh and it is stable until 2030;
- LCOE for NG taking into account the full cost coverage is also stable until 2030 but the cost is approximately double (~0.06US$/kWh) compared to the LCOE for NG with the existing level of tariffs;
- LCOE of utility scale PV plants is constantly decreased from 0.07US$/kWh in 2017 reaching 0.049US$/kWh in 2030;
- LCOE of utility scale Wind Farms is also constantly decreased from 0.09US$/kWh in 2017 reaching 0.072US$/kWh in 2030.However the slope is not so steep comparing against the steep of the Utility scale PV Plants;
- LCOE of the NG with full cost coverage plus the opportunity cost shows a decrease from 0.079 US$/kWh to 0.069 US$/kWh during the years 2017-2019. Nonetheless, the LCOE is slightly increased from 2019 to 2030 reaching a figure of 0.085US$/kWh.

From the aforementioned figures it is concluded that:

- The most cost-efficient solution concerning the RES penetration in TT is the launch of Utility scale PV plants since the high solar resource of the country ensures a high capacity factor of these systems;
- After 2018 utility scale solar energy will be cheaper than natural gas assuming full cost reflectiveness and opportunity costs;
- After 2023 utility scale solar energy will be cheaper than natural gas power generation assuming full cost reflectiveness;
- After 2024 wind energy will be cheaper than natural gas assuming cost reflectiveness and opportunity costs.

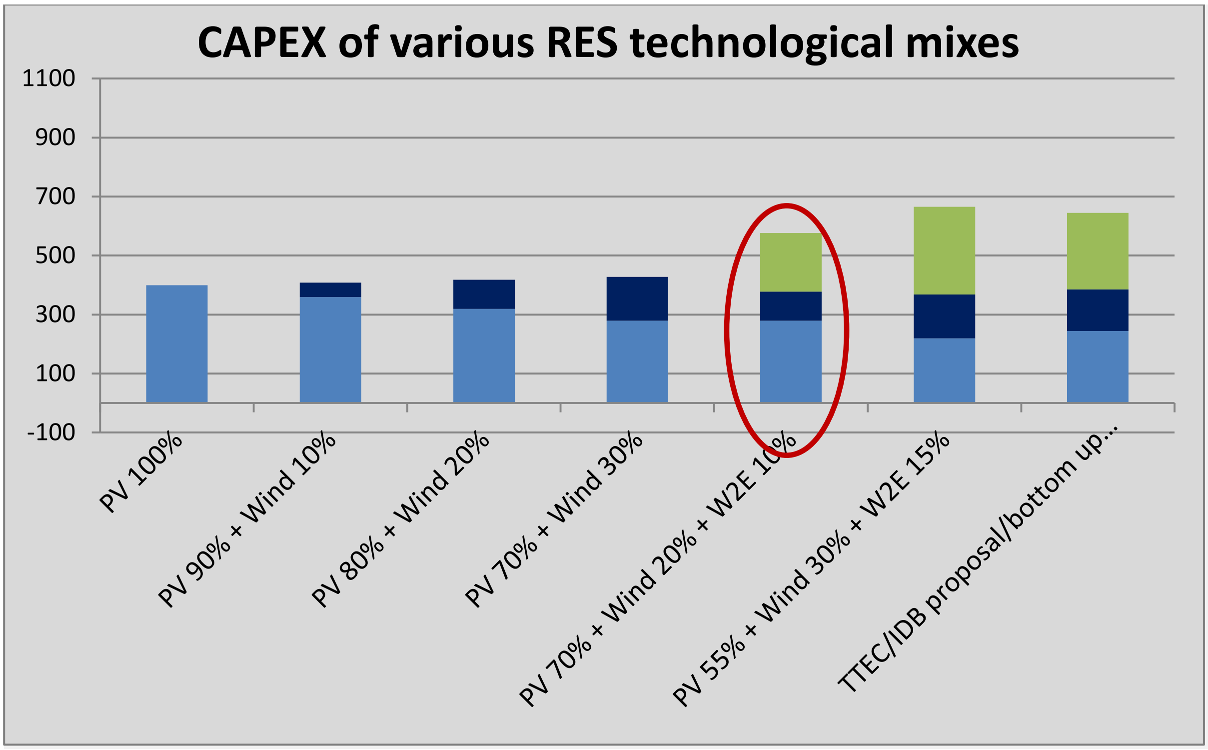
3.3 Optimum RES Technological Mix

Further analysis was conducted to determine the optimum RES mix for the low-RES penetration scenario considering the following aspects:

- Least cost CAPEX;
- Least cost to serve;
- Policy considerations;
- Economic diversification;
- Society engagement;
- Land availability.

