SAARC ENERGY CENTRE ISLAMABAD

ISGF India Smart Grid Forum

STUDY ON DEVELOPMENT OF ROADMAP FOR IMPLEMENTATION OF SMART GRID-CONCEPTS, PRACTICES AND TECHNOLOGIES IN SAARC COUNTRIES

VOLUME 1

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Executive Summary

The South Asian Association for Regional Cooperation (SAARC) comprising of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka accounts for 21% of world population in a relatively small land area of about 3% of the world. Though, SAARC region is endowed with a fairly large potential of diverse energy resources like hydropower, coal, gas, solar and wind, the exploitation and utilization of these resources could not be effectively achieved so far. Consequently, the average percapita consumption of electricity in the SAARC region is 576 kWh per person per year which about one-sixth of the world average of 3,100 kWh. The SAARC nations also depends excessively on fossil fuels which many of them are importing leaving them exposed to price fluctuations in the volatile international energy markets as well as pose serious threat to nations energy security and increasing levels of GHG emissions. All the SAARC member countries have accorded Paris climate agreement and set limits for their Intended Nationally Determined Contributions (INDC) and are working towards energy transition to cleaner and efficient energy production and usage.

Socioeconomic development, industrial competitiveness and people's well-being and overall efficient functioning of the society is dependent on access and availability of safe, secure, sustainable and affordable energy. Looking forward, it is important that SAARC nations have reasonably priced and environmentally sustainable energy resources to support economic growth and attract investments in the region that will provide jobs and prosperity throughout the SAARC region. The emerging philosophy for low carbon development is to electrify almost all human activities including transport and agriculture to the extent possible and decarbonize the electricity sector through mix of renewable energy and energy efficiency.

Globally, the electric grid which is considered as the greatest invention of the 20th century that made every other invention possible, is today at the threshold of a paradigm shift. The electric grid is being modernized with the overarching goals of Decarbonization, Decentralization, Digitalization and Disintermediation. The visible changes taking place are:

- With the increasing share of generation resources being added at the distribution end, the traditional boundaries between generation, transmission and distribution is fast disappearing
- With consumers becoming "prosumers", the grid that is built for one-way flow of electricity is now experiencing bi-directional flow of electrons
- With decreasing cost of energy storage solutions, there is already a debate on whether to invest in transmission or in storage – the choice between "Generation + Transmission + Distribution" and "Distributed Generation + Storage + Distribution" is becoming real. This is even more relevant in regions where T&D losses are very high as with distributed generation there are fewer network losses
- Loads have changed – Incandescent lamps and induction motors that could accommodate frequency and voltage excursions comprised majority of the load on the grid in the past. The present-day digital loads require quality power at constant frequency and voltage real time basis with predictive forecasting
- Power purchase is moving from Volumetric Tariffs to Transactive Tariffs as Inflexible Demand has become Price Responsive Demand

- The “Merit Order Dispatch” has graduated towards an “Energy Efficient and Environmentally Responsible Dispatch” regime
- Solar PV has already achieved grid parity in many parts of the globe which is about to unleash a rooftop PV revolution and with quantum wind power implementation, Hybrid Renewables Solar +Wind will add to the Power Generation in a big way
- Large fleets of Electric Vehicles that can be aggregated as virtual power plants which could support short term supply-demand balancing will make the grid even more dynamic and complex

In the traditional electric grid, the ability to monitor power flows and control it in real-time is limited to high voltage networks which are equipped with automation systems. In the low voltage network, the power system operator has no visibility on who is consuming how much electricity when and where. In a smart grid equipped with sensors and smart meters which are connected to computers in the control room, it is possible to remotely monitor and control the flow of electricity in real time to every customer or even to every smart appliance inside a customer’s premise. So, the evolving smart grid of the 21st century will be drastically different – the grid will soon emerge as the **“grid of things”** like how the internet is evolving as **“internet of everything”.**

Smart Grid:

Smart grid is the electric power system with advanced automation, control, information technology (IT) and operational technology (OT) systems that enables real-time monitoring and control of power flows from sources of generation to sources of consumption. Smart grid solutions comprise of a set of technologies to enable these functionalities and help manage electricity demand in a sustainable, reliable and economic manner. Smart grids can provide consumers with real-time information on their energy use, support pricing that reflects changes in supply and demand, and enable smart appliances and devices to help consumers exercise choices in terms of energy usage.

“Smart grid is an electricity grid with communication, automation and IT systems that enable real time monitoring and control of bi-directional power flows and information flows from points of generation to points of consumption at the appliances level.”

Smart Grid Roadmap for SAARC Nations:

While these transformational shifts are taking place in most regions, the countries in SAARC region are yet to achieve the goal of universal access to electricity to their citizens. The focus therefore should be to expand electricity generation, grid extension and modernization leveraging emerging smart technologies which will transform the power systems of SAARC nations to smart grids at marginal cost. Since most of the infrastructure that will support the economy in 2050 are being built today, SAARC nations have the enviable opportunity to build the new infrastructure as smart infrastructure which are grid interactive and energy efficient. Transition to a cleaner power system will insulate the SAARC countries from price spikes of fossil fuels and will be cheaper in the long run. For example, cost of electricity from solar and wind resources will be stable for 25+ years. In this transitional stage there may be disruptions and requirement for large investments. However, this transition could be managed efficiently through long-term planning and regional cooperation. A large SAARC grid with diverse mix of energy resources could address the region’s needs more effectively and efficiently rather than each country fighting their battles separately. In the planning process it is imperative to include all stakeholders and sufficient care may be taken to protect the interests of low-to-medium income groups and other vulnerable sections of the society. The long-term pursuit would be to boost productivity and quality of life of future generations by helping ensure reliable supply of electricity at affordable cost which is increasingly clean and sustainable.

It is a very pertinent and timely step that SAARC Energy Centre has taken to prepare Smart Grid Roadmap Study for SAARC countries and India Smart Grid Forum has prepared this report considering the diversity amongst the SAARC nations in terms of size, economy, geography, state of development of the electric power systems and the market structure as well as the national priorities. The smart grid roadmap recommended in this report is based on the analysis of data gathered from secondary sources which are though old, but from reputed sources. We have used approach of Smart Grid Maturity Model (SGMM) to suggest a systematic framework for utilities in the SAARC nations to navigate their smart grid journey. Due to lack of power grid in Maldives, ISGF has given basic recommendations for the country. SGMM can only be suggested where a proper grid infrastructure is present.

Smart Grid Maturity Model:

SGMM is a decision-making framework tool developed by a set of forward-looking electric utilities from USA, Europe and Asia during 2006-08. The tool was handed over to the Software Engineering Institute (SEI) of Carnegie Mellon University, USA in 2009 which is the custodian of the tool now. The model describes eight domains, which contain logical groupings of incremental smart grid characteristics and capabilities that represent key elements of smart grid strategy, organization, implementation, and operation. Utilities use the SGMM to assess their current state of smart grid implementation, define their goals for a future state, and generate inputs into their road-mapping, planning, and implementation processes. Hundreds of utilities around the world have used SGMM for their smart grid journey.

Overview of the Model:

The SGMM describes 8 domains containing logical groupings of incremental smart grid characteristics, which represent key elements of smart grid strategy, organization, operation, and capability.

SMR	**Strategy, Management and Regulatory** Vision, Planning, Governance, Stakeholder, Collaboration	TECH	**Technology** IT Architecture, Standards, Infrastructure, Integration, Tools
OS	**Organization and Structure** Culture, Structure, Training, Communications, Knowledge Management	CUST	**Customer** Pricing, Customer Participation & Experience, Advanced Services
GO	**Grid Operations** Reliability, Efficiency, security, Safety, Observability, Control	VCI	**Value Chain Integration** Demand and supply Management, Leveraging market opportunities
WAM	**Work and Asset Management** Asset monitoring, Tracking 7 Maintenance, Mobile workforce	SE	**Societal and Environment** Responsibility, Sustainability, Critical Infrastructure, Efficiency

Figure 1: Domains of SGMM

SGMM navigation process is a five-phase, expert-led process as illustrated below:

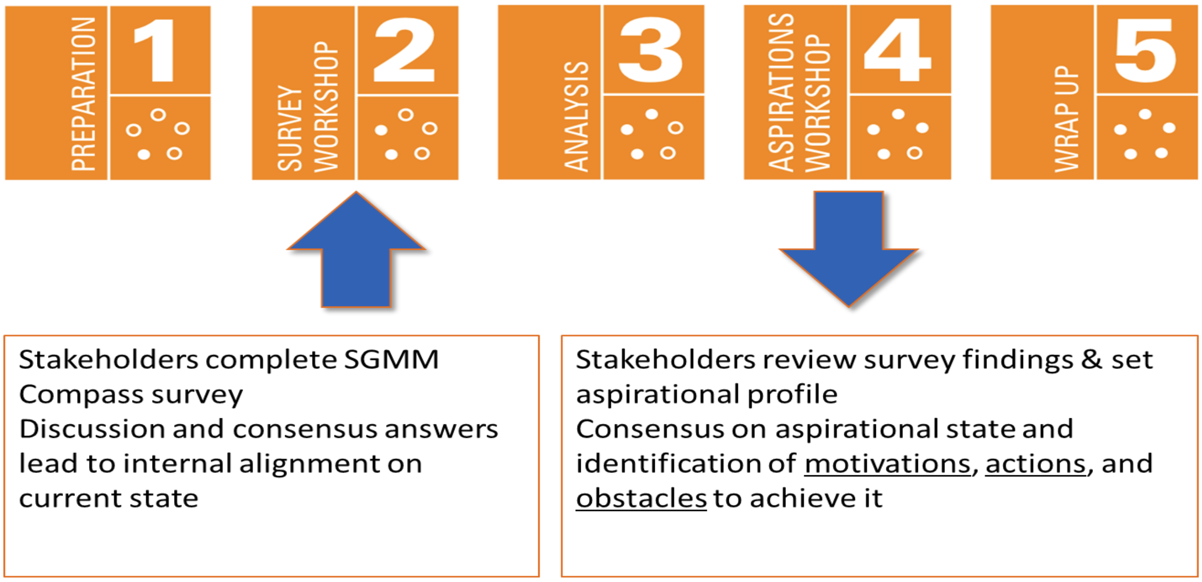


Figure 2: Five Phases of SGMM Navigation

SGMM Levels:

Figure 3: Smart Grid Maturity Model – levels

The compass survey results will determine the AS-IS state of the utility in each of the 8 domains. Thereafter, the key stakeholders of the utility can brainstorm to decide which levels in each of the domains they wish to take the utility in five, ten- or fifteen-year horizon. Once that TO-BE state is decided, different pathways to ascend to higher levels of maturity and technology options and its cost-benefit analysis can be undertaken in a systematic manner. That is the advantage of the SGMM tool.

Benefits to the Utility:

Many utilities have reported that the SGMM comparison yields additional insights about their smart grid progress and plans. Major investor-owned utilities and small public power utilities alike, in the US and around the world, have reported finding the model a valuable tool to help them:

- Identify where they are on the smart grid journey
- Develop a shared smart grid vision and roadmap
- Plan for technological, regulatory and organizational readiness
- Assess resource needs to move from one level to another
- Create alignment and improved execution
- Communicate with internal and external stakeholders using a common language
- Prioritize options and support decision making
- Compare against themselves over time and to the rest of the community

Some of the SAARC nations have just one electric utility and few of them have over dozens of them. Within the country itself, the regions and utilities are in different levels of maturity. In the case of India, the private utilities serving metropolitan cities are at par with utilities in developed countries whereas some of the state government owned utilities are in primitive stages. Hence the recommendations in this report are generic in nature for each country. We have assumed that at least some of the utilities are at initial stages (level-0 in SGMM) in each country and made the recommendations how they can ascend higher levels of maturity. If a utility is already at level 1 or 2 in a particular domain, they can ignore the steps to be taken to reach those levels and rest of the recommendations can be followed.

In general, it is recommended that each country may advise the utilities to undertake SGMM survey and prepare the utility specific roadmap depending on their present levels of maturity and business priorities.

Brief Description of the Contents in this Report:

Chapter 1 provides the broad objective, scope and approach of the study. Smart Grid Maturity Model (SGMM) is also explained in detail here.

Chapter 2 is an introduction to Smart Grid, its components and the various smart grid applications such as SCADA, DMS, GIS, Advance Metering Infrastructure, Distribution Transformer Monitoring System, Outage Management System, Enterprise IT Systems etc. In addition, some select case studies that portray the usage of these smart grid applications in different utilities are also included in this section.

Chapter 3 presents country-wise details of the existing power systems, demand-supply scenario, planned transmission and distribution projects, development and integration of renewable energy, smart grid drivers and policy landscape; and recommendations for smart grid developments by utilities in each of the SAARC countries. Cost benefit analysis of one relevant project for each country has been included in this section.

Chapter 4 discusses the way forward for each member states in terms of policy and regulations, standardization, capacity building, customer engagement, organisational structure and investment facilitation in a phased manner needed for the smooth transformation of the existing grids to smart grids.

1 Project Overview

The South Asian Association for Regional Cooperation (SAARC) comprising of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka constitute:

- 21% of world population
- 3 % of world area
- 576 kWh/ per capita[1] of energy consumption

The SAARC region is endowed with large and diverse energy resources like hydropower, coal, gas, solar, wind and other forms of renewable energy which are yet to be harnessed to their full potential. For example, Nepal and Bhutan has a huge hydropower potential of 83 GW and 30 GW respectively whereas India has huge reserves of 90 billion tons of coal and Bangladesh and Pakistan are bestowed with an extensive gas reserve of 8 and 33 trillion cubic feet respectively[2]. However, excessive dependence and exploitation of fossil fuels and poor achievement in development of hydroelectric plants have left these countries crippling with continuous demand supply imbalance for years. This has urged the governments to look for alternate source of energy such as renewable sources, cross border trading options and off- grid options to act as a stop gap arrangement in the existing demand supply scenario and to harness these resources in future to its fullest potential to ensure energy security. Transmission and distribution systems also lack in terms of capacity as well as efficiency in operation leading to huge network losses, ageing assets, inefficient metering and billing along with policy and regulatory challenges.

Table 1: SAARC Countries - Energy Potential

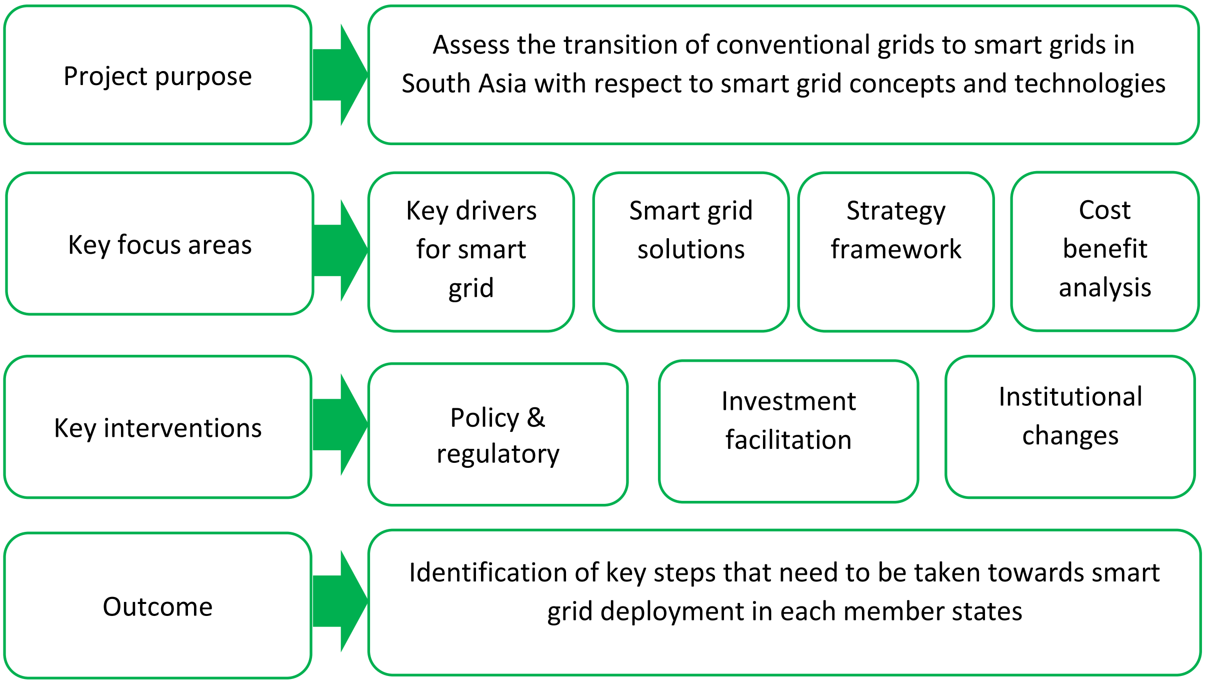
Country	Coal (million tons)	Hydro (GW)	Natural Gas (Trillion cubic feet)
Afghanistan	440	25	15
Bhutan	2	30	0
Bangladesh	884	0.33	8
India	90,085	150	39
Maldives	0	0	0
Nepal	NA	83	0
Pakistan	17,550	59	33
Sri Lanka	NA	2	0

Development and integration of large-scale renewable generation resources, refurbishment of ageing networks, energy efficiency measures and improvement of system reliability require adoption of latest technologies in the most cost-effective manner and thus smart grid is the way forward for SAARC nations. A roadmap for smart grid implementation in electric utilities in the SAARC member states is the immediate need for sustainable progress of the power system both technically and economically.

[1] https://sari-energy.org/wp-content/uploads/2018/09/1.Overview-of-SARI-EI-Innaugural-New-Logo-vkk.pdf
[2] SARI/IRADe

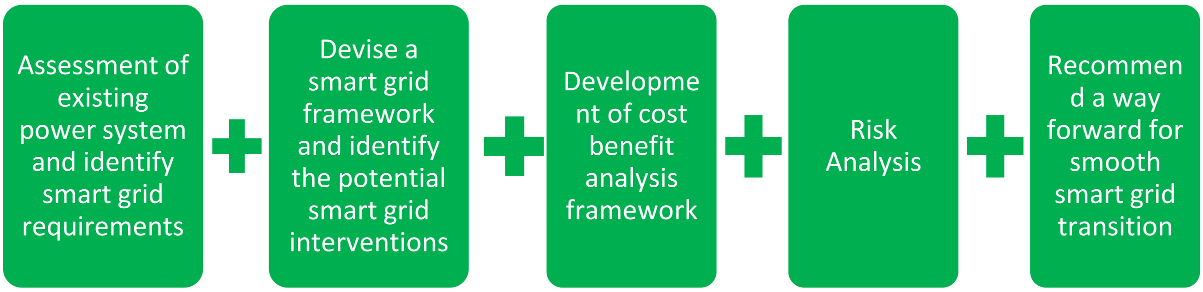
1.1 Project Objective and Scope

SAARC Energy Centre has engaged India Smart Grid Forum (ISGF) for the "Study on Development of Roadmap for Implementation of Smart Grid-Concepts, Practices and Technologies in SAARC Region" in May 2018. The objective of this study is to develop a smart grid framework and to identify a list of potential smart grid interventions along with a clear way forward for all the stakeholders in each of the member states in terms of policy and regulatory requirements, strategy to be adopted, institutional changes etc, for smooth transition from existing grids to smart grids.



