Energy Road Map Series

Promoting Energy Storage in Trinidad and Tobago

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RIC Staff Discussion Paper

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LIST OF ACRONYMS & ABBREVIATIONS

CAES	Compressed air energy storage
CCTV	Closed circuit television
DG	Distributed Generation
DOMLEC	Dominica Electricity Services
EMA	Environmental Management Agency
ES	Energy storage
ESS	Energy storage system
GoRTT	Government of the Republic of Trinidad and Tobago
GTD	Generation, transmission and distribution
IPP	Independent Power Producer
IT	Information technology
IRENA	International Renewable Energy Agency
kW	Kilowatts
MW	Megawatts
MWh	Megawatt-hours
OFGEM	Office of Gas and Electricity Markets
PV	Photovoltaic
RE	Renewable energy
RIC	Regulated Industries Commission
T&D	Transmission and distribution
T&TEC	Trinidad and Tobago Electricity Commission
TTBS	Trinidad and Tobago Bureau of Standards
UK	United Kingdom
UPS	Uninterruptible power supply
USA	United States of America
USD	United States Dollars

EXECUTIVE SUMMARY

This Staff Discussion Paper *"Promoting Energy Storage in Trinidad and Tobago"* is the final publication of the *Energy Road Map Series* of papers. This document outlines some of the options available for deploying Energy Storage (ES) within the local electricity sector. It provides information on the types of ES that are available and illustrates how the country can benefit from ES. It also explores key policy, regulatory and market considerations and challenges that may exist in establishing ES locally and discusses what can be done to mitigate these challenges.

Many first world and transitional countries are realizing the benefits of ES in the electricity sector, both with conventional and renewable energy (RE) generation, for own–use applications and on a commercial scale. Various factors need to be considered when integrating ES into the electricity sector. Some of these factors require attention at the policy level while others need market and regulatory intervention. Thus key stakeholders that play an integral role in the establishment of an efficiently functioning ES market include the government, regulators and the electricity utility.

Locally, the uptake of ES is low compared to other jurisdictions. At this time, ES can be regarded as uncompetitive because of the relatively low energy prices and the high installation costs. Moreover, given that ES is often considered as a complement to RE, which itself has very low penetration locally, the application of ES is seldom considered. This is further exacerbated by the fact that there is excess capacity within the electricity system which can potentially act, in the short term at least, as back-up for non-dispatchable RE. Presently, ES is primarily used by consumers who depend on uninterruptible power supply (UPS) systems, and as a back-up power supply for those very few households using off-grid renewable energy (RE) systems, such as solar photovoltaics (PVs).

The move to incorporate renewable energy into electricity generation on a larger scale, however, provides an opportunity over the medium to long-term to develop the ES sector. The viability of an ES market, inclusive of the role of ES in the electricity sector and the pace and scale of deployment over the medium to long-term, requires an in-depth assessment. Nevertheless, ES deployment will require supportive action on the part of key stakeholders to create an enabling environment. Several key recommendations are made in this regard for ES in Trinidad and Tobago. The recommendations made in this paper focus on the three named stakeholder groups and are as follows:

The Government (GoRTT) should:

- Conduct an in-depth assessment to determine the viability of establishing an ES market in Trinidad and Tobago. This assessment should consider the need for ES, the major costs, benefits and other implications of establishing an ES sub-sector. This study should also evaluate the current legislation, regulations, policies, market opportunities and limitations that can affect the roll-out of an ES sub-sector to ensure the functioning of a fair and transparent market.
- Consider initially defining and classifying ES as Generation. An exception can be made for T&TEC, as the sole transmission and distribution operator, to utilize ES in its operations as it sees fit, provided that the asset is owned and operated by T&TEC. Subsequently, implications of classifying such devices as Transmission and Distribution devices should be fully explored in the in-depth assessment.
- Consider the various business models inclusive of the Market-Based Model (or a suitable hybrid) as options for deploying large-scale ES in Trinidad and Tobago over the medium to long-term. Successful independent power producers (IPPs) already operate in the local electricity sector. Some of the lessons learnt from contracting the IPPs and establishing the generation market can be applied to efficiently develop the potential ES sub-sector.

The Regulators:

The Economic Regulator (Regulated Industries Commission) should:

- Examine the costs and benefits for establishing an ES system, where the investment is to be undertaken by T&TEC and give consideration for the cost to be recovered through tariffs. It is important to determine the financial viability of ES and decide the mechanism for cost recovery.
- Determine how consumers will be compensated for the energy they export to the electricity grid; once appropriate policy decisions are taken.
- Play an integral role in the granting of ES licences in instances where the ES activities are to be provided on a large scale by independent ES providers. The approach currently sanctioned by the RIC Act allows the RIC to give advice to the Minister for the award of licences. If ES is regarded as Generation, a decision will also need to be made on whether

the same licence conditions that will apply to conventional generation can be used for ES operators.

The Technical Regulator (the Electrical Inspectorate) in conjunction with T&TEC should:

- Develop technical standards and regulations for interconnection of ES devices to the electrical grid and monitor installations.

The Utility (Trinidad and Tobago Electricity Commission) should:

- Explore the applications of ES technologies to determine the feasibility of improving its operations and service delivery, including options for alleviating congestion on the network. ES should be considered as part of the utility's strategic and operational planning. The utility should ensure that deployment is done in a manner that optimizes reliability and efficiency of the electricity grid.

SECTION 1.0 INTRODUCTION

1.1 Background

Energy Storage (ES) refers to the technologies used to capture electrical energy at the moment of generation for consumption at a later time. These technologies include electrochemical batteries, capacitors, flywheels, pumped-hydro and compressed air systems[1]. Within recent years, a decline in the price for ES technologies has made ES more affordable and increased its deployment in electricity (energy) markets. Research has shown that the use of ES technologies to augment electricity systems can ultimately lead to improved efficiency for end users. Furthermore, ES can potentially play a vital role in achieving national objectives, such as environmental targets and meeting international energy mix commitments.

Locally, the uptake of ES is low compared to other jurisdictions. It is regarded as uncompetitive because of the relatively low energy prices and the high ES installation costs. Moreover, given that ES is often considered as a complement to RE, which itself has very low penetration locally, the application of ES is seldom considered. This is further exacerbated by the fact that there is excess capacity within the system which can potentially act, in the short term at least, as back up for non-dispatchable RE[2]. Presently, ES is primarily used by consumers who depend on uninterruptible power supply (UPS) systems, and as a back-up power supply for those very few households using off-grid renewable energy (RE) systems, such as solar photovoltaics (PVs). ES can also aid the achievement of environmental targets over the longer term.