In line with the aforementioned and the taking into international benchmarking costs for various RES technologies the CAPEX for various technological RES mixes was estimated as shown in the following Figure. It has also been assumed that a Waste to Energy plant will be built in the last three scenarios, a policy option which is already publicly declared.

Figure 3.3: CAPEX of Various RES Technological Mixes



Source*: Authors calculations, June 2017*

Considering the various policy objectives, limitations and restrictions mentioned above, it is concluded that the optimum RES technological mix comprises 70% PV, 20% wind and 10% waste-to-energy with a total CAPEX of approximately 600 million US until 2030. Further remarks include:

- **Large Scale PV are highly competitive**, while even medium utility scale PV plants (20-60MW) can be highly competitive;
- **Wind Energy is a cost effective technology for TT in general even though de**tailed site measurements are not available for T&T yet;
- **Waste to Energy appears to be an expensive technology.** Nonetheless, this is the case only when seen as a power generation technology and not as part of a wider waste management strategy;
- **Introduction of Residential PV and small scale commercial is relatively more expensive** when compared to utility scale PV. However, it increases awareness and engages people at low cumulative costs.

The installed capacity of the optimum mix of RES technologies in order to achieve the intermediate as well as the 2030 targets is presented below.

Table 3.2: Proposed Mix of RES Technologies for Low-RES Penetration Scenario

Technology	2017 Installed Power (MW)	2021 Istalled Power (MW)	2030 Istalled Power (MW)
PV	**0**	**137**	**198**
PV utility scale (>10MW)	*0*	*109*	*158*
PV small scale (5kW>, 20kW)	*0*	*14*	*20*
PV residential (<5kW)	*0*	*14*	*20*
Wind	**0**	**41**	**57**
W2E	**0**	**20**	**28**
Total	**0**	**195**	**283**

Source*: Authors calculations, June 2017*

3.4 Preferred Financial Incentives per RES Technology

According to the international experience and the analysis of TT energy sector the most suitable schemes per RES technology appear with green colour.

Table 3.3: Preferred Financial Incentives for the Launch of RES in TT

Technology/Class	Competitive tendering	Feed in Tariffs	Duty exemptions	Capital subsidies	PPPs
PV utility scale (>10MW)	✓		✓		✓
PV small scale (5kW>, <20kW)		✓	✓		
PV residential (<5kW)		✓	✓		
Wind	✓		✓		✓
Waste to Energy			✓		✓

3.5 Energy Efficiency in the Demand Side

As concerns Energy Efficiency the Consultant took into consideration the current state of play concerning the efficiency in energy production and energy end-use as well as previous studies on the EE sector in TT. On the basis of the aforementioned the CAPEX, the energy and cost savings and the emissions reductions resulting the implementation of EE measures in the residential and industrial sector as well in hotels (see Table 3.4).

Table 3.4: Energy Efficiency Measures in Trinidad and Tobago

	Residential	Hotels	Industrial	TOTAL
5-Year budget CAPEX, US$ million	12,95+400*	1,75	8,622	**423**
Aggregate Energy Savings, GWh	929,986	10,286	32,604	**973**
Cost Savings, '000 US$	46,499	514	1,630	**49**
CO2 Emissions avoided, kt	651	7	23	**681**

Source: IDB, and author's estimates (June 2017)

The conclusions of the analysis can be summarized as follows:

- A **potential of 9.2 % of savings exists** in the demand side up to 2022 very conservatively (compared to 2016 levels), but should not be seen as uniform and its feasibility should more thoroughly assessed, as it entails large behavioral change from consumers.
- Initial estimates of the **overall CAPEX costs can be up to 300-400 US million** from all sectors (residential, hotels, industrial), which could/should be partially financed by the government as with the current electricity price levels incentives are limited.

3.6 Energy Efficiency in the Generation Side

The upgrades of the natural gas units from open cycle to closed cycle could increase their efficiency by at least 10%. These upgrades cost according to their estimates approximately 0.5 US billion and can lead to enormous natural gas savings and consequent financial savings. Nonetheless, according to the current low and fixed electricity prices, there is no incentive to IPPs to proceed with these upgrades as there is no mechanism to recollect this amount. More importantly, part of this cost can be recovered by fuel savings and sales of NG to the international market. In any case the financing of these costs requires a detailed feasibility study and the careful design of a financing mechanism tailor made to the institutional structure of the T&T energy sector. Alternative options for financing these EE upgrades include:

- The 150% allowance scheme;
- The Increase of electricity tariffs to respective levels.