1.2 Approach and Methodology

The approach and methodology adopted for the assignment included comprehensive analysis on power sector (structure, key players and their organization capacity and present status), policies and regulatory regimes, technological advancements, smart grid deployment status in each of the SAARC member states along with the international best practices followed by leading utilities around the world. We have also leveraged the experience of our highly qualified experts and ISGF Members to carry out deep analysis of available data for this study. The overall approach and methodology are as follows:



1.3 Limitations

The broad scope of the study required us to perform detailed analysis in each of the segments of the power sector namely, generation, transmission, distribution, renewable energy, policies and regulations to identify the key activities that have already been undertaken and the ones that need to be carried out to promote the deployment of smart grid technologies in a sustainable manner. This exercise requires reliable data and information pertaining to the electric power system and the policy and regulations, government's vision on smart grid, operational data of distribution and transmission utilities, and grid reliability indices. Considering the requirement, the project faces certain limitations in terms of time and information availability which are stated below:

- Limited time frame to complete detailed analysis considering each member state has different dynamics in terms of policy, economy, technology adoption, commercial implication; and has to be evaluated independently to identify and recommend the key steps to be undertaken by government and utilities for implementation of smart grids
- Limited project budget defying the possibility of physically contacting utilities in each country to gather the necessary information
- Lack of support from the utilities in SAARC member countries and other stakeholders in terms of sharing relevant data, availability of information related to policy and regulations, technologies deployed and planned and operational performance which are required to carry out the true assessment of the present situation
- The secondary data gathered from credible sources (although bit old in few cases) have been used for this study

Notwithstanding the above limitations, we have tried to carry out study with the data we could gather from reliable sources to ensure project completion in the given time.

2 Introduction to Smart Grids

"Smart grid is an electricity grid with communication, automation and IT systems that enable real time monitoring and control of bi-directional power flows and information flows from points of generation to points of consumption at the appliances level[3]." Smart grid technologies provide for an interactive grid which facilitates consumers with the option of being prosumer and provides them the opportunity to both consume and sell electricity from and to the grid based on the requirement and price of the available electricity.

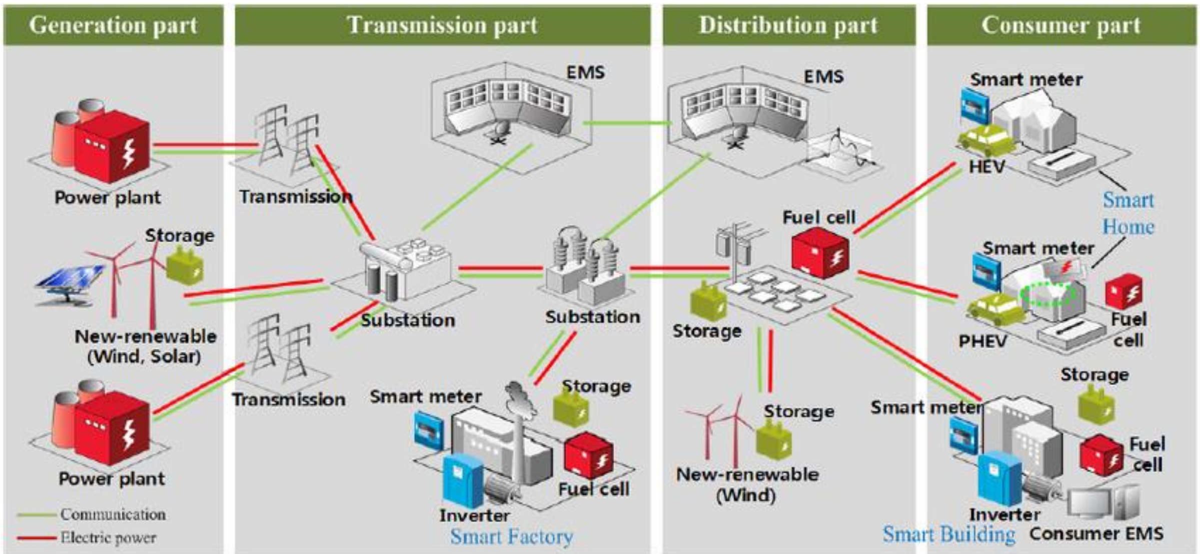


Figure 4: Smart Grid General Architecture

The drivers for smart grid for different stakeholders are:

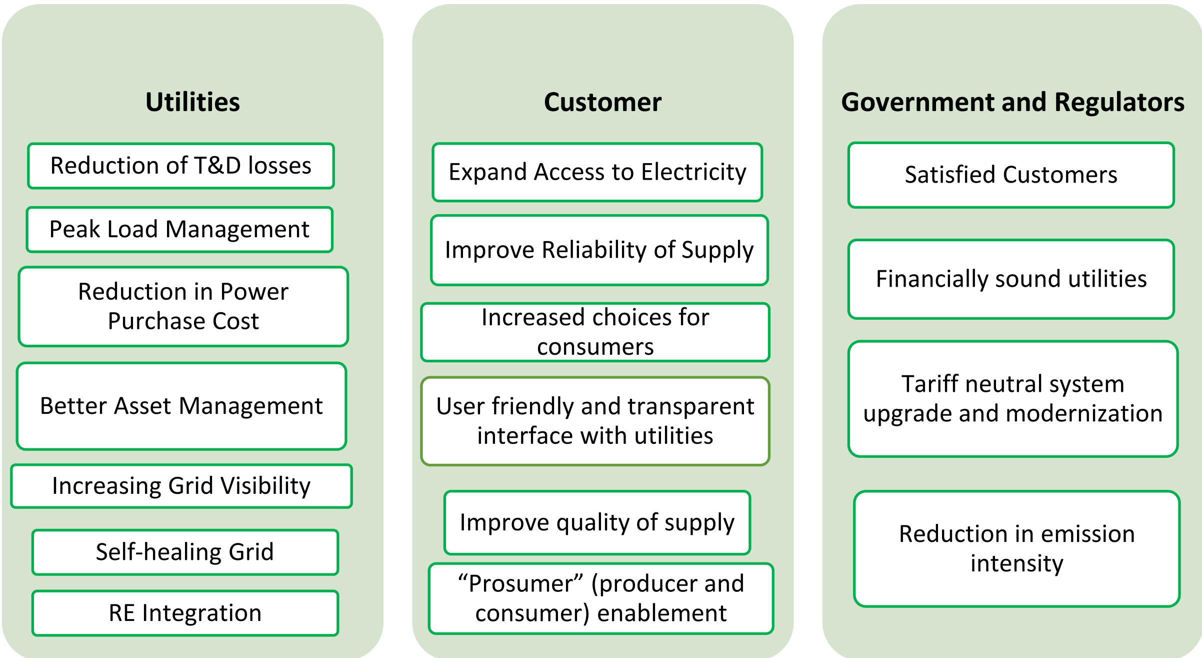


Figure 5: Smart Grid Drivers for different stakeholders

[3] http://shaktifoundation.in/wp-content/uploads/2017/12/Smart-Grid-Handbook.pdf

2.1 Components of Smart Grids

The key components of smart grid are:

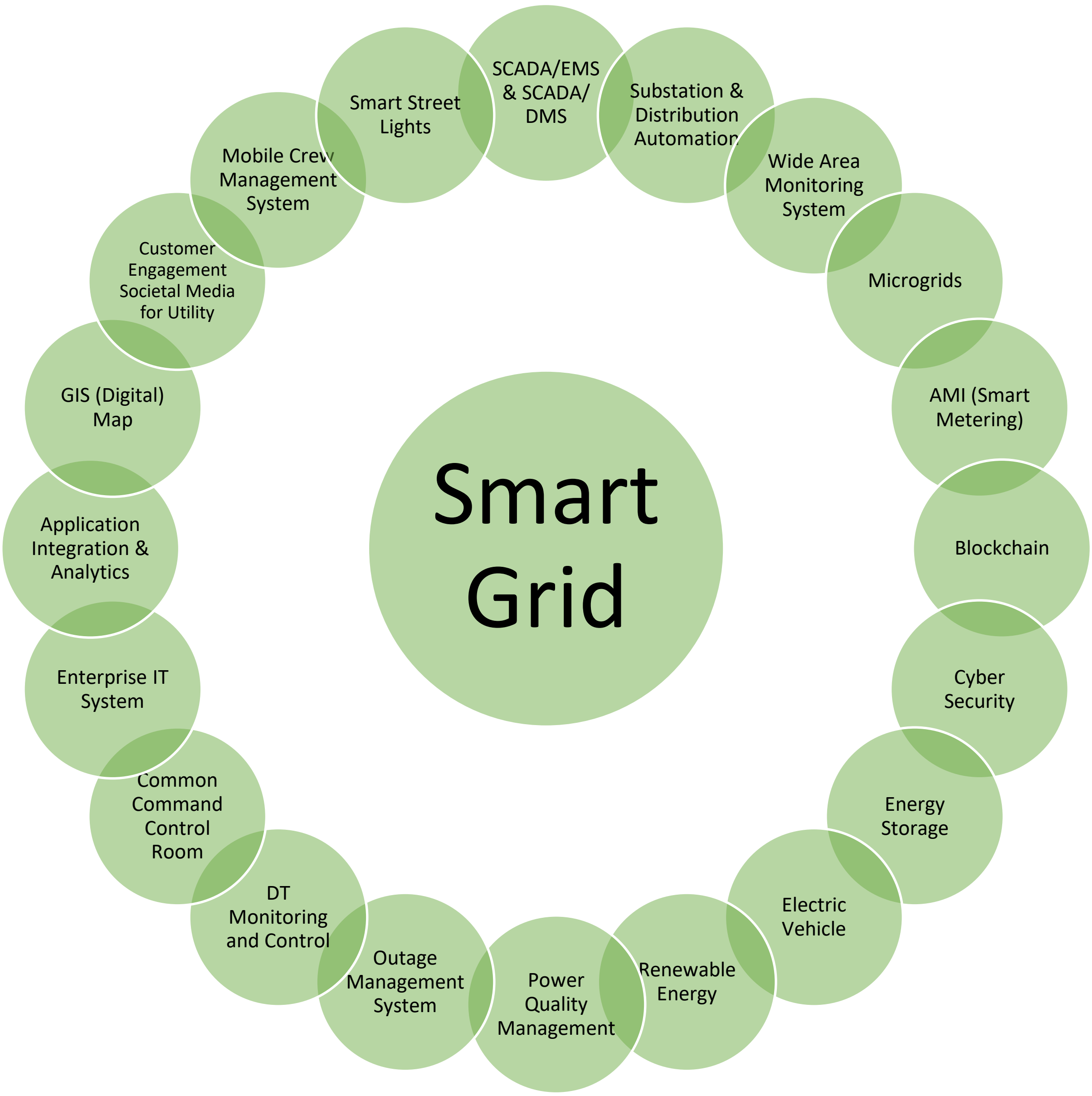


Figure 6: Smart Grid Components

2.2 Smart Grid Technologies

Some of the matured technologies that are being adopted by utilities in SAARC countries and overseas are listed here:

2.2.1 SCADA/DMS

The load dispatch centres or control centres of extra high voltage (EHV) systems deploy Supervisory Control and Data Acquisition (SCADA) and Energy Management System (EMS) to monitor and control the power flows in real-time. For proper functioning of SCADA/EMS, the EHV networks have dedicated communication systems between the control centre and all generating stations and EHV substations. From the control centre, the Operators can regulate generation as well as loads at the substations.

Example

Malegaon 132 KV sub-station in India having capacity of 200 MVA, consists of heavy distribution load because this substation consists of several feeders which are connected with power loom areas having very heavy loads. During fault condition and due to overloading, sub-station used to take long durations for fault clearance. But to after implementation of SCADA system, overloading and faults could be controlled considerably.

2.2.2 Distribution Automation/Substation Automation

Distribution Automation (DA) refers to various automated control techniques that optimize the performance of power distribution networks by allowing individual devices to sense the operating conditions of the grid around them and make adjustments to improve the overall power flow and optimize performance. In present scenario, grid operators in centralized control centres identify and analyze their power system manually and intervene by either remotely activating devices or dispatching a service technician.

Substation Automation (SA) system enables an electric Utility to remotely monitor, control and coordinate the distribution components installed in the substation. SA has been focused on automation functions such as monitoring, controlling, and collecting data inside the substations. SA overcomes the challenges of long service interruptions due to several reasons such as equipment failures, lightning strikes, accidents and natural catastrophes, power disturbances and outages in substations. Main component of SA is digital (or numeric) relays and associated communication systems which can be operated remotely.

2.2.3 Distribution Automation (DA)

Distribution Automation (DA) refers to distinct automated control techniques that enhances the performance of power distribution networks by allowing individual devices to sense the operating conditions of the grid around them and make modifications to improve the overall power flow and optimize performance. DA is considered as a critical component of smart grid as it facilitates in outage prevention with sensors providing early detection of the faulty devices. Whereas Substation Automation SA) facilitates an electric Utility to remotely monitor, control and coordinate the distribution components installed in the substation thereby providing protection against high service interruptions due to various reasons such as equipment failures, lightning strikes, power disturbances and outages in substations.

2.2.4 Energy Management System (EMS)

Energy Management System (EMS) is a set of computer-aided tools used by electric grid operators to monitor, control, and optimize the performance of the generation and/or transmission systems.

Functions of EMS

- Real time network analysis and contingency analysis
- Efficient automatic generation control and load frequency control
- Automatic control and automation of a power system like automated interfaces and electronic tagging

2.2.5 DT Monitoring System

Overloading, phase imbalance and burn outs will be prevented using remote monitoring and control of distribution transformers. This will provide huge financial savings taking into account the high technical losses that occur in the system owing to phase-imbalance. With monitoring systems in place, the loads can be distributed to remove imbalances on transformers and this will enable real-time energy auditing of each feeder.

2.2.6 Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) or smart metering is the cumulative term to describe the infrastructure from smart meter to two way-communication networks that connect the meters to the control centre equipment and all the applications that facilitate the gathering and transfer of energy usage information in near real-time.

Case Study: Oklahoma Gas and Electric (OG&E)

OG&E implemented a WiMAX point-to-multi-point Wide Area Network (WAN) that connects to a point-to-point microwave network for backhaul communications. The project has deployed 818,415 smart meters covering OG&E's entire service territory and supporting information technology infrastructure, including a MDMS.

O&M Cost Savings: Oklahoma Gas and Electric (OG&E) almost saved a total of USD 36 million in O&M cost in 3 years from 2012-2015.

Reduced Peak Demand and Improved Capital Investment Planning: OG&E also conducted a pilot program on virtual power plant which includes 4,000 residences and 1,320 small businesses, including the control group and experiences a reduction in load by 70 megawatts (MW).

Source: https://www.smartgrid.gov/files/Oklahoma-Gas-Electric-Company-Positive-Energy-SmartGrid-Integration-Program-Final-Description.pdf

2.2.7 Outage Management System

Outage Management System (OMS) provides the capability to efficiently identify and resolve outages and to generate and report valuable historical information. OMS integrated with the Geographic information System (GIS) helps to resolve customer complaints faster during power outages.

Case Study: London Hydro uses Outage Management System to Improve Customer Service

Challenge: During an outage event, large call volumes affected dispatchers' ability to efficiently resolve power outages with field crews. The large call volume also left the utility provider's customers receiving busy signals when trying to receive outage information or failing to reach a representative at all.

Solution: London Hydro integrated the OMS with an interactive voice response (IVR) system. The solution has helped the dispatching centre streamline operations and obtain more insight regarding customers and outages. They can send automated push notifications via text messages and Societal media on outages and restoration times, improving customer satisfaction and freeing dispatchers to focus on resolving the outage.

Source: https://www.hexagonsafetyinfrastructure.com/da-dk/case-studies/london-hydro-uses-outage-management-system-improves-customer-service

2.2.8 Geographical Information System (GIS)

All electrical assets mapped on a Geographical Information System (GIS) or digital map and all customers indexed to that map is one of the key inputs for a Utility to plan and manage their assets and operations. GIS map can be unified with other automation and its applications can be extended to asset optimization, outage detection and faster network restoration[4].