1.2 Purpose of Document

This document provides information on the types of ES technologies that are available on the market and discusses how the country can benefit from the deployment of these technologies. It explores key policy, regulatory and market considerations and challenges that exist in establishing an enabling environment for ES locally and discusses what can be done to mitigate these. It also outlines some of the options available for integrating ES within the local electricity sector.

[1] These technologies will be discussed in Section 2 of this paper.

[2] In 2018, peak demand for electricity was 1319 MW. T&TEC currently has excess contracted capacity of approximately 388 MW. However, in terms of installed capacity, there is an excess of 600 MW. See "Energy Road Map Series; Towards Renewable Energy Deployment in the Electricity Sector of Trinidad and Tobago." RIC Staff Discussion Paper, July 2019.

1.3 Structure of Document

The remainder of this document is divided into three (3) sections. **Section 2.0** discusses the applications and benefits of ES and gives a description of the various ES technologies that may be applicable to Trinidad and Tobago. **Section 3.0** explores the use of ES regionally and locally and explores several factors that can affect the establishment of an ES sub-sector. **Section 4.0** provides recommendations which the various stakeholders should consider to facilitate the successful integration of energy storage systems (ESS) into the local electricity sector.

Responding to this Document

All persons wishing to comment on this document are invited to submit their comments.

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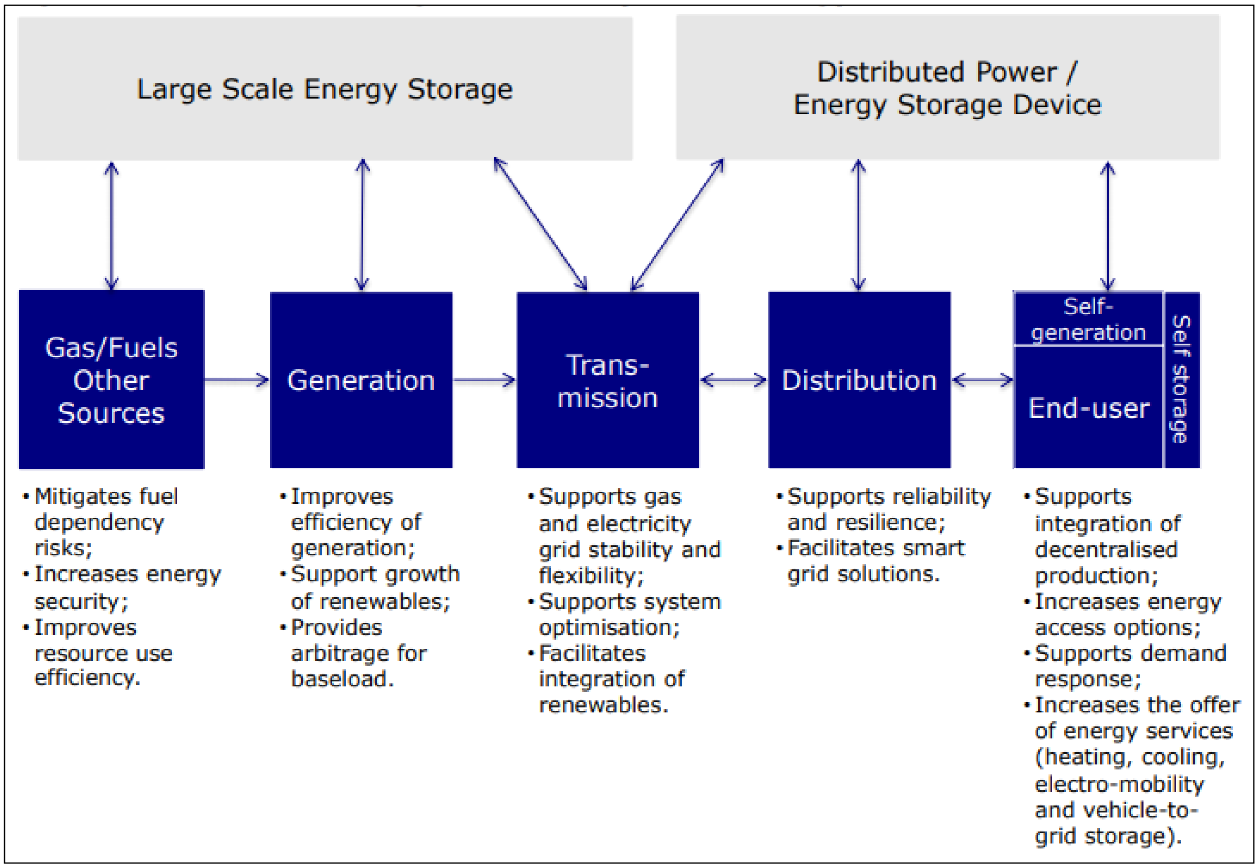
SECTION 2.0 ENERGY STORAGE TECHNOLOGY AND BENEFITS

2.1 Benefits and Applications of Energy Storage

ES has various uses and can provide benefits to different parts of the electricity system or grid, that is, the generation, transmission and distribution (GTD) value chain. Its wide application makes it attractive to different stakeholders. The relevance of ES in each step of the electricity value chain is summarized in figure 1 below.

Figure 1: Value of storage in each step of the energy value chain



Source: Directorate General for Internal Policies, European Parliament.

ES technology is applicable to both traditional and RE generation. It can be used to store large amounts of potential electric energy from the electricity grid and discharge (return energy to the grid) when needed during power disruptions, to offset high load demands or provide a degree of system stability for the demand and supply of electricity. Some forms of RE supply are intermittent by nature and therefore, may not be able to provide energy on demand. Several methods exist that can be used to compensate for intermittent RE supply, such as maintaining an adequate operational reserve[3] or varying demand using specialized systems[4]. ES can provide crucial support for RE, as it is perhaps the technology best suited to manage intermittency of supply. ES is also scalable and can be used for large applications at the generation end or at consumer sites for individual applications, such as back-up power.