4. Conclusions

The current Chapter presents the main findings of the Sustainable Energy Roadmap. The Roadmap has been developed so that it fulfils mainly the two following objectives: (a) the achievement of the 15% GHG emission reduction target from the power generation sector and (b) the achievement of the 10% target for power generation from Renewables by 2021. The Roadmap is also consistent with the country's Innovation Policy and intends to contribute towards economic diversification, stimulation of economic growth and employment creation. The analysis of TT energy sector reveals some in-efficiencies, the most important of which are the large energy subsidies and foregone revenues from natural gas. It was shown that any form substitution of existing capacity (at the existing electricity tariffs) leads to enormous financial benefits for the GoRTT due to opportunity costs. These are estimated between 1.7 and 3.2 billion USD until 2030.

Given the institutional structure and complexities of the energy sector and taken into account a series of considerations both EE and RES have to be seen in the context of the optimum and cost efficient evolution and operation of the energy system. In this context the analysis has indicated that after 2019 new generation capacity will have to gradually enter the system, while after 2022-2023 significant new capacity will be required to cover project demand (approximately 500MW). Additionally, a new CCGT plant of 300-350 MW might be required between 2022/2023 given the existing trends for electricity demand. Renewables could play a major role in covering this demand. EE savings in the demand side should be gradually introduced as they reduce the need for capital investments in power generation. Renewables and Energy Efficiency should be seen as complementary policies for decreasing emissions and decreasing the actual generation costs of electricity when taking into account opportunity costs.

It is clear that the RES target should be expressed clearly as a percentage of the nominal installed capacity (and not peak capacity) i.e. the target of 2021 refers to 195 MW of installed RES capacity. A clear vision for renewables should extend beyond 2021 and reach up to 2030. Therefore, the period up to 2030 has been included in the analysis. The policy scenarios assessed including various energy mixes indicate that a conservative target of at least 15% RES in the power generation by 2030 (equivalent to 283MW of installed capacity) is both cost-efficient and fully achievable. The achievement of the 2021 RES target is essential in various respects, however, given the significant ground that has been lost and all the actions required for enabling the environment it is questionable whether it is fully achievable. Nonetheless, significant emphasis at this stage should be placed on enabling the environment for the creation of a sustainable power sector through various actions (regulatory amendments, enhancement of capacities, etc.).

To satisfy the target of installed capacity of 283 MW various RES mixes can satisfy the achievement of the RES target. The optimum RES comprises 70% PV, 20% wind and 10 waste to energy. Moreover, it was found that utility scale PV is highly competitive and should constitute the largest part of the RES mix. Wind Energy is a cost effective technology for T&T in general, but detailed site measurements are required. Waste to Energy appears to be an expensive technology. Nonetheless, this is the case only when see as power generation technology and not as part of a wider waste management strategy. The introduction of residential PV and small scale commercial is relatively more expensive when compared to utility scale PV. However, it increases awareness and engages people. Therefore, it is strongly advised. Large potential for EE savings exists at both the demand and supply side. A savings potential of approximately 10% in the demand side it a very conservative estimate but should not be seen as uniform and its feasibility should more thoroughly assessed as it entails large behavioral change from consumers. In any case the implementation of EE measures is both necessary and cost-efficient. Initial estimates of the overall CAPEX costs can be up to 400 US million from all sectors (residential, hotels, industrial), which could/should be partially financed by the government as with the current electricity price levels incentives are limited. The EE upgrades in the generation side (i.e. the conversion of specific OCGT units to CCGT units) can lead to significant fuel savings estimated at approximately 10%. The CAPEX for these upgrades stands at around 520 million USD. Currently, there is no incentive to IPPs to proceed with these upgrades as there is no mechanism to recollect this amount. Part of this cost can be recovered by fuel savings and sales of NG to the international market. Thus, in total a 20% potential from the demand and generation side is fully achievable, figure which could be also formalized as declared policy target.

The promotion of EE and RES will require some form of financial support definitely until 2022. For the financing of RES the introduction of a RES levy or CO_2 tax would be the most realistic option. The fuel savings due to RES and eventually avoiding the development new capacity could finance part (or the entire) cost of RES deployment.