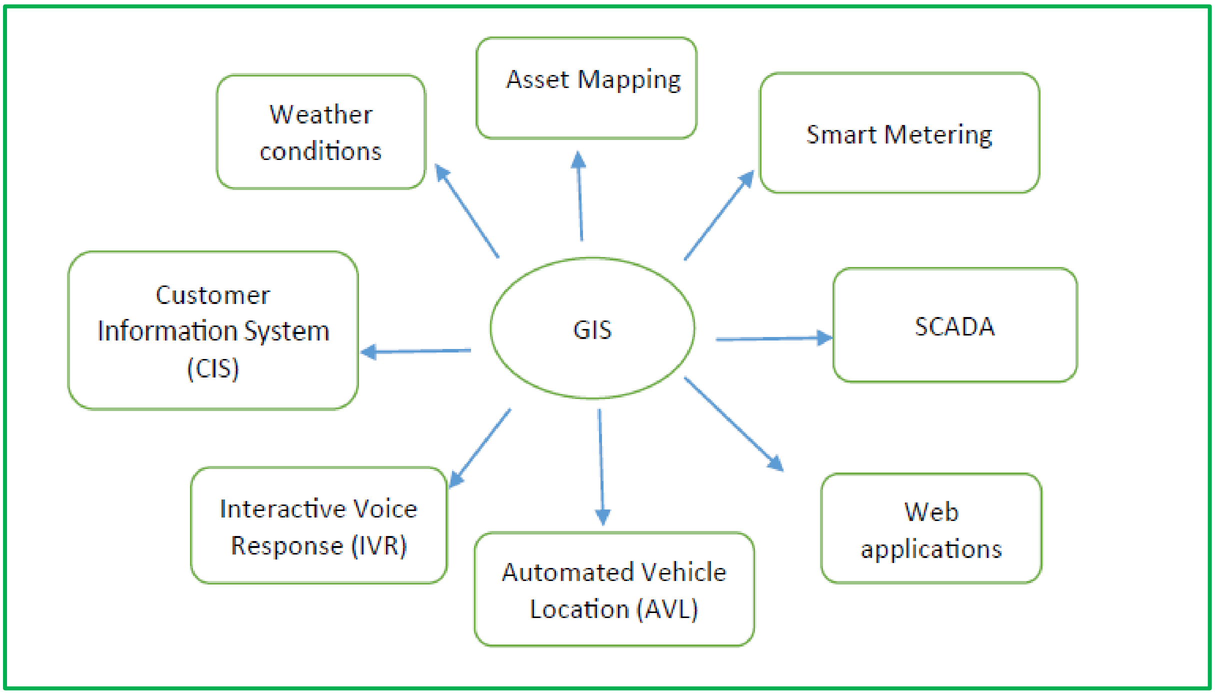


Figure 7: GIS Functionalities

[4] http://shaktifoundation.in/wp-content/uploads/2017/12/Smart-Grid-Handbook.pdf

GIS maps need to be updated on a regular basis. Whenever a new asset is added or removed or a new customer is given connection or an existing customer is removed, that information must be captured in the GIS map so that it remains up to date.

2.2.9 Demand Response

Demand Response (DR) is a strategy used by electric Utility companies to reduce or shift energy consumption from peak hours to off-peak hours thereby curtailing the load at customer premises or disconnect certain equipment of the customer remotely from the Utility's control centre. Customer participation for DR program is sought through incentives and penalties. Equipment and communication systems to remotely control the equipment or appliances at customer premises as well as customer engagement are the major components for the demand response programs. The benefits of DR include averting the utilization of the expensive generation plants during peak hours, avoiding construction of additional generation, transmission and distribution capacity, and brownouts and blackouts.

2.2.10 Microgrids

A microgrid is a network of electricity consumers with localized supply consisting of distributed energy resources and has the ability to connect and disconnect from the grid enabling it to operate in both grids connected or islanded mode. The system can be used to provide uninterrupted power supply to critical loads during the time of Utility power outages by isolating the system from the Utility grid and servicing the critical loads from own generation and energy storage with in the microgrid. The microgrid can also deployed to provide electricity in remote areas and islands.

2.2.11 Electric Vehicles

Electric Vehicles (EV) are propelled by an electric motor which is powered by batteries which can be recharged using an external power source often called as Electric Vehicle Supply Equipment (EVSE). The most serious concern electric utilities have is controlling the EV load when connected to their grid. EV owners tend to charge their EVs during peak hours and the absence of load management would likely have a destabilizing effect on the grid. Utilities must be prepared for multiple customers on the same distribution transformers trying to charge their EVs at the same time[5].

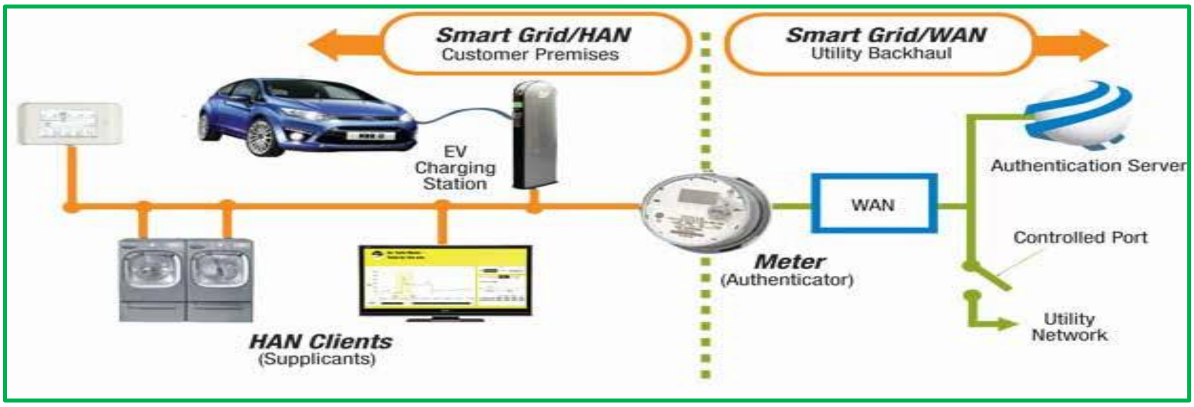


Figure 8: EV Technologies & Integration

In addition, it enables the storage capacity of the batteries in EVs to be used as a supplementary source of power at times of peak load; portion of the power available in those batteries could be fed back

[5] http://shaktifoundation.in/wp-content/uploads/2017/12/Smart-Grid-Handbook.pdf

into the network during the peak time and the battery is recharged during off-peak time. Vehicle – Grid Integration (VGI) is an important component of the emerging smart grid technologies.

2.2.12 Cyber Security

Protection of the critical infrastructure (encompassing energy, transportation, banking and finance, communication and IT, defence, space, law enforcement, sensitive government organizations, critical manufacturing and e-governance) is the primary objective of any nation and the power sector assumes top priority[6].

Case study of Ukrainian Power Grid Cyber-Attack

The cyber-attack on three power companies in Ukraine on 23 December, 2015 was an eye opener for the electric power industry. STUXNET was mainly confined to industrial control system (ICS) infection. It has not touched traditional silos of generation, transmission and distribution aspects of power grid. However, Ukrainian power grid attack was the first known instance where a cyber-attack had actually infected distribution substation automation protocols and devices rendering large demography without electricity. The coordinated cyber-attack disconnected substations from the grid leaving more than 225,000 customers without access to electricity for more than 6 hours. The CRASHOVERRIDE malware used in the cyber-attack was a modular framework consisting of an initial backdoor, a loader module and several supporting and payload modules including modules for IEC 104, IEC 61850 and OPC.

Source: ISGF Smart Grid Handbook for Regulators and Policy Makers

2.2.13 Energy Storage

Energy Storage Systems (ESS) will play a significant role in meeting energy needs by improving the operating capabilities of the grid as well as mitigating infrastructure investments. ESS can address issues with the transmission and dispatch of electricity, while also regulating the quality and reliability of the power generated by traditional and variable sources of power. Modernizing the grid will require a substantial deployment of energy storage. Energy storage technologies—such as pumped hydro, compressed air energy storage, various types of batteries, flywheels, super capacitors, etc.

2.3 Smart Grid – the Future

The smart grid journey for the utilities will encompass implementation of the above key components in a systematic and phased manner depending on the business priorities of the utilities. Renewable energy and electric vehicle integration present a great opportunity for SAARC nations in embracing the energy transition from fossil fuels to clean energy regime which will reduce their dependence on imported fossil fuels as well as enhance the energy security and help achieve the emission reduction goals. Smart grid technologies will play a vital role in achieving this energy transition.

2.4 Smart Grid Roadmap Approach

Typically, Smart Grid Roadmap is prepared based on:

[6] ISGF Smart Grid Handbook for Regulators and Policy Makers

1. Study of AS-IS systems and business process, volumes and data collected
2. Smart Grid Maturity Model (SGMM) Survey to assess the present levels of maturity
3. Aspirational workshop with key stakeholders in the Utility to determine what levels of smart grid maturity the utilities wish to reach in different domains
4. Assessment by ISGF on what levels of maturity in different domains are realistically feasible based on the organization's capability to meet the business needs
5. Recommended Smart Grid Roadmap
6. Implementation Strategy

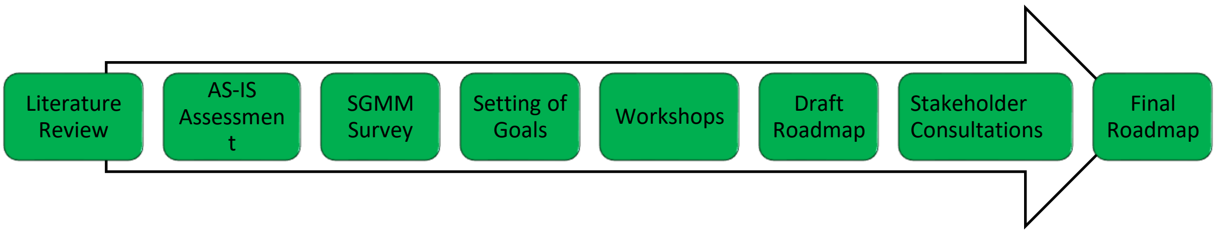


Figure 9: Smart Grid Roadmap Navigation Steps

2.5 Smart Grid Maturity Model (SGMM)

2.5.1 Introduction

The Smart Grid Maturity Model (SGMM) is a management tool that utilities can leverage to plan their smart grid journey, prioritize their options, and measure their progress as they move towards the realization of a smart grid. The SGMM was developed by a group of forward-looking utilities under the umbrella of Global Intelligent Utility Network Coalition (GIUNC), a smart grid collaboration of 11 utilities, realized the need for a standard tool in the industry. This tool is hosted by the Software Engineering Institute (SEI) at Carnegie Mellon University (CMU) with the support of the U.S. Department of Energy. Utilities use SGMM to:

- Assess their current state of smart grid implementation
- Prioritize their options
- Define their goals for a future state
- Generate inputs into their road mapping, planning, and implementation processes
- Measure their progress towards a smarter grid

As more and more utilities around the globe participate and the SGMM experience base grows, the SGMM becomes an increasingly valuable resource for helping to inform the industry's smart grid transformation.

2.5.2 SGMM Details

Smart Grid Maturity Model (SGMM) is considered as the most important aspect or the nucleus of Smart Grid Roadmap development process. It is a management tool that help utilities to "**plan their smart grid journeys, prioritize their options and measure their progress".** The SGMM is structured across 8 domains which represents key elements of smart grid strategy, organization, grid operation, and customer etc.; and 6 Levels of maturity to assess the preparedness and the aspiration of the utilities in the respective domains.

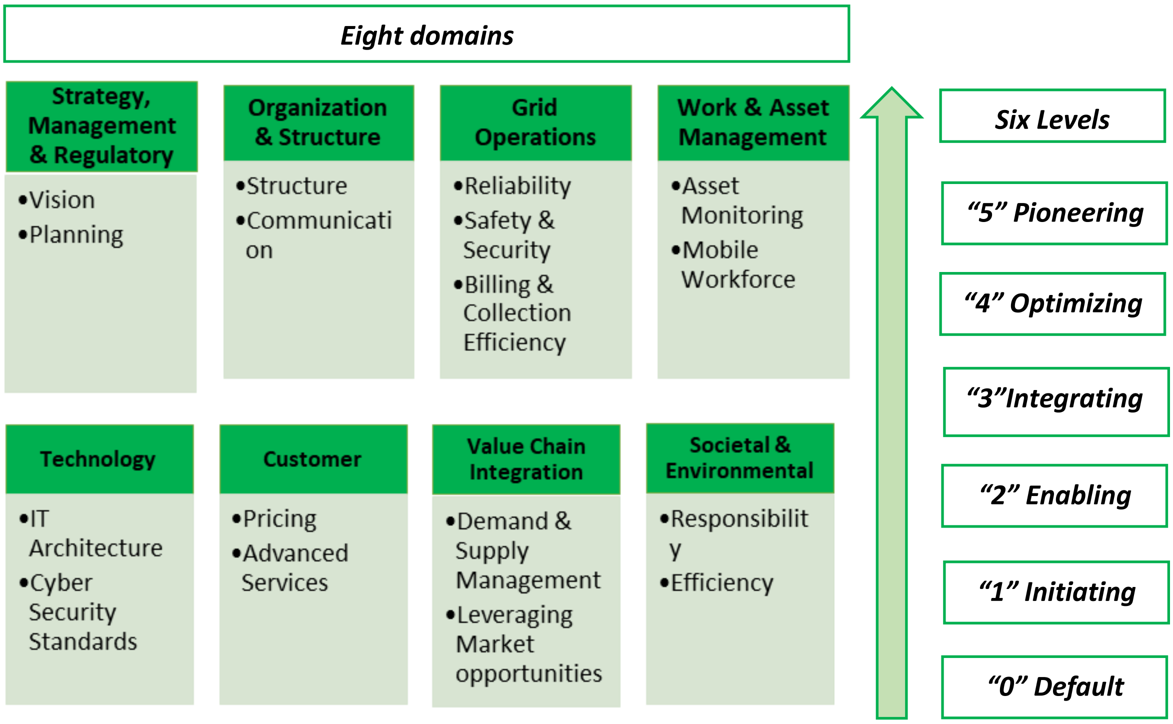


Figure 10: Smart Grid Maturity Model (SGMM)

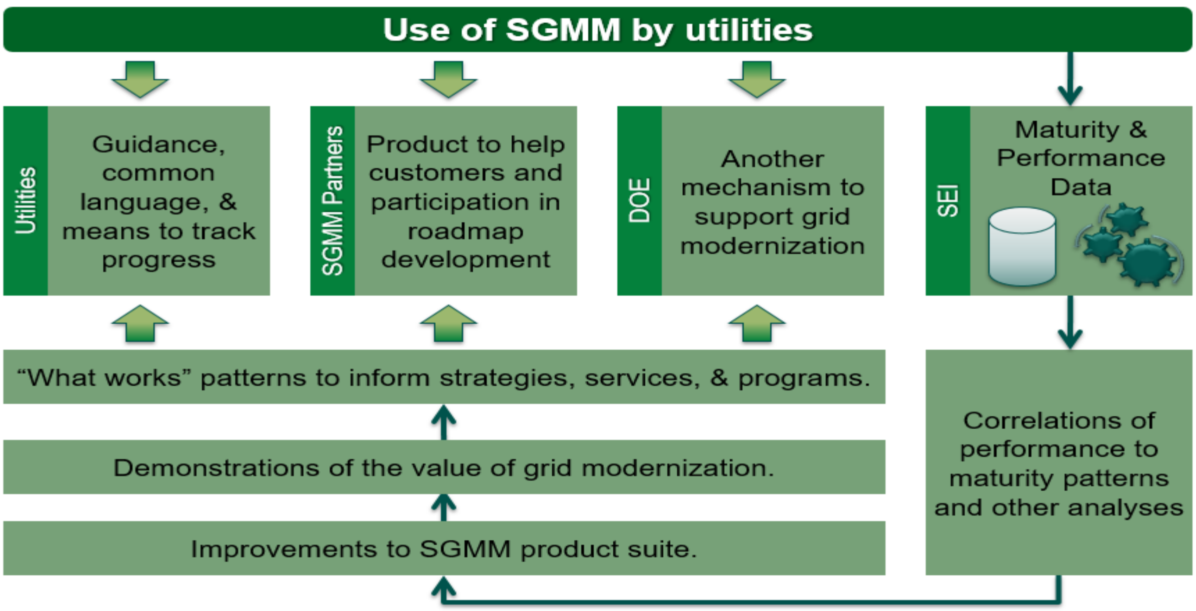


Figure 11: SGMM Benefits for utilities

3 Smart Grid Scenarios in SAARC Countries: AS – IS Study of Power Systems and Recommendations for Smart Grid Roadmap

3.1 Afghanistan

3.1.1 Country Overview

The current situation is in Afghanistan presents a very low rate of electrification with only 30% population having access to electricity nationally, and 9% in the rural areas. It is pertinent to mention here that 71.47 % of Afghans live in rural areas and 70% of the GDP comes the same areas.[7]

3.1.1.1 Power Sector Overview

Da Afghanistan Breshna Sherkat (DABS) is a limited liability company with all its equity shares owned by the Government of Afghanistan (GoA). DABS manage power generation, import, transmission and distribution throughout Afghanistan on a commercial basis. Afghanistan has a total supply capacity of 1,450 MW out of which 1000 MW is served by imports.[8] It has another 50 MW off-grid installed capacity from renewable energy (REN) resources.[9]

The Afghanistan power system is categorized in to 4 segments:

- North East Power System (NEPS) consisting of a grid linking 17 load centres (Kabul, Mazar-i-Shariff, Jalalabad, etc) with Uzbekistan and Tajikistan (220 kV and 110 kV)
- South East Power System (SEPS) consisting of Khandar, linking Kajaki (110 kV)

Land Area and Population

- Population of **Afghanistan** is **36,527,727** as of September 11, 2018, based on the latest United Nations estimates. The total **land** area is 652,860 sqKm (252,071 sq. miles)

Urbanization

- **23.78 %** of the population is **urban** and 71.47% is rural as of 2018 with population denisty of 56 per SqKm

Economic Growth

- GDP 20.82 billion US dollars in 2017.Its 0.03 % of world economy

Sectoral Share in GDP

- Service sector accounts for 49 percent of the GDP followe by agriculture 26 percent, manufacturing and mining 13 percent and and construction 12 percent

Figure 12: General Information

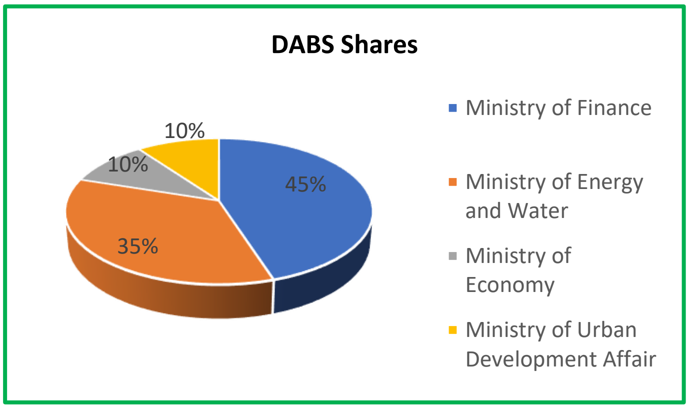


Figure 13: DABS Shares

[7] An Institutional Analysis of the Power Sector in Afghanistan –Barriers to Achieving Universal Access to Electricity, By: Mohsin Amin, Presented March 13, 2017

[8] South Asia Regional Update, January 2018, South Asia: The Robust Outlook Continues, https://www.imf.org/~/media /Files/ Countries/ResRep/IND/2018/011918.ashx

[9] Energy Supply Improvement Investment Program (RRP AFG 47282-001) SECTOR ASSESSMENT (SUMMARY): ENERGY1 Sector Road Map, https://www.adb.org/sites/default/files/linked-documents/47282-001-ssa.pdf

- Herat System linking the Herat Zone with Iran (132 kV and 110 kV)
- Turkmenistan System linking Herat, Aqina, Andkhoi East/West, Shirin Tagab, Mimana, Khoja Doko, Sarepul, Shibirghan, Mazar etc (110 kV)

3.1.1.2 Power Sector Structure in Afghanistan

In Afghanistan, government institutions responsible for the development of energy sector are Ministry of Energy and Water (MEW) and Ministry of Rural Rehabilitation and Development (MRRD) along with DABS which is the only independent state-owned Utility in the country.