ES has existed for several centuries and over time, there have been advances in technology to make the process of storing energy more efficient. A dam[5] is an example of an early ESS. Dams were used to store water with the potential energy to move objects such as waterwheels. Today, with the many advances in ES technology, a complete ESS is composed of several subsystems for its implementation and harmonious operation with other energy sources. ESS differ by technology, methods and principles of operation, and can be categorized into several types. These can be mechanical, electrochemical, chemical, electrical or thermal, and can comprise of the following:

1. **Flywheel** - A mechanical device that is designed to efficiently store rotational energy by virtue of its mass and speed.
2. **Pumped-hydro** – The use of electricity (off-peak) to pump water from a lower reservoir to higher reservoir, for later use in a hydroelectric plant generator during high demand periods.
3. **Compressed Air Energy Storage (CAES)** – The use of electricity to compress air and store for later use to drive the compressor of a natural gas turbine.
4. **Flow Batteries** - The use of two electrolytes in separate tanks, circulated in separate loops to create electricity when a load is connected.
5. **Sodium batteries** – The storage of energy in chemical bonds that is released in the form of sodium ions migrating from anode to cathode and recharging when flowing in the opposite direction.

[3] Generally, a system's operating reserve comprises spinning reserve and non-spinning (supplemental) reserve. The spinning reserve is the extra generating capacity that is available by increasing the power output of generators that are already connected to the power system. The non-spinning reserve is extra capacity that is not currently connected to the system but can be brought quickly online.

[4] Specialized systems include "smart" devices and appliances that can interpret electricity demand and respond accordingly.

[5] A storage area designed to control the flow of a river or store water for various purposes.

6. **Lead-acid batteries** – The use of positive and negative electrodes immersed in an electrolyte solution that facilitate the formation or dissolution of lead to transfer energy through electrons.
7. **Lithium-ion batteries -** The transfer of positively charged lithium ions from the anode to the cathode and vice versa through a separator. The movement of the lithium ions creates free electrons in the anode which creates a charge at the positive current collector.

Each of these ES technologies has shortcomings, which are important to take into consideration when determining the optimal ES application. These are summarized in table 1.

Table 1: Shortcomings of Energy Storage Systems[6]

ES Technology	Shortcomings
Flywheels	• High level of self-discharge from air resistance and bearing losses. • Relatively low energy capacity. • Sensitive to vibration.
Pumped-hydro	• Geographic limitation.
Compressed air energy storage (CAES)	• Relatively low efficiencies compared to battery storage. • Geological limitation. • Relatively difficult to modify for smaller installation.
Flow Batteries	• Reduced efficiency due to rapid charge/discharge. • Relatively high infrastructure cost.
Sodium	• Potentially flammable. • Higher cost for scalable design.
Lead-Acid Batteries	• Useable capacity decreases when high power is discharged and poor ability to operate in partially charged state. • Short lifespan.
Lithium Ion Batteries	• Requires protection circuit to operate within safe limits. • Relatively low life span. • Technology not fully mature.

[6] "Levelized Cost of Storage v2.0" Lazard and Enovation Partners, December 2016.

The ES technologies discussed thus far are those that have been widely deployed. There are emerging technologies and developments that may significantly improve ES performance. Advancements in technology have also improved the reliability and efficiency of electric vehicles (EV) in the transport industry. This leads to the added benefit of providing a form of mobile ES. Liquefied-Air Energy Storage (LAES) is also an emerging technology. It is an innovative application of well-established cryogenic principles, which promises to significantly reduce the cost of ES.[7]

Some of the applications and associated benefits of ES are discussed in greater detail below.

2.1.1 Power Quality

Frequency[8] variation and voltage fluctuation are problems that can affect power quality in the electricity system. ES can improve power quality at the point of generation by facilitating faster response to frequency changes and compensating for voltage deficits and surges, on the electricity grid. Utilities can benefit from ESS installed at strategic locations on the transmission and distribution (T&D) network to help mitigate electricity supply issues such as overvoltage[9]. Additionally, ES can prevent damage to consumer devices by providing voltage support that can mitigate issues, such as voltage drops. Thus, ES provides for improved power quality at different points along the GTD value-chain.

2.1.2 Renewable Firming

Some forms of RE present challenges of intermittency and variability of supply as mentioned previously. For instance, RE sources such as wind and solar are intermittent by nature because they are dependent on the weather. Renewable firming comprises measures taken to guarantee an energy supply from RE sources[10]. Hence, ES enables utilities and consumers to better manage RE sources and optimize the use of energy.

[7] Highview Power, 2019. https://www.highviewpower.com/plants/

[8] Frequency in an electricity system is a real-time variable that indicates the balance between generation and demand. The integration of RE reduces system inertia (the stored rotating energy in the power system). A low inertia power system will encounter faster and more severe frequency deviations in cases of sudden changes in supply or demand.

[9] A sudden undesirable increase of voltage

[10] Warren, M. 2018. “Firming renewables: The market delivers” Australian Energy Council. 2018. https://www.energycouncil.com.au/analysis/firming-renewables-the-market-delivers/

In 2009, the Public Service Company of New Mexico, USA (New Mexico's largest electricity provider) demonstrated that utility-scale battery systems can be used to "firm" solar PV[11] energy. It also demonstrated how battery systems can smooth fluctuations in PV plant output and reduce peak power at the substation. The hybrid ESS consisted of two battery systems; a 0.25MW "shifting" battery system that could store solar energy and discharge it later, when demand was higher, and a 0.5MW "smoothing" battery system that could lessen variations in the output of a 500 kilowatt (kW) PV Plant.[12]

Similarly, RE systems equipped with ES, such as rooftop solar PV systems, can be used as a micro-grid or for self-generation. RE with ES installed at strategic locations on the grid can compensate for power losses and disruptions.

2.1.3 Time Shifting and Peak Shaving

Electric energy time-shifting involves storing excess electric energy produced during periods of low demand (i.e. off-peak) for later use when demand is high (i.e. on-peak). ESSs have been employed in peak shaving to offset load demand and flatten the generation load profile. This can improve the operating efficiency of generation facilities by reducing the dispatch of less efficient generation assets, as it reduces the need for additional electricity production at peak demand times. In this scenario, consumers can benefit indirectly, if these cost savings are eventually passed to them.

Capacity or demand charges are fees charged by the utility for the peak power demand that is required to be available to large load customers during the billing cycle. ES can be used by these customers to reduce their demand charge by offsetting their demand from the electricity grid during periods of peak demand. This provides the consumer with a measure of control over their demand related charges.