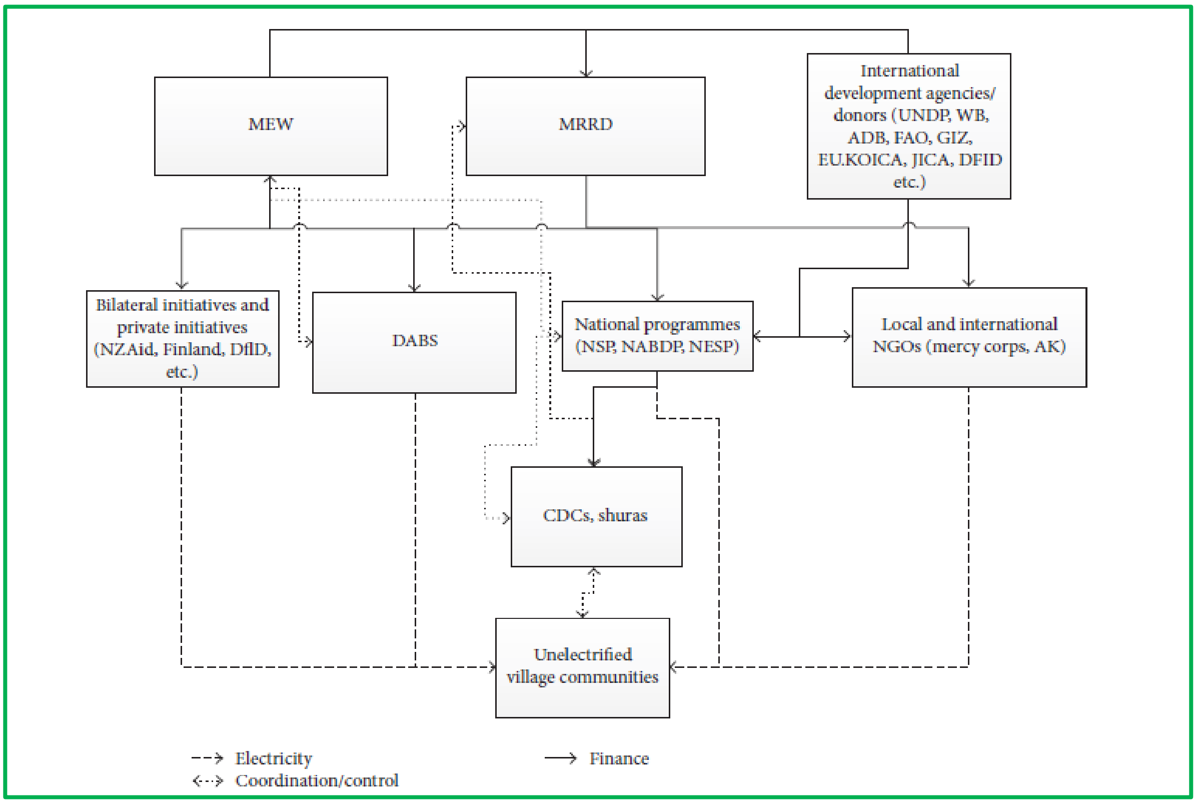


Figure 14: Institutional Arrangement of Power Sector in Afghanistan

Table 2: DABS Details

Number of Distribution Companies	Areas of Operation	No. of Customers	Annual Growth of Customers (% CAGR)	Annual Energy Sales (U)	Annual energy Consumption Growth Rate (% CAGR)
Da Afghanistan Breshna Sherkat (DABS)	32 Provinces of Afghanistan	15,08,008	6.63	36,34,224	3.55

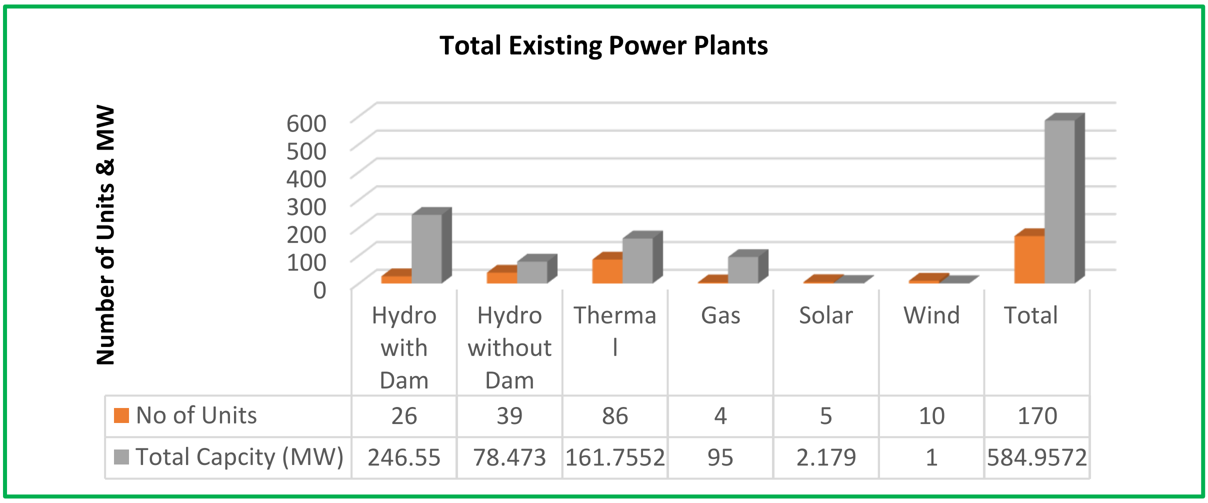


Figure 15: Total Existing Power Plants

3.1.2 Generation

The electricity generation in Afghanistan is 585 MW comprising of 20% hydro and 1% thermal. In addition, Afghanistan imports about 27% from Uzbekistan, 25% from Turkmenistan, 17% from Iran and 10% from Tajikistan. Considering that the grid in these countries operate in asynchronous mode, it is not possible to connect one network to the other in the system. This results in inefficient load dispatch and frequent blackouts.[10] At present 80% of the power consumed is imported from neighboring countries. [11]

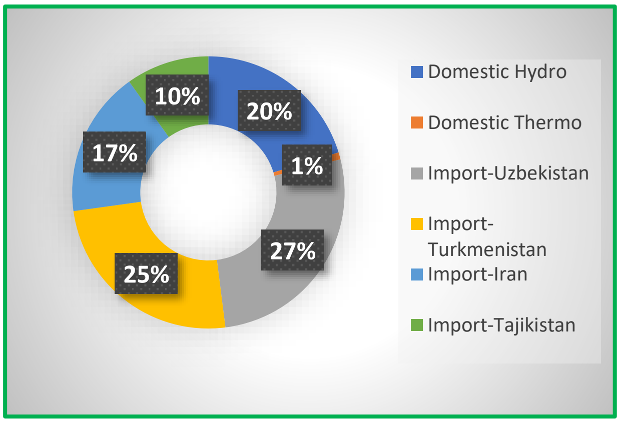


Figure 16: Grid Supply of Afghanistan 2015-16

3.1.2.1 Electricity Demand

Annual electricity demand in Afghanistan is expected to increase to 18,409 GWh by 2032 whereas annual peak demand is expected to increase by almost 5 times from 742 MW in 2011 to 3502 MW in 2032.

Table 3: Demand Forecast for 2032

Forecast Scenario 2032	Gross Demand (GWh)	Net Demand (GWh)	Peak Load (MW)
Base Case	18,409	15,900	3,502
High Scenario	22,534	19,474	4,287
Low Scenario	13,701	11,840	2,607

[10] The Sixth Regional Economic Cooperation Conference on Afghanistan Annotated Working Group Program, Abdul Razique "Samadi" CEO DABS Afghanistan, September 3, 2015 Kabul Afghanistan

[11] An Institutional Analysis of the Power Sector in Afghanistan –Barriers to Achieving Universal Access to Electricity, By: Mohsin Amin

The net demand in high case scenario is showing an increase of 22% whereas in low it is showing an increase of 5% whereas the gross demand shows an annual average growth rate of 9%[12].

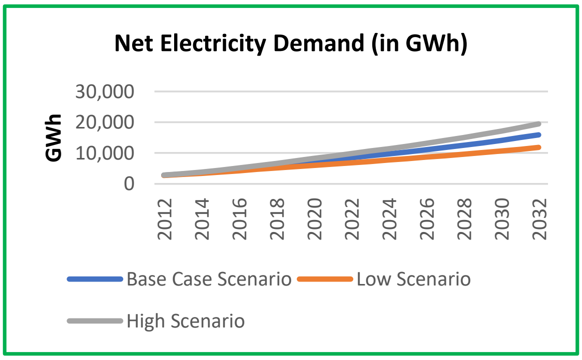


Figure 17: Net Electricity Demand

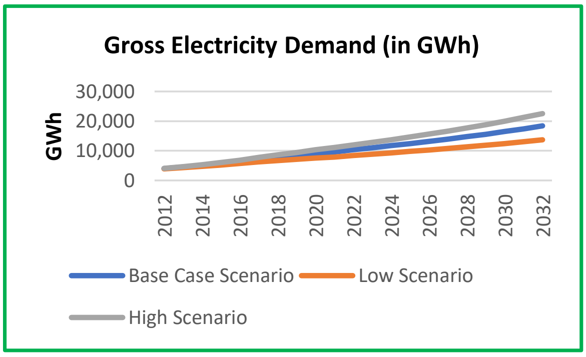


Figure 18: Gross Electricity Demand

3.1.3 Transmission Sector

Transmission network and system operation is under the ownership of DABS which is currently taking number of initiatives to improve the electricity access scenario such as

- Expansion of transmission network
- Capacity development of DABS to manage, operate and maintain the national power system
- Policy implementation to attract private sector investment in power sector

The existing Afghanistan transmission system consists of 10 islands supplied through 220 kV and 110 kV links. Afghanistan imports power from Iran, Tajikistan, Turkmenistan, and Uzbekistan. Currently, there are five transmission lines used for power import from Turkmenistan, Uzbekistan and Tajikistan and three lines for import power from Iran. The total transmission network of Afghanistan stands at 2534.5 km with the highest voltage level used for electricity transmission is 220 kV which is about 935.4 km long, followed by other lower voltage level as mentioned below. In addition, a 500 kV DC transmission line is in planning stage for exporting power from Turkmenistan to western and southern parts of Afghanistan. Similarly, another 500kV transmission line is also being built under CASA 1000 to connect Kyrgyz Republic and Tajikistan with Afghanistan and Pakistan. More priority is also been given to connect the southern part of the country with the northern part of the power system.

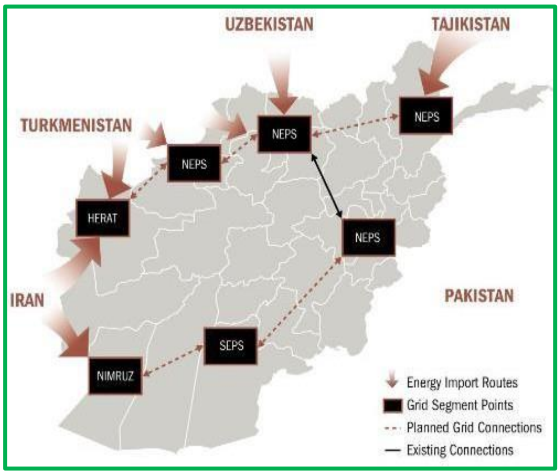


Figure 19: Grid Structure

[12] https://eneken.ieej.or.jp/data/5015.pdf, https://eneken.ieej.or.jp/data/5015.pdf

Table 4: Length of Transmission Line

Line Voltage in KV	Existing (km)	Planned (km)	Total
35	75.1	NA	75.1
44	5		5
110	1,419	1,225.2	2,644.2
132	100	45	145
220	935.4	1,993	2,928.4
500 (Planned)		967	967
Total	**2,534.5**	**4,230.2**	**6,764.7**

3.1.4 Distribution Sector

DABS is also responsible for distribution of electricity in Afghanistan. DABS has about 1.4 million consumers divided in its 8 regional zones with residential consumers accounting for about 92% of total consumers. Per estimates by 2035, there will be about 7 times more customers compared to 2005 primarily due to grid extension to cover more population in the rural areas.

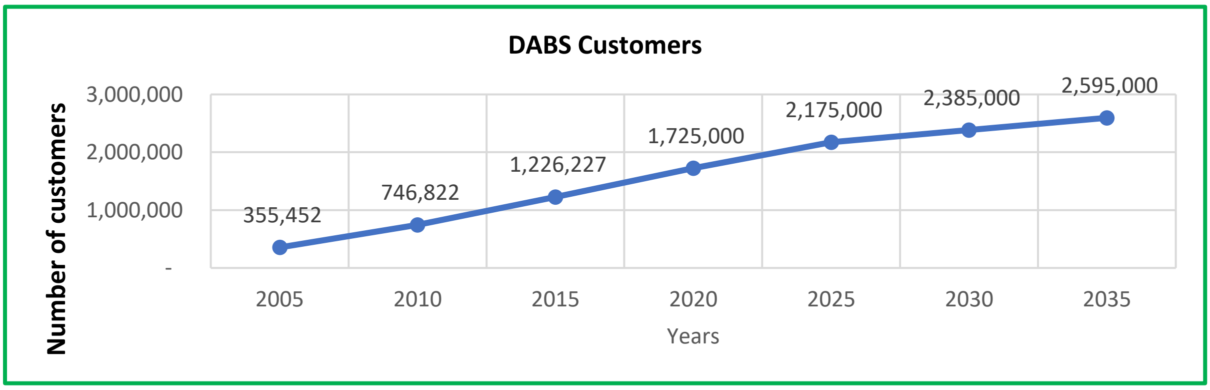


Figure 20: DABS Customers

3.1.4.1 Distribution Network

The distribution network comprises of medium voltage (MV) substation levels of 20 kV or 11 KV and distribution transformers (DT) of 20/0.4 kV. The total number of DTs are about 13,639 whereas length of MV network and LV network are approximately 5920.92 km and 7497.1 km respectively. Since large number of populations is still not connected to the grid, government has planned to strengthen the distribution network which will add a Moreover, to

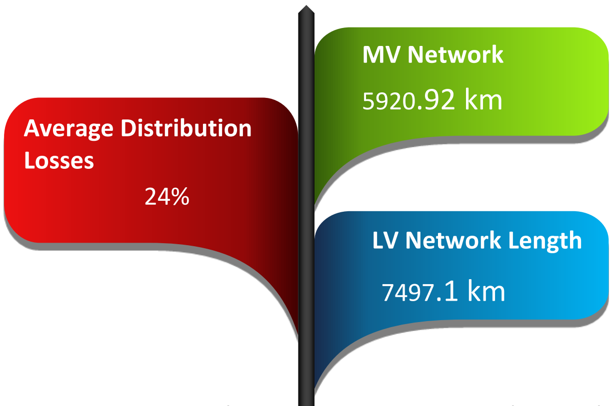


Figure 21: Distribution Losses & Network Length

address the issue of technical and commercial losses which is at 24%, regional governments are planning to install pre-paid meters.

3.1.5 Renewable Energy

Afghanistan has a very large untapped potential of renewable energy sources as given below:

Hydroelectric Plants: Afghanistan is estimated to have hydro potential of about 23,000 MW. Total installed capacity as at end of March 2016 was 298MW.

Biomass: The electricity generating potential from biomass in Afghanistan is estimated around 4,000 MW, including 3,092 from crop residue, 841 from animal manure and 94 from municipal solid waste.

Solar: With 300 days of good sunshine per year, the solar potential in Afghanistan is estimated at 222,000 MW[13].

Wind: The country's total capacity is estimated at approximately 150,000 MW, based on total windy area and the exploitable capacity is estimated to be 66,700 MW. The total installed capacity of wind power is 300 kW with the largest wind power system is of 100 kW.

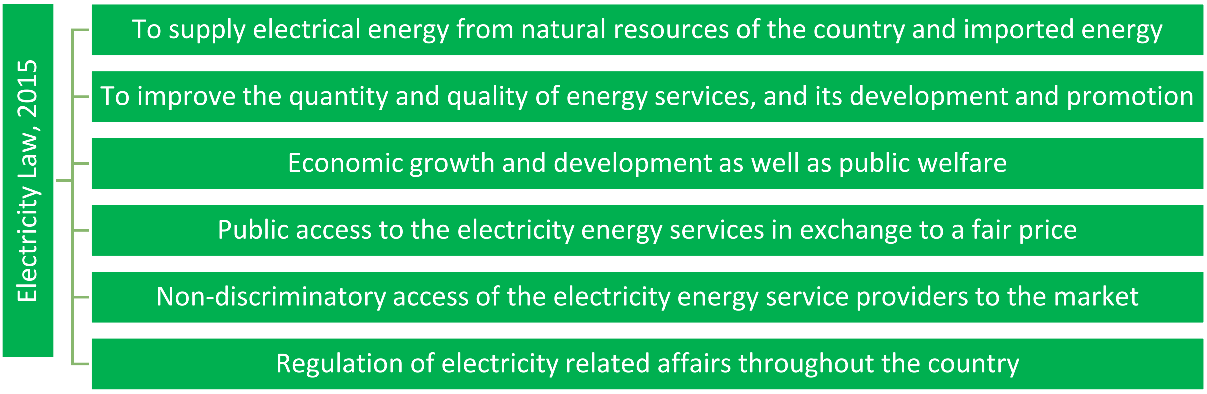
Table 5: Renewable Energy Potential

Renewable Energy Resource	Potential (MW)
Hydropower	23,000
Wind	66,700
Solar power	2,22,000
Biomass	4,000

3.1.6 Policies and Regulations

At present, the electricity sector in Afghanistan is governed by the electricity law which provides for access to electricity for a fair price and a "non- discriminatory access of the electric energy service providers to the market". The law also makes MEW the custodian and the prime implementing actor of the law and establishment of the Energy Regulatory Authority (ERA) under Ministry of Energy & Water (MEW's) structure (Electricity Law, 2015). Considering the objective of electricity for all, government came out with a Renewable Energy Policy and a Power Sector Master Plan to prioritize the development of key infrastructure projects in generation, including renewables transmission and distribution segments. It also suggests cost plus tariff, evacuation infrastructure and incentives to facilitate renewable energy development and provides for net metering option for prosumer enablement.