2.1.4 Backup & Reserve Capacity

Investing in stored energy can be a less expensive alternative to providing additional generating capacity in the form of spinning reserve[13]. ES may be used in conjunction with a primary electricity

[11] The conversion of light into electricity at an atomic level.
[12] Energy Storage System Firms a Renewable Resource, published by the Department of Energy USA, 2019
[13] Generation capacity which is online but considered unloaded but can respond within minutes to compensate for the lack of generation or transmission of power.

generation source and act as spinning reserve, thereby lowering the operational costs associated with using additional generation. ES also provides swift response to compensate for power outages and generation deficits within seconds. Additionally, utilities benefit from the ability to provide backup power, which allows the network to run more reliably and efficiently in the event of major service disruptions. Use of ES devices in households and small commercial businesses can also give consumers an energy reserve during instances of power interruptions on the electricity grid.

2.1.5 Upgrade Deferral

T&D facilities periodically require upgrades to meet increasing demands. These can be costly and the returns vary with the amount of additional load to be served. Typically, upgrades to accommodate an increase in capacity over 30% are more economically feasible. Utilities can thus defer upgrades for smaller load increases by using ES as an economical alternative to provide the additional capacity required by its T&D facilities. Employing ES at strategic locations where peak demands are highest can therefore postpone the need for investment of costly upgrades to T&D infrastructure and/or investment in additional generation capacity. Consumers also benefit as utilities would now require lower investment costs to be covered in the tariffs.

2.2 Selection of Energy Storage Technologies

When establishing policies for ES integration, the following criteria are important for selecting the most appropriate technologies, given a country's socio-economic and geographical environment: life expectancy, installation cost, operating cost, capacity, energy density[14], efficiency, and cycle life[15]. Table 2 provides standard data for five (5) of these decision-making criteria, with respect to the ES technologies mentioned in section 2.1.

[14] The energy that can be stored per unit volume of the specific storage medium.
[15] The amount of recharges/discharges of the storage technology before its maximum capacity deteriorates.

Table 2: Decision-making Criteria and typical values by ESS type

ES Technology	Expected Lifespan (years)	Energy Storage Installation Cost (USD/kWh)	Energy Density (Wh/L)	Efficiency (%)[16]	Cycle life (cycles)[17]
Flywheel	20+	3,000	110	90 - 95	200,000
Pumped-hydro	20+	21	1	70 - 85	40,000
Compressed Air Energy Storage	20	53	4	70	20,000
Flow Battery	10 – 20	900	45	65 - 80	10,000 – 20,000
Sodium	10	368	220	75 - 90	4,000 – 5,000
Lead-Acid	5 – 10	147	75	65 - 90	1,250[18]
Lithium-Ion	5 – 10	352	410	75 - 96	300 – 2,000

Sources: Adapted from Lazard & Enovation Partners and International Renewable Energy Agency (IRENA, 2017).

Output capacity, measured in megawatts (MW), and energy capacity, measured in megawatt-hours (MWh),[19] are two of the key criteria to be considered when choosing ES technology, especially, for applications where the provision of reserve power/power quality is critical. The energy storage device will be required to reliably maintain the level of the demand over the designated availability period. However, certain criteria, such as energy density, may be given greater importance (weighting) for instances where land space is limited. Hence, it is a more important selection criterion in small island states.

[16] "Energy Storage Technologies White Paper" Port of Long Beach, 2016.
[17] Ghenai, C. & Janajreh, I., 2015. "Comparison of Energy Storage Options and Determination of Suitable Technique for Solar Power Systems"
[18] Derendorf, K. et al. "Comparative Life Cycle Assessment of Battery Storage Systems for Stationary Applications" Next Energy – EWE Research Centre for Energy Technology.
[19] Discussed in greater detail in Section 3.3.6 of this paper.

ES lifespan (or life expectancy) and cycle life may appear to be similar but they are not the same. Lifespan is the average useable years of the ES technology, whereas the cycle life is the amount of full recharge/discharge cycles the storage technology can tolerate before deteriorating from its maximum capacity. Lifespan must be considered in situations where the replacement of the ES technology is expected to occur several decades apart due to the potentially high cost of installations. Conversely, the system's life cycle must be taken into consideration where the ES technology may have the possibility of being completely discharged. Partial discharging and recharging of some ES technologies can extend the useable life of the ES technology. An example of this would be if a battery is discharged to 50% every day, it may last about twice as long as if it were cycled to almost full discharge daily.[20]

Installation cost, operating cost and efficiency are also important criteria. However, the selection of suitable ES technologies should not rely solely on cost, as the least expensive system may not always be appropriate for the task and has the potential to cost more over the longer term. Efficiency can indirectly impact the operating cost of an ES technology because it is a ratio of the useful output of the system to the amount of energy input. Some of the energy output from ES can be lost due to heat or vibration. This can lower the net benefit of the storage technology.

The criteria presented above, in conjunction with the benefits and applications, can guide stakeholders with their assessments of the suitability of ES for their specific circumstances. However, each ESS option should be considered holistically taking into account additional considerations, such as safety and environmental impacts, to ensure that the selected system is the most appropriate for the country.[21] Furthermore, decision makers must be cognizant that some of the criteria are not strictly mutually exclusive.

[20] "Deep Cycle Battery FAQ" Northern Arizona Wind and Sun. 2017. https://www.solar-electric.com/learning-center/batteries-and-charging/deep-cycle-battery-faq.html#Lifespan%20of%20Batteries

[21] Abumeteir, H. & Vural, M. 2016. "The Determining Factors of Selecting Energy Storage Systems for the Renewable Energy Sources in the Energy-Efficient Building" IEC Proceedings. Pp .96 – 101. 2016.

SECTION 3.0 ENERGY STORAGE WITHIN THE CARIBBEAN AND LOCAL CONTEXT

3.1 Energy Storage in the Caribbean

Barbados, Dominica and Jamaica are some of the countries within the region where there is keen interest in establishing ES systems. The electric utility of Jamaica is currently undertaking a project to install the first hybrid ES facility in the Caribbean[22]. The facility will consist of high and low-speed flywheels and lithium-ion batteries with a storage capacity of 24.5MW to help enhance grid stability and improve reliability. Jamaica has a National Energy Policy document, however, no specific targets exist for ES. In terms of licensing requirements, the Minister of Science, Technology and Energy is currently responsible for granting electricity licences to traditional and RE generators as well as energy providers, inclusive of ES. Since ES is usually a component that is combined with RE generation, RE licences cover the ES operations that are attached to RE generation.

In Barbados, the presence of RE within the electricity grid encourages the development of ES. The country's first large-scale solar installation is equipped with a 5MW battery that is integrated into the grid at the St. Lucy solar facility[23]. Barbados has a National Energy Policy document, however, while no specific targets for ES exist, the document notes that the electricity sector should maximize the potential in "using storage technologies to improve the dispatch of supply"[24]. The Electric Light and Power Act (2013), in Barbados, makes provisions for the granting of RE licences to new applicants to supply electricity to the national grid. The electricity utility regulator is responsible for issuing ES licences which specify technical requirements for installations and the operations of ES on the grid.

In Dominica, the electric utility is in the process of restoring the electricity network to full operation in the aftermath of Hurricane Maria (2017), however, some consumers have proactively installed RE systems. These RE systems are equipped with ES technology which can be used to store the energy that has been generated. The Dominica Electricity Services (DOMLEC) is presently exploring the possibility of utilizing ES as it seeks to fully restore its national electricity

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[22] Jamaica Public Service Company "Ground Breaking this week for US$21.6M Hybrid Energy Storage Facility", 2019

[23] "Sustainable Energy Framework for Barbados", 2012 and "Barbados Sustainable Energy Industry Market Assessment Report", 2018

[24] "Barbados National Energy Policy (2017-2037)", December 2017

grid after the damage sustained in 2017[25]. Similar to Barbados, ES companies and DOMLEC must be licensed to operate as an ES provider. The Independent Regulatory Commission (the electricity utility regulator) is the issuer of these licences.

3.2 Energy Storage in Trinidad and Tobago

Unlike many other Caribbean territories, currently, there is no national RE policy and no ES policy in Trinidad and Tobago. Low RE penetration means that ES is not being pursued on a large scale. Additionally, as previously mentioned, the availability of excess capacity may allow integration of a certain amount of non-dispatchable RE without the requirement of backup ES systems. The penetration of EVs, a popular ES medium, is extremely low in the local context.[26] Furthermore, the current infrastructure does not facilitate vehicle-to-grid (V2G) charging[27,28]. However, ES is being used at the consumer level (residential and commercial). Examples of consumer level energy storage are back-up supply for information technology (IT) equipment, closed-circuit television (CCTV), critical equipment at hospitals and other similar applications. ES is also used in some rural areas where consumers are not connected to the grid.

Although a national ES policy does not exist, some key stakeholders such as the Trinidad and Tobago Bureau of Standards (TTBS) and the Environmental Management Agency (EMA) have begun implementing standards and regulations for the production and use of specific ES technologies, such as, lead-acid batteries in the form of starter batteries for automotive applications. The TTBS gives specifications relating to size and density for battery storage production whilst the EMA gives input on the allowed levels of lead that can be used in battery production. The EMA also gives guidelines on the disposal of batteries.

Given the unique circumstances that exist locally, careful consideration will have to be given as to how ES can and should be integrated into the local power sector, which will require further in-

[25] Dominica Geothermal Development Company Ltd "Dominica Reviews First Phase of Sustainable and Resilient Energy Plan". 2018
[26] See "Energy Road Map papers: Advancing Electric Vehicle Adoption in T&T", RIC Staff Discussion Paper, August 2019.
[27] A system that enables plug-in electric vehicles to connect to the power grid and return electricity to it on demand.
[28] *Ibid, 26.*

depth study. This assessment of the local power sector should consider the need for ES, the major costs, benefits and other implications of establishing an ES sub-sector. The results of this assessment will inform the potential viability of an ES market in Trinidad and Tobago. If an ES market is found to be potentially viable, there are factors which must be taken into consideration for the formulation of an ES policy for Trinidad and Tobago and these are discussed below.

3.3 Considerations for ES Policy in Trinidad and Tobago

Several factors must be considered when formulating a policy for the integration of ES within the electricity sector, and these are discussed in Sections 3.3.1 – 3.3.6 below.

3.3.1 The establishment of targets for ES within the Electricity Sector

The Government of the Republic of Trinidad and Tobago (GoRTT) has signaled its intention to incorporate RE into the energy mix. This includes the incorporation of between 3 MW and 130MW of Solar and/or Wind resources into the national grid. Consequently, the decision to pursue RE will also bring into focus the extent to which ES will be deployed alongside RE infrastructure. Since ES supports the dispatch of RE on demand, it is imperative that RE coupled with ES be considered for both its technical and economic benefits. Over the long term, greater RE penetration in the current electricity sector may see a new era of decommissioned excess power generation and peaking plants, as the value of ES becomes more prominent.

Hence, one of the first steps is to decide whether specific ES targets/goals should be established. The experiences from countries that are world-leaders in use of ES are varied. On the one hand, ES goals can be clear and easily measurable, as is the case in some jurisdictions in the USA, such as, Arizona[29] and New York[30]. The RE markets in these areas are well established and make use of ES to bolster RE targets. Hence, the demand for ES is a derived demand based on the targets set for RE generation. For example, in New York in 2018, energy capacity was 7,315 MW and the New York Energy Storage Roadmap included the goal of deploying 1,500 MW of stored RE by 2025[31]. Additionally, establishing specific ES targets has legal and regulatory implications.

[29] Energy Storage News: Arizona utility's 950MW solar-plus-storage plan: 'clean energy and clean air', 2019.
[30] New York State Energy Research and Development Authority, 2019.
[31] A target of 20.5% of renewable energy capacity is to be stored by 2025.

Entities such as utilities and energy companies are mandated by law to achieve a certain level of stored energy by a specific time. In the jurisdictions cited above, ES legislation requires the utility regulator to develop guidelines as they relate to technical specifications of ES projects, while entities are required to furnish descriptions of the types of ES services to be provided and the estimated overall costs of the projects. Some countries have chosen to include ES targets in RE legislation, and it is usually in conjunction with other industry requirements.

On the other hand, Germany and France[32] are examples of countries where there are no specific targets for ES capacity; the desired ES capacity is pegged to other distributed generation (DG)[33] targets such as RE targets. In the case of Germany, there is no official ES target to be attained over time. However, there is an explicit RE target that the energy market is expected to reach. ES services are complementary to RE generation and as a result, ES capacity can change over time proportionate to RE targets.

Potential investors may be cautious in making large, long-term capital investments in such cases where national targets are not clearly articulated. However, from the country experiences presented above, given that ES is generally a derived demand, the critical national target may not be an ES target but the establishment of a specific RE target. This is perhaps the most feasible approach for Trinidad and Tobago.