[13] Afghanistan renewable energy development issues and options, 26/6/2018, http://documents.worldbank.org/curated/en/352991530527393098/Afghanistan-Renewable-Energy-Development-Issues-and-Options.docx



3.1.7 Key Drivers for Smart Grids in Afghanistan

Post war in 2002, power supply in Afghanistan was limited to few pockets. Renovation of the power plants and transmission and distribution systems, interconnections with neighbouring countries have improved the power situation considerably in the past decade. With the government focusing on strengthening of generation, transmission and distribution capacity and increase in renewable energy generation, operational efficiency of DABS needs to improve grid reliability, billing efficiency, loss reduction, asset management and smart grid technologies will play a key role in meeting those objectives.

Following are key observations from the analysis of the Afghanistan power sector[14]:

1. **Isolated asynchronous power grids:** Afghanistan is currently operating as 10 isolated grids supplied by different power systems through 220 kV and 110 kV links and also import power from neighboring countries. Considering that the grid in these imports are taking place on radial-mode, it is not possible to connect one network to the other in the system. This results in inefficient load dispatch and frequent blackouts. Moreover, due to imbalance of generation and load centers in the network, most the generation capacity is not being fully utilized leading to an increase in the demand supply gap
2. **Low coverage of distribution network**: Currently only 30% of the total population is connected to distribution grid which can be further segregated to 75% of urban population and less than 9% of rural population

3. **High losses and low energy efficiency:** The current level of technical and commercial losses is estimated to be about 24%, and according to Asian Development Bank, with 10% being assumed as an acceptable level of technical and commercial losses, the balance of 14% is estimated to be worth $71.2 million a year at $0.12 per kWh. Reduction in technical and commercial losses will improve the financial viability of the Utility and also cater to improved power quality, reduced tariff and consumer satisfaction

[14] Energy Supply Improvement Investment Program (RRP AFG 47282-001), https://www.adb.org/sites/default/files/linked-documents/47282-001-ssa.pdf

4. **Regional power trading:** Different regional grids in Afghanistan are connected to the power systems of neighbouring countries it is imperative to HVDC back to back systems and other smart grid technologies to seamlessly connect the grids in the region and build a regional power market

3.1.8 Smart Grid Initiatives

- The Asian Development Bank (ADB) has approved a $415 million grant to help Afghanistan improve its energy generation, distribution and transmission infrastructure. The loan forms part of efforts by the ADB to help Afghanistan improve its domestic energy generation from 20% in 2016 to 67% by 2030. Afghanistan will use the capital to increase its electrification rate from 30% to 83% by 2030. The project will include the laying of 1,300km of distribution power lines and 3,900km of power transmission lines to subscribers, as well as the installation of 108,400 smart meters, tens of substations and thousands of transformers
- DABS decided to install first smart meters in business centers, government offices, factories and individuals defaulting on power bills

3.1.9 Smart Grid Scenarios for Afghanistan

As explained in the previous chapters, the power sector in Afghanistan need to develop the power system rapidly in order to:

- Ensure access to electricity for all citizen
- Ensure 24x7 quality supply to all customers
- Develop hydroelectric power stations and renewable energy resources that can bring down the cost of power as well as CHG emissions

To ensure the fulfilment of these objectives, DABS need to overhaul their business strategy and improve their operational efficacy which will require them to undertake the following activities as mentioned in the recommendations in a phased manner.

3.1.9.1 Smart Grid Roadmap Recommendations

For preparing the smart grid roadmap we have used the Smart Grid Maturity Model (which is explained in the previous chapter). Based on the data gathered about the Afghanistan power system, DABS is considered to be at the Initial level on smart grid maturity – level zero (0) in all 8 domains of the Smart Grid Maturity Model (SGMM).

The key assumptions considered for drawing the smart grid roadmap are given below:

a. Growth of electrical network will accelerate to increase electrification rate from 30% to 83% by 2030 and domestic generation from 20% to 67% as envisaged in the National Energy Supply Program.

b. New policies and regulations will be recommended by 2020 for accelerated development and integration of renewable energy sources to grid by 2030

c. Growth of renewable energy resources including rooftop PV will accelerate in the coming years owing to policy mandates as well as cost reduction of PV systems making them economically attractive for larger sections of customers

d. New initiatives and projects will be defined to integrate electric grid as one network by 2025

e. New projects and policies will be initiated for AMI, GIS, integrated billing system etc to reduce T&D losses and improved asset mapping by 2020

f. Government programs continue to increase generation capacity to 1500 MW by 2028 and transmission capacity to 1200 MW (2025) (as per target define in DABS annual report 2015)

The Smart Grid Roadmap recommended in this report are in 3 stages:

a. Immediate term (2018-2020): Proposed some immediate action items that can bring clear strategy and plan for power system development and grid modernization in Afghanistan in alignment with the long-term goals set by the Government

b. Near Term (2020-2025): Proposed a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction

c. Medium Term (2025-2030): Proposed several measures that would transform DABS in to a modern Utility using planning tools and advanced automation and IT systems and analytics to optimize the assets and operations

The above steps are described in detail in the following sections:

3.1.9.1.1 Afghanistan Smart Grid Roadmap 2018 - 2020

The Afghanistan Smart Grid Roadmap 2020 defines the progressive trajectory of developments from present state (in 2018) to 2020 in following areas: Strategy, Management and Regulatory (SMR), Organization Structure (OS), Grid Operation (GO) and Work and Asset Management (WAM).

Elementary preparations have been observed as government has taken initiative to expand electrical infrastructure for transmission and distribution network, Policy recommendations, National Energy Supply program and other projects/ programs for 2020 and 2030 targets. Government has also taken initiative to install pre-paid metering at some of the locations and have plans to expand the same.

1. Strategy, Management, and Regulatory (SMR)

Present Maturity Level (in 2018): 0 (default); Target Maturity Level by 2020: 1

Although DABS vision, policies and other projects are already in progress, they require a compelling Smart Grid Vision and Roadmap. Planning need to be done to achieve targets for 2020 and 2030. In ISGF's view, DABS should target to achieve maturity level 1 in Strategy, Management and Regulatory domain by 2020. As per detailed evaluation of the existing systems and ongoing efforts in Afghanistan, it is possible to reach maturity Level-1 by undertaking following steps:

- Define Smart Grid Vision and Roadmap, strategy and policies in consultation with Ministry of Energy and Water
- Arrange training to key personnel to have common understanding about smart grid vision and technologies
- Initiate discussion with Regulators on DABS's Smart Grid Roadmap
- Make departmental structure for smart grid implementation (DMS, SCADA, Substation Automation, AMI) and define their roles and responsibilities
- Define area load dispatch centre, regional load dispatch centre, central load dispatch centre and SCADA hierarchy for the country

- Identify areas for renewable energy growth and integration with grid
- Identify potential area for pilot project implementation for Smart Grid Pilot Projects - SCADA/DMS, Substation Automation and AMI
- Approval of funds for the pilot projects

2. Organization and Structure (OS)

Present Maturity Level (in 2018): default (0); Target Maturity Level by 2020: 1

Afghanistan has restructured its power sector structure in 2008. DABS has taken steps to strengthen electrical network and achieve higher electrification rate. Smart Grid Vision, Roadmap and its awareness need to be understood all across the organization. There is a need to demonstrate their commitment towards implementing smart grid vision by creating a dedicated smart grid department headed by senior management official. So, organization need to be restructured in alignment with the Smart Grid Roadmap. It is assumed that DABS is at default level on “Organization and Structure”. ISGF recommends DABS should target to achieve maturity level 1 by 2020 on SGMM by undertaking following steps:

- Organization should articulate (communicate) it’s needs to build smart grid competencies in its workforce
- Organization structure and workforce need to align as per Smart Grid Vision and Roadmap
- Leadership should demonstrate a commitment to change the organization in support of achieving smart grid objectives and targets by assigning resources and budgets
- Conduct workshops/ awareness sessions on Smart Grid technologies and needs across multiple functions/line of business to support smart grid activities

3. Grid Operations (GO)

Present Maturity Level (in 2018): default (0); Target Maturity Level by 2020: 1

Many projects are in progress by DABS for strengthening of electrical network across country. In ISGF view, DABS should target to achieve maturity level 1 in Grid Operations on SGMM by 2020. In the realm of Grid Operations, DABS must undertake following steps to reach maturity level 1:

- Prepare a Smart Grid Roadmap (10-15 years) for DABS and get its approved by the Board of Directors of DABS
- Define Smart Grid as an important item in business plan, budget and annual revenue requirement (ARR) plan and define future work plan for the same
- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g., AMI with remote disconnect, SCADA / DMS, GIS etc.) may be undertaken
- Establish framework to calculate outages and reliability indices at distribution level
- Expand and upgrade of electrical network to enhance electrification rate from 30% to 83% (by 2030) and domestic generation target from 20% to 67% (by 2030). In line with this define and achieve targets for 2020. Some of the suggested steps are:
    - Firm plan for integration of grid as one network through the country by 2025
    - Building new substations and medium voltage (MV) and low voltage (LV) lines to meet demand growth

- Addition of new DT's, feeders and bifurcation of existing feeders in order to increase transmission and distribution capacity and reduce network losses
- Upgrade the load dispatch centres with automation and control system
- Replacement of existing DTs with new higher capacity DT's wherever required according to load growth
- Implementation of peak load management through demand response (DR) at distribution level
- Make strategy and plan to implement pilot projects of AMI at required locations
- Plan to expand renewable energy capacity from 4500 MW to 5000 MW by 2032 and achieve planned targets for 2020

- Implementation of Cyber security measures such as:
  - Identify and access management system
  - Implement relevant recommendations of statutory guidelines by government agencies on cyber security (if any)
  - Compliance with IEC or country specific Cyber Security standards

4. Work and Asset Management (WAM)

Present Maturity Level (in 2018): default (0); Target Maturity Level by 2020: 1

It is assumed that DABS is at default level (i.e. 0 level) in Work and Asset Management domain. Looking into present progress of work, it is expected that DABS could target for Level-1 by 2020 by undertaking following steps:

- Define business case for GIS and asset mapping at transmission and distribution levels and get approval for the same
- Perform consumer indexing at distribution level and map it on GIS
- Institute work flow for continuous updating of assets and customers on GIS map
- Implementation of ERP system
- Develop and implement a communication system plan to meet near and long-term communication needs adopting a multi-tier, multi-service telecommunication architecture infrastructure architecture consisting of a core network and an edge network
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

3.1.9.1.2 Afghanistan Smart Grid Road Map 2020 – 2025

The Afghanistan Smart Grid Roadmap 2025 defines the progressive trajectory of developments from 2020 to 2025 in 7 domains as recommended in the following sections:

1. Strategy, Management and Regulatory (SMR)

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

For achieving maturity level – 2 by 2025, DABS need to take following measures:

- Approval and acceptance of Smart Grid Roadmap from higher management across all multiple functions and line of business (LOB) of DABS. Include the same in the Business Plan of DABS

- Approval of smart grid projects and investments as envisaged in the per Smart Grid Roadmap
- Update policies and regulations if needed to implement measures envisaged in the approved Smart Grid Roadmap
- Support from funding agencies for smart grid projects and make plan/ strategy to implement smart grid projects such as SCADA/DMS, AMI and OMS; and identify potential areas where new projects can be implemented

2. Organization and Structure (OS)

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

For achieving maturity level-2 by 2025, DABS need to take following measures:

- Approval of Manpower Plan (including Training plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on approved Smart Grid Roadmap, restructure the organization hierarchy and its business process which can align end to end process for smart grid operations
- Create cross functional teams among all LOB's for implementation of smart grid initiatives as per approved Smart Grid Roadmap
- Plan workshop and train key personnel to develop smart grid competencies
- Plan for linking compensation and incentives with achievement of smart gird milestones

3. Grid Operations (GO)

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

For achieving maturity level-2 by 2025, DABS need to take following measures:

- Upgrade electrical network to support estimated peak load for 2025 targets in line with the overall target of 3502 MW by 2032 through combination of steps such as:
    - Create new generation resources and transmission network, substations, medium voltage and low voltage lines as well as upgrading the transmission and distribution capacity
    - Replacement of existing / old DT's with new higher capacity DT's where ever required
    - Bifurcation and trifurcation of lines / feeders wherever required
    - Replacement of old wire / undersize conductors/ cables and replace old wire joints on overhead LV lines with proper crimped joints
    - Establish demand response (DR) for peak load management at customer level
- Establish SCADA/DMS in urban areas in phased manner by 2025
- Implement AMI in one division in DABS
- Undertake pilot trials in energy storage for grid balancing on feeders with higher penetration of renewable energy
- Pilot installation on EV charging infrastructure in Kabul and other urban areas

4. Work and Asset Management

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

For achieving maturity level-2 by 2025, DABS need to take following measures:

- Systems for tracking inventory and event history of assets on GIS maps
- Successful completion of enterprise resource planning (ERP) implementation and its integration with GIS and other IT and automation systems
- Augmentation of the multi-tier, multi-service telecommunication infrastructure architecture consisting of a core network and an edge network to meet the requirements of new systems being added by 2025
- Develop network model for the distribution grid up to DT level so that modelling studies can be undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Plan for hotline maintenance – bare hand methods using trucks with insulated baskets and other hotline tools
- Prepare plan for mobile workforce management (MWFM) system
- System in place for load forecast every year and system upgrade plans to be reviewed and amended appropriately based on actual and expected load growth in each sub-division

5. Technology

Maturity Level in 2020: 0 (default), Target Maturity Level by 2025: 1

For achieving maturity level-1 by 2025, DABS need to take following measures:

- Enterprise IT Architecture: DABS must develop an enterprise IT Architecture and start its implementation. Need to retire several IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated (even through a middleware) must be replaced with commercially available off the shelf (COTS) applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT Architecture should enable integration of new assets and applications acquired by different LOBs
- Implement one integrated billing system across DABS covering every type of customer
- Conduct audit for Cyber Security and adopt the recommendations to secure systems form cyber-attacks
- Prepare cloud strategy for future expansion

6. Customer

The electrification rate is being increased to cover 83% of population by 2030, several million new customers will be added to the DABS network in the coming years New systems must be put in place to handle the customers queries and needs.

Present Level (in 2020): 0 (default), Target Maturity Level by 2025: 1

Recommendations for reaching maturity level 1 by 2025 are:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved Smart Grid Roadmap. These studies will identify customer benefits and satisfaction. DABS may conduct these studies with input from different category of customers in urban and rural areas
- Conduct workshops to educate customers about Smart Grid Vision and Roadmap of DABS

- Conduct study or research work for security and data privacy implication of new technologies and business process/functions to be adopted which can enable customer participation to leverage smart grid functionalities
- Consult with public Utility commission and /or other government related organization regarding impact of technologies on different categories customers

7. Societal and Environmental

It is assumed that DABS is at default maturity level for this domain.

Present Level (in 2020): 0 (default), Target Maturity Level by 2025: 1

Recommendations for reaching maturity level 1 by 2025 are:

- Publish the smart road map with emphasis on:
    - DABS role in environment and societal issues with respect to smart grid vision or strategy
    - DABS publicly promote the environmental benefits of using smart grid technologies
- Approved environmental compliance records may be made available for public inspection

3.1.9.1.3 Afghanistan Smart Grid Road Map 2025 – 2030

Afghanistan Smart Grid Roadmap 2030defines the progressive trajectory of development from 2025 to 2030 as explained below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level in 2025: 2; Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, DABS need to undertake following measures:

- Establish Smart Grid Governance Model for smart grid development and decision making. Define roles, process and tools for the same
- Designate a Single Smart Grid Leader in all key line of businesses with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap
- Adopt smart grid vision, strategy and business case in organization’s vision and strategy
- Approval for smart grid investments for key initiatives envisaged in the approved Smart Grid Roadmap

2. Organization and Structure (OS)

Maturity Level in 2025: 2, Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, DABS need to take following measures:

- Redesign organization structure to support smart grid initiatives e.g. matrix organization structure or similar and also execute this structure in view of the new programs and projects for 2040
- Commitment and consistency of leadership in communication and actions related to smart grid programs and projects
- Performance awards and compensations are linked to success of smart grid programs and projects

- Conduct educational training programs which are aligned to build smart grid capabilities in the organization
- All changes in organization structure, appointments / transfer / changes being made in consideration and support with smart grid program and projects
- Knowledge management framework to be put in place to capture the learnings from technology trials and new projects planned as per smart grid roadmap. This knowledge must be institutionalized

3. Grid Operations (GO)

Maturity Level in 2025: 2, Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, DABS need to take following measures:

- Upgrade electrical network to support estimated peak demand growth to 3502 MW, energy requirement of 15,909 GWh and increase electrification rate to 83 % by 2032
    - Building new generating plants, transmission lines, substations and medium voltage (MV), low voltage (LV) lines and upgrade the capacity of existing generation, transmission and distribution systems
    - Plan and execute bifurcation and trifurcation of distribution lines and expand distribution network to rural and urban areas ensuring to meet targets of electrification rate and increase in peak demand
    - Increase transformation capacity at DT level to meet the demand target of 2030
    - Replacement of exiting DTs with higher capacity DTs where ever required
    - Addition of new capacitor banks to regulate power quality where ever required
    - Peak load management through demand response (DR) at customer premises
    - HT: LT ratio is brought to 1:2 in urban area and 1:4 in rural area
    - Replace undersize / old conductors and old wire joints on overhead LV lines with proper crimped joints
- Integration of regional grids to enhance capacity of transmission and distribution and establish centralized scheduling and dispatch
- Expand renewable energy capacity from 4500 MW to 5000 MW by 2032 and integration with grid
- Implementation of SCADA /DMS, distribution automation (DAS) and AMI across country or selected locations as per organization goals
- Implement outage management system (OMS) and its integration with SCADA /DMS, DAS and GIS in urban areas
- All new grid equipment being installed with remote monitoring capabilities
- Plan for rollout of EV charging infrastructure and Vehicle to Grid Integration (VGI) in all urban areas
- Deployment of advanced analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all lines of business (LOBs), dashboard with relevant information are made available in each LOBs
- Grid operation data is being leveraged for grid planning using advanced analytical and planning tools
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real time load and voltage data on selected urban and rural feeders