3.3.2 Obligations to International Agreements

Government's commitment to international treaties may influence its policy position as it relates to ES. The Kyoto Protocol, the Paris Agreement and the Rio Convention are examples of international agreements ratified by GoRTT, that pertain to the issues of decarbonization and climate change. The main objective of these agreements is the reduction of greenhouses gas emissions. These agreements and consequential country obligations can influence the government's ES policy direction since they are hinged on the use of RE sources, and hence, a derived demand for ES can be established.

[32] The Energy Transition Law, France.

[33] A variety of technologies that generate electricity at or near where it will be used, such as solar panels and combined heat and power

3.3.3 Penetration of Distributed Generation

In most jurisdictions, electricity generation has traditionally been done at centralized facilities. Under a centralized generation structure, the failure of a generator can lead to major power outages. Shifts towards improved efficiency and reliability through decentralization can be made possible by facilitating more localized storage of energy, using ES.[34] Therefore, DG can be beneficial by reducing the negative impacts of interruptions in the traditional energy generation grid. These benefits of decentralization are becoming more recognizable, therefore, countries are expressing deeper interest in establishing ES systems. However, the decisions to decentralize and to employ ES will require substantial input and advice from T&TEC, which operates the T&D grid. The decision to decentralize is also dependent on the policies instituted to promote small-scale RE development, inclusive of a Feed-in-Tariff (FIT) policy[35].

3.3.4 Classification of ES – Implications for the Definition of Energy Storage

In light of the functionality of ES devices, there is some debate as to how ES should be classified. Both the regulator and the utility company have significant roles in advising the government on how ES devices on this issue, that is, whether as solely generation or alternatively, as GTD devices. In some jurisdictions[36], ES devices are considered as *sui generis* generators and they are treated as such with regards to cost allocation and being held to technical requirements. The supporting rationale is that ES devices regenerate energy that can be transferred to the grid and consequently, ES devices are regarded as generation units.

When ES devices are classified as generation devices there can be major market implications. Existing regulations may prevent T&D companies from investing and participating in generation (ES) markets. Conversely, where ES is classified as GTD, this may prevent companies involved in generation from investing in ES at the T&D level.

In Canada, ES devices are treated as GTD devices in the legislation. This jurisdiction is of the view that ES devices not only regenerate energy, but also provide T&D services referred to as grid utility

[34] United States Environmental Protection Agency. “Distributed Generation of Electricity and its Environmental Impacts” 2018.
[35] At the time of writing, the FIT policy for Trinidad and Tobago is still under development.
[36] In some states in the USA such as: California and New York and other jurisdictions such as Norway.

support system[37]. These ES systems distribute electricity primarily to remote areas where electrification is low.

In the United Kingdom (UK), Ofgem[38] has consulted on instituting a modified generation licence, which clarifies ES as a subset of generation and the industry codes for storage. It also enables the licence holder to avoid the overpayment of consumption levies.[39] In December 2018, Ofgem instituted a new standard licence condition which prohibited distribution network operators from carrying out any generation activity, including ES, unless the activity is captured by an exception or the licence issued with a specific direction.

Thus in certain jurisdictions, because of unbundling requirements, T&D operators are not allowed to directly own or control ES infrastructure, which ensures that the market remains competitive. However, this can have a number of disadvantages since storage can add value along the entire electricity value chain. Currently in Trinidad and Tobago, the electricity market is not a competitive one[40] hence it can be argued that distorting competition in the generation and supply markets is not an issue at this time. Therefore, it may be suitable to initially define ES as generation in the local context. Alternatively, if ES is classified as GTD in Trinidad and Tobago, it can be used at all levels of the electricity value-chain and its benefits can be optimized. However, if Trinidad and Tobago were to move to competitive markets, there would be various implications for classifying ES technology as GTD devices. Therefore, defining ES as GTD may be more applicable in the long run. These include the ability and extent to which a stakeholder is able to participate in the ES market. This is a decision that has to be made with consideration given to the appropriate mode of introduction and business model, which is discussed below.

3.3.5 Scale of Deployment

Another factor that should be considered for ES policy planning is the intended scale of ES deployment. The scale of ES deployment refers to the extent and manner by which ES is incorporated into the existing electricity grid. The two main approaches to ES are large-scale

[37] Richardson, S. "Storage Has a Vital Role" T&D World, 2017.
[38] Office of Gas and Electricity Markets, the electricity regulator in England and Wales.
[39] "Upgrading our Energy System Smart Systems and Flexibility Plan: Progress Update", 2018 Ofgem.
[40] While there are different operators in the generation sector, they all operate by virtue of long term supply contracts (Power Purchase Agreements) and do not directly compete for market share. T&TEC is the sole transmission and distribution authority, and continues to own and operate generation facilities in Tobago

deployment and small-scale storage. Both scales of deployment can occur simultaneously, as in the case of Germany. Large scale deployment of ES refers to a combination of all ES technologies connected to the grid with a capacity of 50MW and above[41] and are usually associated with commercial activity. Utilities and private energy companies usually utilize a large-scale approach to supply electricity to the national grid. Small scale deployment refers to ES technologies with a capacity of less than 50MW and usually takes place at a consumer level for own-use or prosumer[42] level. When deciding on the scale of deployment, one must consider the benefits of each approach.

One major benefit of both approaches is cost savings. Large scale storage can provide cost savings for utilities however, there is no guaranteed cost reduction for the end user if the existing cost structure is not revised to reflect these savings. Small scale deployment means that these users are able to self-generate and benefit from these savings. However, it is necessary to also take into consideration the possible implications in terms of the number of end-users turning towards self-production and local storage. This can impact the revenue streams of grid operators and their ability to maintain the serviceability of the grid, which can in turn result in increased tariffs for those customers who are supplied by the utility.

It is clear that, while energy storage can be economically beneficial to the key stakeholders, there is a trade-off between the amount of self-generation that can be allowed versus the need to maintain serviceability of the grid. Thus an in-depth study, to determine the value and corresponding costs attached to the various applications of ES locally, should be done to determine the most appropriate combination of large and small scale deployment of ES. This study should specifically evaluate the impact of the deployment of ES on the utility inclusive of its finances as well as the role ES in RE firming given the unique circumstances that exist locally. Therefore, government policy and regulatory frameworks should by carefully developed to plan and manage the amount of ES capacity within the energy mix.

3.3.6 Costs of Energy Storage

Cost is a major factor to be considered when formulating policy, setting targets and deciding on the mode and the scale of ES deployment. The cost of an ES project is a key factor that will affect

[41] Balasubramanian Pinnangudi, Shoham Bhadra "The Power Grid", Elsevier. 2017
[42] Prosumers are those who generate their own power from distributed energy resources.

its feasibility. Researchers at Bloomberg estimate that over USD $600 billion will be invested in the ES market globally between 2018 and 2040[43]. This is due to the various realizable benefits of ES in conjunction with falling costs. Two significant criteria that influence the cost for ES technology are power output and energy capacity[44]. Power output, measured in megawatts (MW), is the output capacity that the ES device can deliver at a given point in time. Energy capacity is measured in megawatt-hours (MWh) and specifies the total amount of energy the ES device can store. When deciding on an ES technology, it is useful to examine these two ratings against the intended use of the device. The annualized cost would be less for ES devices with longer life spans because the cost can be spread over a longer period of time.

As with other related technologies, the cost for ES devices has been declining over the years and is expected to continue on that downward path, however, there are other expenses that decision makers should consider before launching an ES project. Another major cost attached to the ES market are interconnection costs[45]. Interconnection costs can be viewed as an impediment to investing in the ES market due to the high costs of hardware and other resources necessary to connect ES devices to the grid. In some parts of the United States, interconnection costs associated with jurisdictional upgrades to the grid to accommodate ES by third parties are fully reimbursable over a five-year period. Smaller ES projects may be foregone due to a lack of financial viability when there are high interconnection costs and low estimated revenue inflows. Currently the cost of ES is relatively high for consumers. Other factors that may also have a cost implication and therefore, need to be considered, were discussed in Section 2.2. above.

3.4 Options for ES Deployment

The structure of electricity markets can vary among countries and this can impact on the approach utilized to bring ES onto the grid. In open market jurisdictions such as Denmark and Germany, where there is competition among private ES entities in the market, this encourages higher standards of service and lower prices for the end user. At the other end, there are also instances where countries choose not to open their electricity sector to private investors, but position the ES function within the existing utility[46]. A major benefit of this approach is that utilities can easily

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[43] Forbes Magazine. “Battery Energy Storage is a $620 Billion Opportunity as Costs Continue to Crash”. 2018.
[44] Office of Energy Efficiency and Renewable Energy. “Solar-Plus-Storage 101”. 2019
[45] Costs attached with connecting ES devices to the grid.
[46] Australia, Belgium and New Zealand.

integrate storage into long-term resource planning. Countries can also choose to incorporate various elements of both of these variants to establish functioning ES markets. In-depth assessments by key stakeholders can assist in determining the best suited model given local legislative, regulatory and economic factors.

The three most common or primary approaches from various country experiences can be characterized as the market-based model, the utility-owned model and the state-investment model. The first two models are differentiated on the basis of ownership of the asset. It can be argued that the state investment model is more of a financing mechanism rather than a third option, as the state either funds the asset directly or through the creation of a private company, while the utility owns the asset.

The choice of model will determine how the ES sub-sector is managed. Some aspects of these models are discussed further below.

- **The Market-Based Model**

In this ES business model, the government's role is to create a platform from which several market participants can engage. Through a successful bid, an independent ES company enters into a medium to long term contract with a utility provider[47]. Additionally, the owner of the ES system receives a fixed fee (usually on a monthly basis) from the utility provider for rights to charge and/or discharge the storage system within parameters that have been agreed upon in the contract. This fee is essentially a reservation charge, payable to the ES company for providing reserved capacity to the utility's customers, in areas and at times where the utility has difficulty to meet peak demand from generation.

Prior to the deployment of any ES system, the operations of the independent ES company must be approved by a regulating body with respect to a number of criteria. These include system details, work requirements, specifications for the design, construction and operation of an ES facility and any associated transmission system connection facilities that connects the ES company to the national grid. The ES market in Jamaica follows this market-based model.

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[47] Power Engineering "Merchant Power" https://www.power-eng.com/articles/print/volume-102/issue-4/products-literature-showcase/merchant-power.html 1998.

A main advantage of this model is that the ES company provides a guarantee of a pre-determined degree of availability of the ES plant at all times, as well as the assurance of certain efficiency levels[48]. However, the purchaser assumes off-taker risks through the guaranteed purchase agreement.

- **Utility-Owned Model**

This model entails electricity utilities investing directly in ES[49]. These utilities may be state-owned or private, and may be involved in traditional carbon-based or RE generation. Utilities have been more inclined to make significant investments in ES over recent years owing to more favorable cost and performance characteristics of ES technology. In this model, the utility acts as an all-encompassing platform, retaining responsibility for safety and reliability as well as planning investment and ownership of distributed and utility-scale generation. In some regulated markets, such as in the USA and in Germany, the sector's economic regulator is responsible for evaluating utilities' requests and granting them permission to establish ES systems.

Utilities possess an in-depth understanding of the technical capabilities and requirements of the electricity network, and hence ES technology can be more seamlessly applied to the electricity system. However, the utility must obtain financing and in some instances increase its internal expertise in the particular technology. Some examples of jurisdictions using the utility-owned model are China, Singapore and Russia.

- **State Investment Model (State Funded)**

In the state investment model, the government is the major investor in ESS[50]. The government funds ES projects either directly or through an intermediary, such as a private ES company. In the case of the latter, the government appoints the agency to manage the ES fund as it relates to the application procedure, vetting of applications and the granting of funding. This model allows for coordinated funding efforts among various projects, such as, those that are categorized under the 'Advancing Renewables Programme' in Australia[51].

[48] Asian Development Bank "Handbook on Battery Energy Storage System", 2018.
[49] McKinsey & Company "The new economics of energy storage", 2016.
[50] U.S. Department of Energy – Office of Technology Transitions. "Solving Challenges in Energy Storage". 2018
[51] "$50 million fund to support new energy storage projects to make electricity more affordable and reliable in SA" Australian Government, Department of Energy. 2018.

State-owned energy companies can have access to government funding in addition to favourable financial instruments such as lower rates of interests on loans. However, state-owned and operated companies are more susceptible to political influence, which can have a negative impact on the company's governance.

Choosing the most suitable business model for ES services requires careful consideration of the advantages and disadvantages of each approach, as well as local conditions. In this regard, access to financing and technical expertise are critical factors for consideration. Irrespective of the deployment model selected, cost considerations should entail, but not be limited to, administrative, capital, interconnection, human resource training, real-estate and maintenance costs. Some costs are mandatory for any model selected such as capital cost, interconnection and administrative costs. Notably, some costs are selective and flexible depending on the business model, such as human resource training, real estate and financial incentive expenses.