- Establishment of dedicated Smart Meter Operation Centre (SMOC) that will monitor and control smart meter operations and provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operation
- System for condition-based maintenance of circuit breakers and power transformers
- Extension of voltage and reactive power (Volt-VAR) optimization (VVO) systems to entire service area
- Automated operation of capacitor banks (if not part of VVO solution)
- Advanced ground fault detection by installing protective relays (or IEDs) to detect high impedance (very low fault current) faults for faster isolation of downed conductors/ section promoting enhanced safety and improved service reliability
- Implementation of state of art Security Operation Centre (SOC) to safeguard the system from cyber and physical attacks

4. Work and Asset Management

Maturity Level in 2025: 2, Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, DABS need to undertake following measures:

- Asset performance trend analysis and event audit reports are available for all major assets and systems
- Integrated view of all major/ key assets on GIS system with remote monitoring facility and their further integration with ERP system and mobile workforce management system (MWFM) covering all major urban areas
- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals
- Network model of transmission and distribution grids up to DT level is regularly updated and modelling studies undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Analytical tools for predictive maintenance are deployed on trial basis
- AMI integration with OMS – restoration / disconnection messages from smart meters are integrated with OMS for faster restoration and improved customer satisfaction
- AMI- GIS integration to enhance the visualization of network to provide safety, reliability and operational benefits

5. Technology

Maturity Level in 2025: 1, Target Maturity Level by 2030: 2

For achieving maturity level-2 by 2030, DABS need to undertake following measures:

- Alignment of line of business with enterprise IT Architecture across entire organization. If required modify business process to align it with IT Architecture and systems
- Framework in process for change control of all IT applications and infrastructure
- Organization uses an informal common technology evaluation and selection process for smart grid activities including selection of vendors and external services
- Conduct pilot trials on wide area monitoring and distributed sensor network
- Smart grid technologies implemented are leveraged in such a fashion that it improves the cross-LOB performance

- Data collection from smart sensor network installed on distribution lines are leveraged by other applications for grid operation and customer service functions
- Cloud services are in place and all new applications are hosted on secured public cloud; existing applications are migrated to the cloud as the old hardware becomes redundant
- Cyber security systems in place

6. Customer

Maturity Level in 2025: 1, Target Maturity Level (in 2030): 2

For achieving maturity level-2 by 2030, DABS need to undertake following measures:

- DABS’s vision of the future grid is communicated to customers
- Analyze electricity consumption behavior and pattern of residential customers area-wise and align system to support their usage pattern and minimize outages; model the reliability of grid equipment
- Assess the impact of new smart grid systems and services on different categories of customers
- Measures for security and privacy requirements of customers and identify the specifications for new systems being procured as per measures
- Implementation of a state-of-the-art customer portal
- Prosumer enablement and net-metering plans available to all customers
- Leveraging Societal media for customer engagement effectively

7. Societal and Environmental

Maturity Level in 2025: 1; Target Maturity Level by 2030: 2

DABS should undertake following steps to reach maturity level 2 by 2030:

- Finalize work plans for addressing the Societal and environmental issues through smarter technologies
- Offer smart grid supported energy efficiency programs for customers Adopt “Triple Bottom Line” (TBL) framework for key decisions – TBL method covers Societal, Environmental and Financial aspects of every investment plans/projects
- Provide details of granular level energy consumption data to customers – from AMI system through customer portal

8. Value Chain Management (VCM)

Present Maturity Level (in 2025): 0 Default, Target Maturity Level by 2030:1

DABS should undertake following steps to reach maturity level 1 by 2030 on value chain management:

- Formulation of a strategy for creating and managing a diverse resource portfolio
- Identification of:
    - Assets and programs for load management
    - Distributed generation resources, its locations and its capabilities
    - Security requirements to enable interactions with an expanded portfolio of value chain partners
- Evaluate and identify the security requirement to enable interaction with expanded portfolio of value chain partners

The recommended Smart Grid Roadmap for DABS:

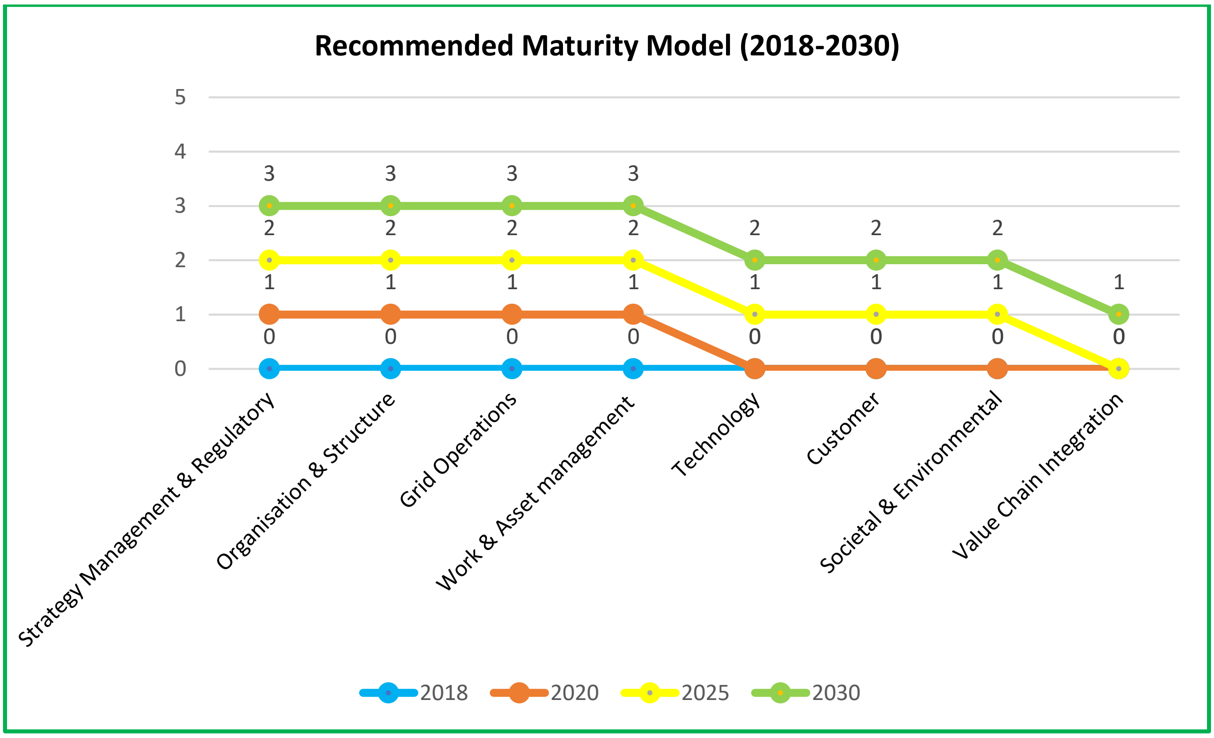


Figure 22: Recommended Smart Grid Maturity Levels (2018-2030)

3.1.10 Cost Benefit Analysis

Based on the above recommendations till 2030 in each of the eight domains, various activities have been identified which need to be undertaken by the utilities in different phases and also identified one project for development in future based on various parameters as mentioned below. These parameters have also taken into account the envisaged or future targets of the governments in terms of electricity supply, renewable energy development, cross border power trading, operational performance of the utilities etc.

National priority + Business requirement of the utilities + Investment & duration of project development + Higher return on investment

With the increase in renewable generation and roof top PV penetration, integration of these variable resources into low voltage grid poses serious concern to the grid reliability and increases the operational difficulties for the utilities. Therefore, load control mitigation measures need to be in place with the increase in roof top PV penetration in the urban areas. The detailed cost benefit analysis for the project has been done considering its priority and the huge amount of benefits it accrues compared to the investment it needs.

3.1.10.1 Background

Afghanistan's key challenges are (i) lack of generation capacity, (ii) increasing constraints in transmission and distribution systems, (iii) weak financial management and sustainability of sector entities caused by lack of cost-reflective tariff frameworks, and (iv) inadequate sector regulation.

About 80% of the total power is imported and the import bill of energy has increased 14 folds from $16 million in 2007 to nearly $224 million to 2015. Despite 75% of Afghans living in rural areas contributes to about 67% of GDP, only a mere 9% has access to electricity. Afghanistan has an estimated potential for 23 GW Hydro, 67 GW wind potential, and 222 GW solar. Installed capacity of solar PV is 13MW mainly stand-alone systems and used for rural house lighting purposes.

3.1.10.2 Project Objective and Description

Evaluate a scalable PV Rural Energy Access program pilot for enabling/supporting the 75% population towards their 67% GDP contribution in agro/small industry.

500 households with each house having micro-1 KW PV systems (capable of daisy-chained to 5KW), consisting of:

1. 500 no’s 1-KW (4 x 300W dc self-configurable inputs) "Quad-inverters" (USD 1,000 each)
2. 1,500 no’s PV solar panels of 300 W each (USD 200/panel)
3. 500 nos., small LFP batteries 300W x 4 hr BESS (USD 240/KWh)
4. A set of small agro tools and electric power tools (USD 50,000 lumpsum)
5. Other household appliances (lights, fans, TV, small DC Refrigerators) - (USD 50,000)

Initial Investment	YEAR	1	2	3
Equipment	$1,044,000.00			
Engineering and Development	$100,000.00			
Installation & Commissioning	$75,000.00			
Total Initial Investments	**$1,219,000.00**			

Benefits	YEAR	1	2	3
Diesel Fuel import Saved (av. 125 KW x 6000 hrs x 0.28 L/KW x USD 1.75/L)		$367,500.00	$367,500.00	$367,500.00
Carbon Emissions Avoidance {(2.7kg/L x (1000-300 KW) x 0.28 L/KW x USD 25/tonne)		$56,700.00	$56,700.00	$56,700.00
Economic benefit: Agro/small scale industry promotion av. 50% at 3 x 0.10cent tariff		$450,000.00	$450,000.00	$450,000.00
DG main. savings (USD 1.00/hour/50 KW x (av. 250 KW) x 6000 hours)		$30,000.00	$30,000.00	$30,000.00
Total Benefits		**$904,200.00**	**$904,200.00**	**$904,200.00**

Costs (Excluding Initial Capital Investments)	YEAR	1	2	3
Operations		$25,000.00	$25,000.00	$25,000.00
Maintenance		$15,000.00	$15,000.00	$15,000.00
Project management, customer support		$35,000.00	$35,000.00	$35,000.00
Capital cost recovery from residents (10-year amortization)		$168,210.14	$168,210.14	$168,210.14
Depreciation on capital expenditures (calculation uses 5-year period)		$243,800.00	$243,800.00	$243,800.00
Total Costs		**$487,010.14**	**$487,010.14**	**$487,010.14**

Totals	YEAR	1	2	3
Net Benefits (Costs)		$417,189.86	$417,189.86	$417,189.86
Tax		$104,297.47	$104,297.47	$104,297.47
Value after tax		$312,892.40	$312,892.40	$312,892.40
Depreciation added back		$243,800.00	$243,800.00	$243,800.00
Cash flow	-$1,219,000.00	$556,692.40	$556,692.40	$556,692.40
Cumulative cash flow	-$1,219,000.00	($662,307.60)	($105,615.20)	$451,077.19

Evaluation Metrics	
Net present value (NPV)	$215,650.30
Internal rate of return (IRR)	17.56%
Payback period (in years)	2.19

Cautionary Note:

All costs are budgetary for discussions purposes only.

A detailed project report (DPR) needs to be done.

3.1.10.3 Relevance of CBA Analysis to SG transition

Afghanistan faces many challenges meeting the energy needs of its vast majority (75%) of people who live in rural areas. The cost of building traditional transmission and distribution lines (for such small distributed loads) to reach these far-flung places will not only be expensive but time consuming as well (may be upwards of 15 years +). With the advent of PV, BESS and hybrid inverter technologies that support distributed small communities, the current project is worthwhile exploring.

Benefits:

The CBA results look promising with a positive NPV and short payback and are worth implementing. A detailed project report (DPR) with formal quotes will be required. The following are the key benefits:

1. Fuel savings in the order of USD $ 367,500 per annum is extremely beneficial for the economy
2. The economic benefit to enabling agro and small-scale service industries in rural areas will boost the country's GDP and provide employment
3. If successful, similar projects can be implemented in other villages/semi-urban clusters
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Local O&M services will also get a boost in operating and maintaining distributed PV and BESS equipment as a part of community responsibilities
6. All these are low power equipment and hence can be managed in rural areas

3.1.10.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions of the island (temperature, altitude, dust, etc.)
2. Some special training/skills may be required by rural people for installation and commissioning of PV, inverters and battery systems
3. Unless planned well with good lead times, the supplies/delivery of such equipment may get held up in road transport to rural areas
4. It is important that the systems and architecture designs of this pilot project be supervised by global experts who are knowledgeable in this
5. Training of O&M personnel in new technology equipment (PV, inverters, batteries, etc.)

3.2 Bangladesh

3.2.1 Bangladesh Country Overview

Bangladesh had a GDP growth rate of at 7.28%[15] in 2017 which is the highest amongst the SAARC countries. Since 2004, Bangladesh has witnessed export-oriented industrialization with key sectors like shipbuilding, textiles, jute & leather, seafood and has developed industries in pharmaceuticals, food processing and steel. There is increasing demand for electricity in agriculture, industrial, commercial and residential sectors in Bangladesh. In this context, government of Bangladesh is giving top priority for the energy sector.

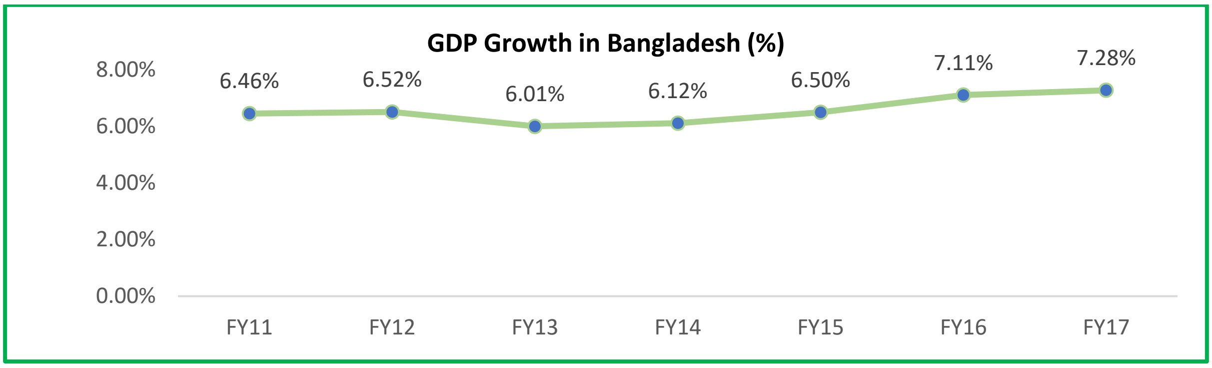


Figure 23: GDP Growth in Bangladesh

3.2.1.1 Power Sector

The government aims to develop Bangladesh into "middle income country" by 2021[16] and "high income country" by 2041 to improve the socio-economic conditions. Electricity plays a key role in poverty reduction, improvement in quality of life, infrastructure development and sustained economy. Bangladesh experiences power crisis owing to neglect of sector in past. This crisis is manifested in the form of load shedding. Over the years, the demand for power has increased but generation has not increased accordingly. The electricity consumption per capita of 310.39 kWh in 2014 which grew 6% than previous year is less than 10% of the world average of 3,200 kWh per year.

Bangladesh has formulated an extensive energy development strategy "Power Sector Master Plan 2010 & 2016 (PSMP)" for development of the sector. The key objectives of PMSP 2016 are given below:

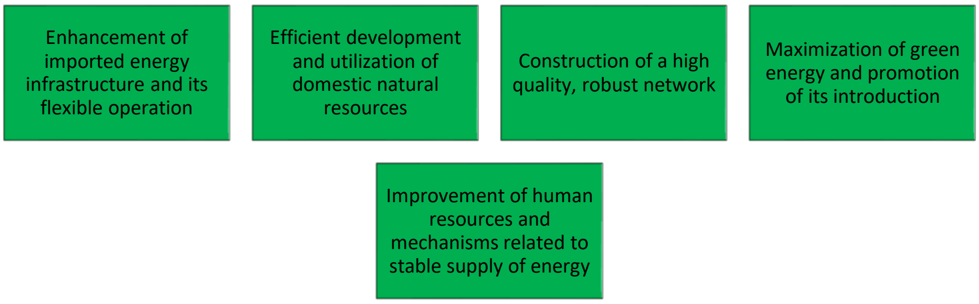


Figure 24: Key viewpoints of PMSP 2016

[15] https://data.worldbank.org/indicator/ny.gdp.mktp.kd.zg?locations=bd & world bank
[16] http://www.plancomm.gov.bd/upload/2014/Perspective%20Plan/Perspective%20Plan_Final.pdf

3.2.1.2 History of Power Sector Transition in Bangladesh

- Major reforms took place in 1990s & 2000s
- In 1996, Independent Power Producers were added with existing power plants
- Enactment of Private Sector Power Generation Policy, breaking the monopoly business of BPDB in generation

- In 1996, Power Grid Company of Bangladesh (PGCB) was formed, thereby splitting the transmission segment
- PGCB acquired 100% transmission assets from BPDB. National Load Dispatch centre also works under PGCB
- In 2002, transmission assets of DESA have been handed over to PGCB

- In 1998, Power Division was established with the responsibility of overall management of power sector.
- In 2003, Bangladesh Energy Regulatory Commission (BERC) was formed to regulate Gas, Electricity and Petroleum Products. It started functioning in 2004.
- Chief Electrical Inspector (CEI) was formed to ensure human safety, issuing licenses and standards of equipment.

- 1977, the first ever reform in Distribution segment took place
- Supply of electricity in Urban areas by BPDB (Bangladesh Power Development Board) only and rural areas by REB (Rural Electrification Board)

- Formation of Dhaka Electric Supply Authority (DESA) and Dhaka Electricity Supply Company Ltd. (DESCO) in 1991 & 1994 respectively. Operation of BPDB got reduced
- In 1995, Power Cell was established with objectives to conduct reforms in power industry and to promote private power development
- Initiative for Quick Rental Plants to meet immediate demand

- In 2002, Corporatization of Ashuganj Power Station (APSCL) took place
- In 2003, West Zone Power Distribution Company was formed.
- Retail segment in capital city DHAKA is maintained by DESCO & DPDC. DHAKA constitutes 50% of total country demand.
- Distribution in rural areas outside metropolitan DHAKA was undertaken by REB, which created 8 cooperative societies or Pali Bidyut Samities.

- Currently, power sector is in transition from public domain to private domain
- The reforms were undertaken with objectives of providing mass electrification, improving technical efficiency, attract foreign investments, cost minimization & ensure economic growth

3.2.1.3 Power Sector Structure

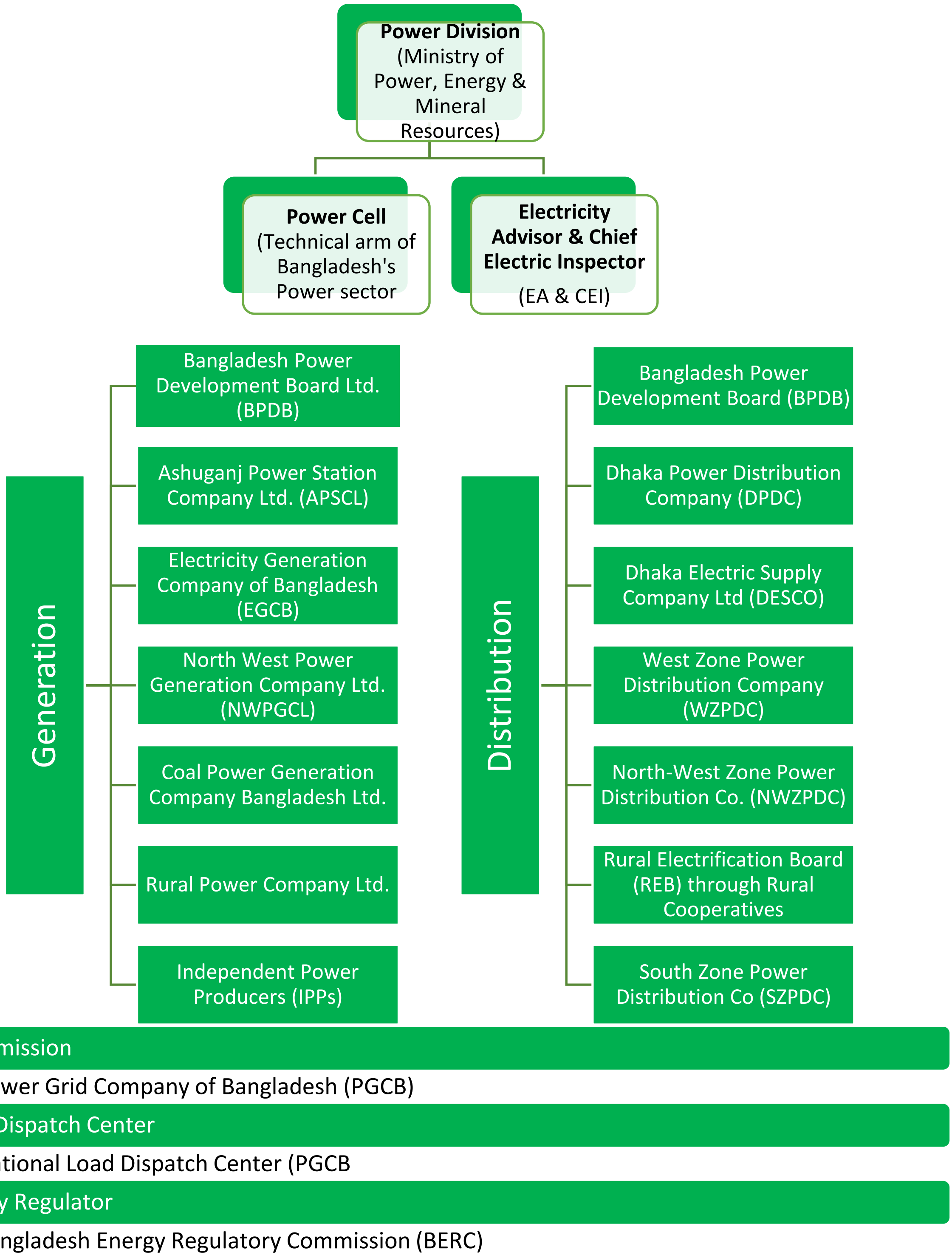


Figure 25: Bangladesh Power Sector Structure

3.2.1.4 Key Challenges and Priorities

Major constraints are: inadequate investment in power generation, skewed tariff which is not cost-reflective. Challenges and possible strategies are mentioned below.

Challenges in Power Sector

- Balancing Supply-Demand Scenario
- Ensuring Energy Security For All
- Economize Consumption of Natural Gas
- Finalization of Coal Extraction Plan
- Cost-effective Pricing Policy for Gas, Coal and Electricity
- Promotion of Renewable Energy
- Energy Conservation
- Reduction of System Loss
- Energy Mix for Electricity Generation

Possibilities of Sector Strategies

- To increase sector efficiency, reform measures must be implemented
- To have provision for dual fuels in power plants whenever possible
- Finance power generation projects through pulblic-private partnerships
- To increase power generation through renewable resources
- To adjust price in a view to reduce burden of budgetary subsidy while ensuring affordability to consumers

3.2.2 Generation

3.2.2.1 Overview

Bangladesh Power Development Board (BPDB) and its subsidiaries are primarily responsible for generation of electricity besides private generators.

Table 6: Generating entities in Bangladesh

S. No	Name of Generation Company	Installed Capacity (MW)
1	Bangladesh Power Development Board Ltd. (BPDB)	17,340[17]
2	Ashuganj Power Station Company Ltd. (APSCL)	1,577
3	Electricity Generation Company of Bangladesh (EGCB)	622
4	North West Power Generation Company Ltd. (NWPGCL)	718
5	Coal Power Generation Company Bangladesh Ltd (CPGCBL)	1,200
6	Rural Power Company Ltd.	77
7	Independent Power Producers (IPPs)	3232

[17] http://www.bpdb.gov.bd/bpdb/pdb_utility/maxgen/dailygen_archive/4003report.pdf

Present installed generation capacity in Bangladesh is 20,430 MW18 (October 2018) which include captive generation capacity. Out of this 20,430 MW, 52% is from private sector and 48% from public sector. During the period between 2009 and 2018, the access to electricity increased from 47% to 90% while installed capacity tripled. Despite that there is huge shortage owing to constantly increasing demand and that is expected to continue in near future. To mitigate the situation, government plans to increase the generation capacity to 40,000 MW by 2030. Ensuring adequate supply of power will be important to emerge as one of the attractive investment destinations in South Asia.

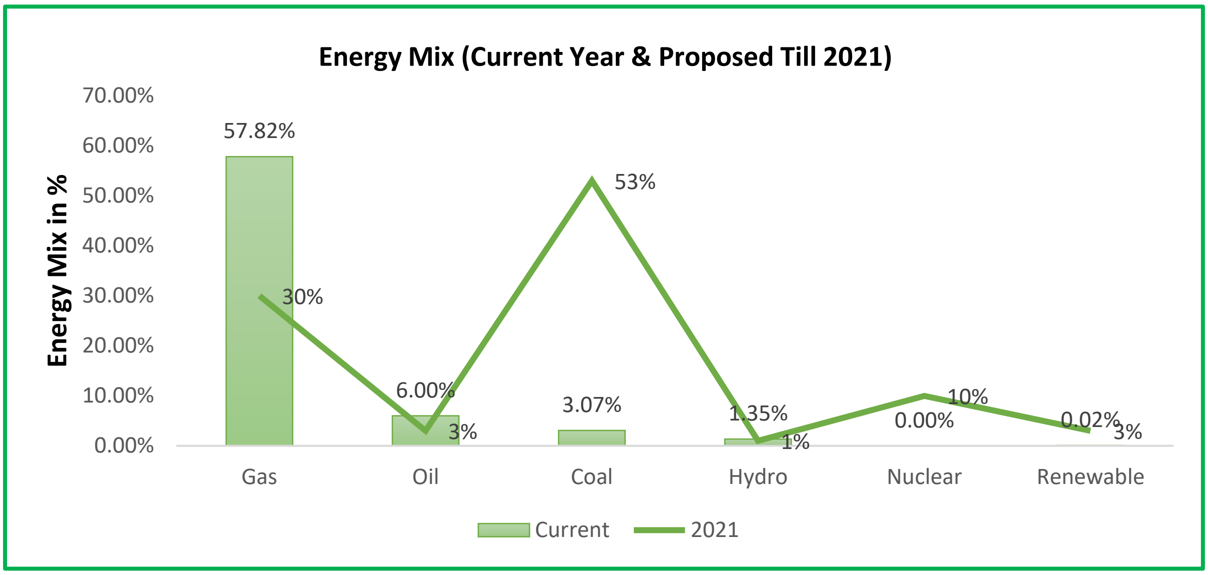


Figure 26: Energy Mix

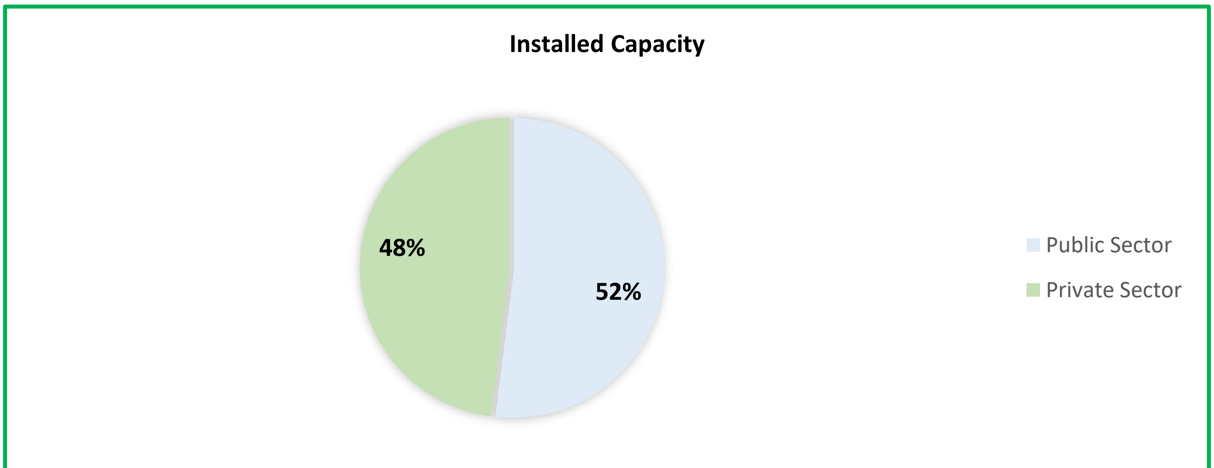


Figure 27: Installed Capacity and Demand and Generation gap from FY10 to FY17

Bangladesh Power Development Board (BPDB) has undertaken extensive capacity addition plans to add 11,600 MW to meet govt. target of generating 24,000 MW electricity by 2021, and 40,000 MW by 2030. [19]

[18] http://www.bpdb.gov.bd/bpdb_new/index.php/site/page/13e9-2cc0-ce41-9c09-088d-94d5-f546-04a6-b4fa-1d18

[19] http://www.bpdb.gov.bd/bpdb_new/resourcefile/annualreports/annualreport_1542104191_Annual_Report_2017-18_2.pdf

As per Power System Master Plan 2010 (PSMP), the demand forecast was made based on 7% GDP growth rate. Based on this analysis, peak demand would be 17,304 MW in FY20 and 33, 708 MW in 2030.

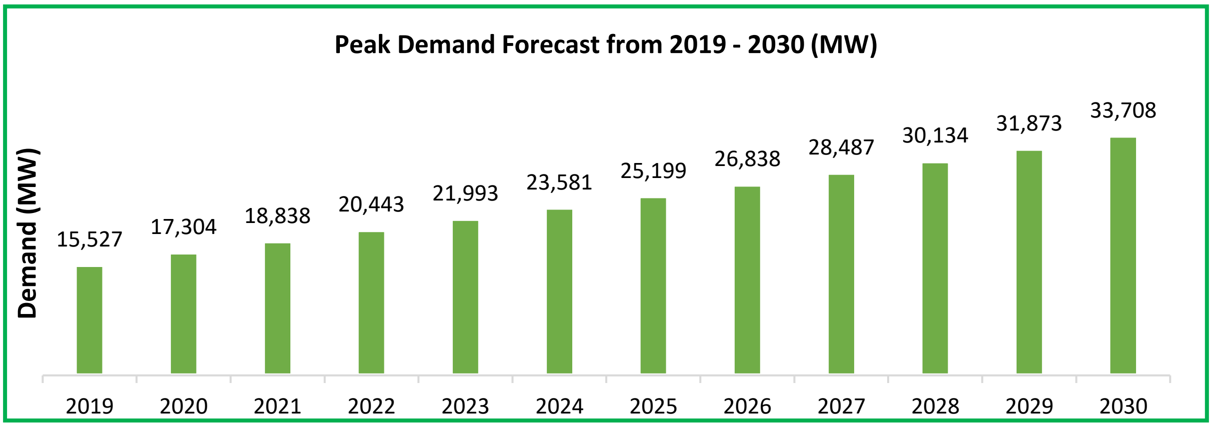


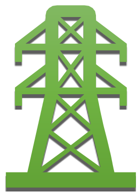
Figure 28: Peak Demand Forecast (2019-30) (MW)

3.2.3 Transmission and System Operation

3.2.3.1 Overview

The transmission network in Bangladesh is solely operated by Power Grid Company of Bangladesh (PGCB). It was formed with the vision of bringing out commercial environment in the transmission network business. PGCB performs activities like:

- Load Dispatch
- Operation & Maintenance of Grid Sub-Station and Transmission Line
- Operation & Maintenance of SCADA systems
- Communication Systems
- Protection & Relay Coordination of Transmission Systems
- Performs Design & Evaluation like Drawing Approvals, Testing & Commissioning



Presently, power generated in various power plants in Bangladesh is transmitted to the national grid through 230 kV and 132 kV transmission lines. Several projects are underway for augmenting transmission capacities. At the time of PGCB's inception, the total lengths of 230 kV and 132 kV line was 8,500 Ckt km.

The total length of the OPGW (optical ground wire) installed in the transmission lines is 5,549 km. In FY17, the transmission network of Bangladesh was upgraded to 400kV with the inauguration of first 400 kV transmission line of 196.50 km. To keep pace with the increasing power generation PGCB has taken up plans to construct around 10,513 Ckt km transmission lines and 160 numbers of grid substations at different voltage levels till 2021.

3.2.3.2 Cross Border Interconnections

Considering the present status of natural resources and alternative fuel supplies with demand supply-mismatch, and increasing energy needs, Bangladesh intends to establish interconnection of the power system with its neighbouring countries. The first such project was the interconnection with India through a 500 MW capacity HVDC back to back at Bheramara in Bangladesh. This interconnection line is presently being utilized at 80to 90% load factor. The electricity from 13 power stations in India is transmitted to Bangladesh in open market form. It suffers its own challenges as day ahead and real-time scheduling is to be handled by national level control centres. The second phase of HVDC is in development stage to import additional 500 MW through Bheramara from India.

Smart equipment that can improve the operation of Bangladesh transmission system are:

Frequency Support
- Synchronous condensers and flywheels to provide inertia

Voltage support/Short-circuit availability
- Protective relay schemes to isolate faults within cycles, Secondary VAR controllers, Synchronous Condensers to provide reactive power support and short circuit current

3.2.4 Distribution

3.2.4.1 Overview

In Bangladesh, the electrification rate has improved enormously during the past decade and electricity access is now 90% (2018) in the country. But the country still short of quality and reliable power for all. The government of Bangladesh is taking various measures to improve the ageing distribution infrastructure, increase customer satisfaction, and reduce system loss. The electrification ratio in villages is improving by the efforts of Rural Electricity Board (REB). About 64% of the population resides in rural areas and around 90% of villages were electrified till 2018 (out of 83,303 villages for rural electrification program, 74,926 villages were electrified)[20]. Enormous changes have taken place in rural areas in terms of quality of life and economic growth as most of the people now have access to electricity. In Bangladesh, system loss has been one of the key indicators for electricity distribution companies. The total loss here shows distribution loss and commercial loss.

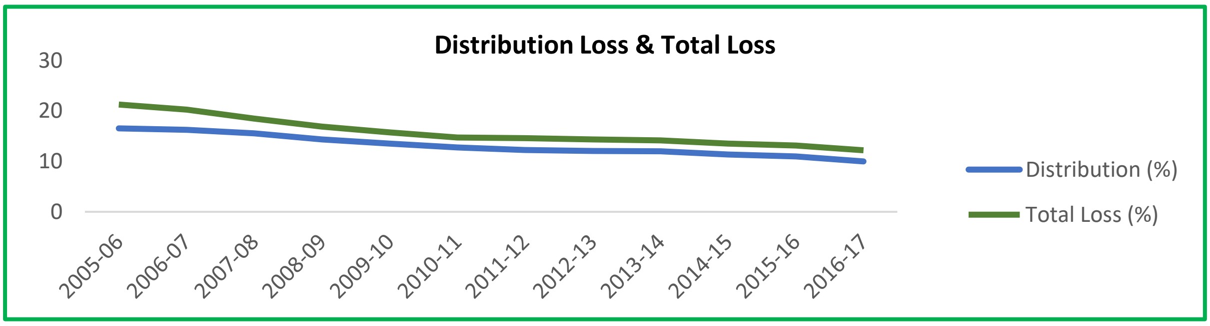


Figure 29: Distribution and Total loss

Table 7: Distribution entities in Bangladesh

S. No	Name of DISCOM	No. of Customers	Annual Energy Sale (MU)
1	WZPDCL (West Zone Power Distribution Company Limited)	10,08,561	2,725.919

[20] http://www.reb.gov.bd/site/page/c08b56bd-c300-4d08-8ea2-c25eedffbfdb/At-a-Glance

2	NESCO (Northern Electricity Supply Company Limited)	7,20,852	2,486
3	Bangladesh Rural Electrification Board (BREB) & Pali Bidyut Samiti (PBS)	17,978,410	NA
4	Bangladesh Power Development Board (BPDB)	2,526,682	NA
5	Dhaka Electricity Supply Company (DESCO)	NA	NA
6	Dhaka Power Distribution Company (DPDC)	NA	NA

3.2.4.2 Distribution network development projects and initiatives in Bangladesh

Efficiency improvement in Distribution Sector	Strengthening of Power Distribution System	Power Distribution Projects
•Power factor improvement through installation of capacitor bank/PFI plants •Implementation of prepayment metering system	•Augmentation of infrastructure capacity upto 440 MVA •Conversion of overhead distribution systems into underground electric distribution network	•Prepaid metering project established almost in all distribution network •Installation of capacitor bank in power system of Bangladesh

3.2.5 Renewable Energy

3.2.5.1 Overview

SREDA (Sustainable Renewable Energy Development Authority) is created as a nodal organization of the Government to advocate and establish renewable energy and energy efficiency activities in public and private sectors. Besides SREDA, cells/wings have been established in various power sector utilities to deal with renewable energy and energy efficiency issues.