The market-based model may have the most potential in Trinidad and Tobago over the longer term as it provides an opportunity to obtain the requisite expertise and allows for some of the financing risk to be transferred to the private sector. ES companies possessing some level of experience in the field may be able to secure financing at favourable rates and can be contracted to provide the service required by the utility. There is also the opportunity to employ a hybrid model, however, this will require in-depth analysis of the local environment. It is noteworthy to mention here that local conditions in the short term may favour small scale deployment, which may require a certain level of state support.

3.5 Current Legislation: Opportunities and Challenges

Several jurisdictions have enacted legislation that specifically addresses the use and treatment of ES, such as New Jersey, California and Germany. There are some areas of similarity among ES legislation in various countries which focus primarily on: the definition and categorization of ES devices; the inclusion of ES as a component of the energy system; and the granting of responsibilities to various bodies to ensure a sustainable ES system.

Even though some jurisdictions have enacted holistic ES legislation, it is also possible to have fully functional ES markets without explicit legislation, as in the case of France. Specific legislation is therefore not a necessary requirement for the successful deployment of ES.

At this time, there is no ES legislation, primary or supplemental, that specifically addresses ES for the electricity sector in Trinidad and Tobago. In accordance with Section 31 (2) (ac) of the Trinidad and Tobago Electricity Commission Act Chapter 54:70, T&TEC is at liberty to purchase energy from an approved generator of electricity with the consent of the Minister. This provides an opportunity for T&TEC to possibly purchase stored energy. Further, Section 66 (1) (b) precludes non-licensed entities from supplying the grid with energy (stored or otherwise). Hence, these third parties would need to obtain the requisite licence to operate. This also precludes residential customers from discharging stored energy to the grid.

It is important to note that if the market structure of the electricity industry in Trinidad and Tobago were to be changed to accommodate competition, there would be a need for appropriate legislative changes to facilitate this. The particular changes to legislation which are appropriate for Trinidad and Tobago require further assessment, as successful ES markets depend heavily on a facilitative environment, which is largely dependent on legislation.

3.6 Regulatory Considerations

The Regulated Industries Commission (RIC), is the economic regulator of the electricity sector in Trinidad and Tobago. If the utility, or any other entity falling under the purview of the regulator, engages in ES activities, the RIC will be responsible for developing the methodology to allow for the costs associated with ES activities to be recovered.

The RIC is responsible for establishing the principles and methodologies by which service providers determine rates for services. ES devices can be combined with RE technologies to supply free intermittent energy to the grid as a dispatchable resource. In the case of RE generation, net metering allows customers to save on electricity bills by compensating appropriately for self-generation that is sold back to the grid. Other mechanisms include net billing and FITs. Therefore, there is the need to develop a suitable mechanism and rate for energy sold back to the grid for small-scale RE.

Hence, issues that need to be considered by the regulator include:

- The use of a standardized cost-benefit analysis to determine the viability of ES projects, in the case of the utility-owned ES model as well as the method to be used to determine how the utility will cover its investment costs for capital and operational expenses on ES equipment and systems.
- The method of compensating small-scale consumers for energy that they have supplied to the grid e.g. non-cash credit on bills.
- Its role, if any, in licensing ES providers.

Other regulatory implications include the establishment of technical and environmental standards which may vary according to the element of the GTD value-chain. This will also have implications for stakeholders and the appropriate regulatory bodies

SECTION 4.0 RECOMMENDATIONS FOR ENERGY STORAGE ADOPTION IN TRINIDAD AND TOBAGO

The current status of the local energy sector provides both opportunities and challenges for the establishment of an ES market. Supportive policy instruments such as RE targets and commitments to international agreements and falling ES costs encourage its emergence. However, excess generation capacity and low RE penetration hinder the efficient establishment the market. Thus, careful consideration must be given to all factors in order to formulate a way forward for ES in Trinidad. It is important to note that as a first step GoRTT would need to conduct the in-depth assessment to determine the viability of an ES market, inclusive of role of ES in the electricity sector and the pace and scale of deployment over the medium to long term.

The establishment of a viable ES sub-sector will require the major stakeholders, government, regulator and service provider, to play their part in facilitating the establishment and proper management of ESS locally.

The following recommendations are suggested for the GoRTT, the regulators and the utility.

GoRTT should:

- Conduct an in-depth assessment to determine the viability of establishing an ES market in Trinidad and Tobago. This assessment should consider the need for ES, the major costs, benefits and other implications of establishing an ES sub-sector. This study should also evaluate the current legislation, regulations, policies, market opportunities and limitations that can affect the roll-out of an ES sub-sector to ensure the functioning of a fair and transparent market.
- Consider initially defining and classifying ES as Generation. An exception can be made for T&TEC, as the sole transmission and distribution operator, to utilize ES in its operations as it sees fit, provided that the asset is owned and operated by T&TEC. Subsequently, implications of classifying such devices as Transmission and Distribution devices should be fully explored in the in-depth assessment.
- Consider the various business models inclusive of the Market-Based Model (or a suitable hybrid) as options for deploying large-scale ES in Trinidad and Tobago over the medium to long-term. Successful independent power producers (IPPs) already operate in the local

electricity sector. Some of the lessons learnt from contracting the IPPs and establishing the generation market can be applied to efficiently develop the potential ES sub-sector.

The Regulators:

The Economic Regulator (Regulated Industries Commission) should:

- Examine the costs and benefits for establishing an ES system, where the investment is to be undertaken by T&TEC and give consideration for the cost to be recovered through tariffs. It is important to determine the financial viability of ES and decide the mechanism for cost recovery.
- Determine how consumers will be compensated for the energy they export to the electricity grid; once appropriate policy decisions are taken.
- Play an integral role in the granting of ES licences in instances where the ES activities are to be provided on a large scale by independent ES providers. The approach currently sanctioned by the RIC Act allows the RIC to give advice to the Minister for the award of licences. If ES is regarded as Generation, a decision will also need to be made on whether the same licence conditions that will apply to conventional generation can be used for ES operators.

The Technical Regulator (the Electrical Inspectorate) in conjunction with T&TEC should:

- Develop technical standards and regulations for interconnection of ES devices to the electrical grid and monitor installations.

The Utility (Trinidad and Tobago Electricity Commission) should:

- Explore the applications of ES technologies to determine the feasibility of improving its operations and service delivery, including options for alleviating congestion on the network. ES should be considered as part of the utility's strategic and operational planning. The utility should ensure that deployment is done in a manner that optimizes reliability and efficiency of the electricity grid.