3.2.5.2 Installed Capacity of Renewable Energy Resources in Bangladesh in FY 19

Table 8: Installed Capacity of Renewable Energy Sources

Technology	Off-Grid (MW)	On-Grid (MW)	Total (MW)
Solar	268.29	17.35	285.64
Wind	2	0.90	2.90
Hydro	NA	230	230
Total (MW)	**271.37**	**248.25**	**519.62**

3.2.5.3 Planned Capacity Addition of Renewables

Bangladesh is planning to set up some large-scale solar power projects, in order to transform its energy mix and reduce dependence on fossil fuels. As of now Bangladesh has no Utility-scale solar power projects and its power sector is skewed towards thermal plants.

The Power System Master Plan 2016 projects the installed capacity to be increased by 24,000 MW and 40,000 MW by 2021 and 2030 respectively. As per renewable energy policy, the renewable energy share should be 10% in the total energy mix by 2020. It would be 2,000 MW. In order to meet the target, government has taken various projects.

Table 9: Planned Capacity Addition of Renewable Energy sources in Bangladesh

Technology	2018	2019	2020	2021	Total
Solar	350	250	300	250	1,470
Wind	150	350	300	300	1,153
Biomass	6	6	6	6	30
Biogas	0.5	0.5	0.5	0.5	7
Hydro	1	1	2	2	236
Total	**507.5**	**607.5**	**608.5**	**558.5**	**2,896**

3.2.6 Policies & Regulations

3.2.6.1 Overview

Policy and Regulatory framework of Bangladesh's power sector is not conducive for rapid developments in the sector. The restructuring and reforms done in past decade, and the rules and regulations implemented are out of sync with recent global trends and advancements. Existing policies on private sector participation for electricity generation must be amended to spur the growth in generation sector. Key policy initiatives in the recent past related to grid network expansion and off-grid development are highlighted below.

The draft "Net-Metering" Policy highlights prosumer enablement, interconnection requirements & financial mechanism for RE integration. Also, it shows tariff aspects like Flat rate consumers, peak/off-peak rates & Metering arrangements like Smart Meters etc.

RAPSS & Private Sector generation policy are two approaches that accelerates electrification pace with private players' involvement. Serving as intermediaries' b/w customer & utilities will open new business models in the market.

Tariff:

Operational Tariff in Bangladesh includes Bulk Tariff, Wheeling Charge and Retail Tariff. Current tariff policies lack on Cost-reflective pricing or tariff rationalization.

Renewable Energy:

RE policy mandates 10% of electricity to be generated by renewable energy sources. This step is an attempt to modernize the existing grid with renewable resources.

Energy Efficiency:

Though it is a plan and not policy/regulation, it intends to stimulate energy efficiency and conservation practices in Industrial, Residential and Infrastructure sectors through a roadmap till 2030.

Distribution of Electricity: Off-grid:

Remote Area Power Supply Systems (RAPSS) promotes development and operation of electricity distribution and retail supply system through private sector participation.

3.2.7 Key Drivers for Smart Grid in Bangladesh

Energy Access:

Currently energy access in the country is around 90%. Rural houses in Bangladesh use electricity and kerosene for lighting. It is estimated that 70% of lighting comes from kerosene and 30% from electricity. For cooking, 90% of rural population is dependent on biomass. In order to enhance access and availability of electricity to entire citizen Bangladesh needs to develop renewable resources, off-grid systems and deploy smart grid technologies to integrate the different energy resources and operate the grid efficiently.

Reliability and Quality of Supply:

Large parts of the country experience load shedding which is threatening to industry, agriculture and commerce. Because of load shedding, rental power plants are deployed to supplement the grid power. Quality of supply also suffers owing to supply-demand mismatch. Smart grid technologies can control loads and help bridge the supply-demand gaps which will enhance the reliability and quality of supply. This will reduce the reliance on peaking plants (which are rental).

Grid Expansion:

In entire power sector value chain, several capacity augmentation plans are under implementation stage. The generating stations in Bangladesh are located at large distance from load centres. The existing transmission network runs on short and medium transmission line network and plans are there to develop high capacity transmission infrastructure for reliable and quality supply of electricity. As the transmission and distribution capacity being augmented, smart grid technologies for increased visualization and situation awareness must be deployed to improve the reliability and efficiency.

RE Integration:

Since, the electricity demand is increasing in Bangladesh, it is impossible to build power plants rapidly. However large solar farms and wind farms can be installed in 12-18 months. Micro and mini-grids ensures proper distribution of electricity in remote areas. Smart grid technologies enable to integrate renewable resources with the man grid by providing flexible operation of the grid.

Demand Side Management (DSM):

The growing demand requires new power plants which requires huge investment and time. So, it is a wise act to control demand of electricity at consumer side and implementation of DSM techniques which will address issues like reliability, network problems and load management. This will help in supporting the customers in reducing bills, lower dependence on foreign energy sources and reduction in peak power prices of electricity. The country should explore opportunities of DSM implementation in the form of energy efficiency and demand response which require smart grid technologies.

Cross Broder Interconnections and Trading:

Energy Security and CO_2 emissions are the keys aspects that motivates cross-border interconnections for Bangladesh. Cross border trade will help Bangladesh to lower the fossil fuel consumption that substantially reduces the CO_2 emissions. Through electricity import, the investments made for augmenting the capacities in Bangladesh can be postponed or avoided. Smart grid systems will improve system operations with interconnection with neighbouring countries.

DER and Prosumer Enablement:

With the advent of renewable energy resources, concept of net-metering for consumers will help them to produce and consume the electricity on their own thereby increasing the electricity access in Bangladesh. The regulations for the implementation of net-metering must be planned, designed and implemented so that residential, commercial and industrial consumers of grid-connected electricity can harness the potential of solar energy for power generation by installing solar panels on their own roof. This will create new business models for the power market and challenge for utilities to understand this transformation. The rooftop PV will have its own engineering challenges owing to reverse power flow. As the share of distributed energy resources (DER) from rooftop PV and other resources at customer premises increases, smart grid solutions are necessary to manage the stability of medium voltage (MV) and low voltage (LV) grids.

3.2.8 Smart Grid Initiatives

- Dhaka Power Distribution Company (DPDC) will be installing smart grids for the first time in Bangladesh in the capital's Dhanmondi, Azimpur, Green Road, Lalmatia and Asad Gate areas. New substations will accompany the smart grids in these five areas. France Development Agency (FDA) has agreed to spend $12 million on this project
- DPDC will be install Electric meter boxes containing a type of SIM card at households and organizations. These boxes will transmit consumption data to a modern central management ward every 15 minutes

3.2.9 Smart Grid Scenario

3.2.9.1 Existing Smart Grid Status

The present power system in Bangladesh is facing many systemic, operational, management, financing and capacity challenges. Strategic efforts are required from all stakeholders to not only upgrade the existing grid infrastructure but transition towards cleaner and reliable power system integrating the diverse energy resources through smart grid technologies.

3.2.9.2 Smart Grid Roadmap for Bangladesh

With available data and its analysis, a pragmatic smart grid roadmap has been prepared for Bangladesh as detailed in this chapter.

The key assumptions behind the proposed roadmap are:

- The planned targets for power system expansion set by the Government will be achieved in the envisaged time horizon
- Polices favoring transmission and distribution (T&D) and strengthening of grid infrastructure in the country by 2020 and integration of renewable energy sources to the grid by 2025
- As the country is doing well with off- grid solar development, Solar PV and Rooftop PV policies would be made more attractive so that much of the population can reap the benefits in near future
- Smart grid initiatives and policies will be given importance and transmission and distribution losses would be reduced from present level of 12.6% to 10% by 2025 and to 6% by 2030
- We have used the Smart Grid Maturity Model (SGMM) tool to assess the current situation of the grid and prepare the smart grid roadmap. However, from the data gathered from secondary sources we could not assess the exact level of maturity of the utilities in Bangladesh on different domains of SGMM. Hence it is assumed that all utilities are at ZERO level on all the domains and prepared the roadmap with recommendations on what they should undertake to ascend to higher levels. If any of the utilities have already implemented some of the recommendations, they can do the remaining

The proposed Smart Grid Roadmap is in 3 stages:

a. Immediate Term (2018-2020): Proposed some immediate action items for power system development and grid modernization in Bangladesh in alignment with long term goals set by the Government

b. Near Term (2020-2025): Proposed a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction

c. Medium Term (2025-2030): Proposed several measures that would transform the Utilities in the country to a modern organization using planning tools and advanced automation and IT systems and analytics to optimize their assets and operations

3.2.9.2.1 Bangladesh Smart Grid Roadmap 2018 – 2020

The Bangladesh Smart Grid Roadmap 2020 defines the progressive trajectory of developments from present state (in 2018) to 2020 in following areas: Strategy, Management and Regulation (SMR), Organization and Structure (OS), Grid Operations (GO), Work and Asset Management (WAM), Technology and Customer.

Bangladesh is seen to be a country which is looking to improve and work towards integrating new technologies. The government has taken several initiatives and is working for achieving new milestones in terms of smart grid and its applications across the country. Dhaka Power Distribution Company (DPDC) is installing smart grids which is first in the country.

1. Strategy, Management and Regulatory (SMR)

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level to achieve in 2020: 1

- Electricity Distribution Utilities in the country should target to achieve Maturity level 1 on Strategy, Management and Regulatory domain of SGMM by 2020 by undertaking following steps: Define smart grid vision, strategy and policy in consultation with Ministry of Power, Energy and Mineral Resources (MPEMR) vision and technologies
- Initiate discussion with Regulators on Smart Grid Roadmap
- Make departmental structure in utilities for smart grid implementation (DMS, SCADA, Substation Automation, AMI) and define their roles and responsibilities
- Define area load dispatch centre, regional load dispatch centre, central load dispatch centre and SCADA hierarchy for the country
- Identify areas for renewable energy growth and integration with grid
- Identify potential area for pilot project implementation for Smart Grid Pilot Projects - SCADA/DMS, Substation Automation and AMI
- Approval of funds for the pilot projects

2. Organization and Structure (OS)

Present Maturity Level (in 2018): 0; Target Maturity Level (in 2020): 1

A Smart Grid department may be created by the MPEMR so that the vision could be clear, and implementations can be monitored in all utilities.

Utilities in Bangladesh must undertake following steps to ascend to Maturity Level-1:

- Organization and Utilities should look into the benefits and try to build positive scenario for Smart Grid and its applications
- Organization structure and workforce need to align as per Smart Grid Vision and Roadmap
- Conduct workshops/ awareness session of Smart Grid technology and needs across multiple functions/line of business to support smart grid activities
- Leadership should demonstrate commitment to change the organization to support by assigning resources and budgets to achieving the targets envisaged in the smart grid roadmap

3. Grid Operations (GO)

Present Level (in 2018): 0; Target Maturity Level in 2020: 1

In Bangladesh, many projects are in progress by BPDP, DPDC and other utilities for strengthening of electrical network across country. Organizations should target to achieve maturity level 1 on SGMM by 2020 by undertaking following steps:

- Utilities should prepare their Smart Grid Roadmap for 2030 and hold discussions with regulators and policy makers for approval
- Define Smart Grid as an important item in business plan, budget and annual revenue requirement (ARR) plan and define future work plan for the same
- Utilize Geographical Information Systems (GIS) for planning and expansion of the power grid systems

- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g. AMI, with remote disconnect, SCADA/DMS, GIS etc.) may be undertaken
- Define strategy and plan for proof of concept projects and/or component testing for grid monitoring and control underway related to smart grid technologies
- Implementation of peak load management through demand response (DR) at distribution level
- Installation of transformer monitoring units (TMU) on all power transformers and distribution transformers feeding to key customers and critical assets
- Make plan to implement SCADA/DMS, substation automation and IT system in phased manner in urban areas by 2020
- Make strategy and plan to implement pilot projects of AMI at required locations by 2020
- Implementation of Cyber security measures such as:
    - Identify and access management system
    - Implement relevant recommendations of statutory guidelines by government agencies on cyber security (if any)
    - Compliance with IEC or country specific Cyber Security standards

4. Work and Asset Management

Present Maturity Level (in 2018): 0; Target Maturity Level (in 2020): 1

Utilities could target for Level-1 by 2020 by undertaking following steps:

- Define business case for GIS and asset mapping for transmission and distribution assets and get approval for the same
- Perform consumer indexing at distribution level and map it to GIS
- Institute work flow for continuous updating of assets and customers on the GIS map
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

5. Technology

Maturity Level in 2018: 0 (default), Target Maturity Level by 2020: 1

For achieving maturity level-1 by 2020, Utilities need to take following measures:

- Enterprise IT Architecture: Utilities must develop an enterprise IT Architecture and start its implementation. Need to retire several IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated (even through a middleware) must be replaced with commercially available off the shelf (COTS) applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT Architecture should enable integration of new assets and applications acquired by different LOBs
- Implement one integrated billing system across Utilities covering every type of customer
- Conduct audit for Cyber Security and adopt the recommendations to secure systems form cyber-attacks
- Prepare cloud strategy for future expansion

6. Customer

The electrification rate is being increased to cover 83% of population by 2030, several million new customers will be added to the Utilities network in the coming years New systems must be put in place to handle the customers queries and needs.

Present Level (in 2018): 0 (default), Target Maturity Level by 2020: 1

Recommendations for reaching maturity level 1 by 2020 are:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved Smart Grid Roadmap. These studies will identify customer benefits and satisfaction. Utilities may conduct these studies with input from different category of customers in urban and rural areas
- Conduct workshops to educate customers about Smart Grid Vision and Roadmap of Utilities
- Conduct study or research work for security and data privacy implication of new technologies and business process/functions to be adopted which can enable customer participation to leverage smart grid functionalities
- Consult with public Utility commission and /or other government related organization regarding impact of technologies on different categories customers

3.2.9.2.2 Bangladesh Smart Grid Roadmap 2020 – 2025

The Bangladesh Smart Grid Roadmap 2025 defines the progressive trajectory of developments from the state in 2020 to 2025 in 7 domains as recommended below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level (in 2020): 1, Target Maturity Level (in 2025):2

For achieving maturity level-2 by 2025, utilities in Bangladesh need to undertake following measures:

- Approval and acceptance of smart grid roadmap from regulators/higher management and ministry across all multiple functions
- Approval of smart grid projects/investments as per smart grid roadmap
- Designate and make hierarchy of smart grid leaders in all key line of business (LOB's) with authority / responsibilities to implement measures envisaged as per approved smart grid roadmap

2. Organization and Structure (OS)

Maturity Level (in 2020): 1, Target Maturity Level (in 2025): 2

For achieving level-2 by 2025, Utilities need to take following steps:

- Approval of a Manpower Plan (including Training Plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on the Smart Grid Roadmap, restructure the organization hierarchy and its business process which can align end to end process for smart grid operations
- Create cross functional teams among all LOBs for implementation of smart grid initiatives as per the Smart Grid Roadmap

3. Grid Operations (GO)

Maturity Level (in 2020): 1, Target Maturity Level (in 2025): 2

As per analysis of available data, it is assumed that Utilities can achieve maturity level 2 by 2025. For achieving maturity level 2 by 2025, following measures may be taken:

- Upgrade the electrical network to support the estimated peak load and energy requirements in 2025 through a combination of steps such as:
  - Building new substations and medium voltage (MV) and low voltage (LV) lines; and upgrading the capacity of existing substations
  - Increasing the transformation capacity at DT levels
  - Replacement of existing DTs with higher capacity DTs where ever required
  - Addition of capacitor banks to regulate power quality where ever required
  - Peak load management through demand response (DR) at customer premises
  - HT: LT ratio is brought to 1:2 in urban area and 1:4 in rural area
  - All old wire joints on overhead LV lines are replaced with proper crimped joints

- All new grid equipment being installed are with remote monitoring capabilities
- Implementation of SCADA/DMS and Distribution Automation System (DAS) in smart cities
- Implementation of AMI across Dhaka
- Extension of Outage Management System (OMS) to smart cities and its integration with SCADA/DMS, DAS and GIS
- Deployment of Energy Storage Systems (ESS) for grid balancing in urban areas with high rooftop PV penetration
- Rollout of EV charging infrastructure and Vehicle-Grid Integration solution in key locations in urban areas and national and state highways
- Deployment of Advanced Analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all LOBs; dash boards with relevant information are made available in each LOB; cross-LOB decision making is achieved efficiently through analytical inputs
- Grid operations data is being leveraged for grid planning using advanced analytical and planning tools
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real-time load and voltage data in all urban feeders and select rural feeders
- Installation of electronic wall map to assist distribution operations control centre consolidation (if not part of DA system) which assist operations personnel in managing and making operational decisions
- Establishment of a dedicated Smart Meter Operations Centre (SMOC) that will monitor and control smart meter operations; provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operations
- Advanced Ground Fault Detection by installing protective relays to detect high impedance (very low fault current) faults for faster isolation of downed conductors promoting enhanced safety and improved service reliability
- Systems for condition-based maintenance of Circuit Breakers and Power Transformers

- Extension of Voltage and Reactive Power (Volt-VAR) Optimization (VVO) systems to entire service area
- Systems for automated operation of Capacitor Banks (if not part of VVO solution)
- Implementation of state-of-the-art Security Operations Centre (SOC) to safeguard the system from cyber and physical threats

4. Work and Asset Management

Maturity Level (in 2020): 1, Target Maturity Level (in 2025): 2

It is reasonable to assume that Utilities can target for maturity level 2 by 2025. For achieving maturity level 2 by 2025, following steps should be taken:

- Asset performance trend analysis and event audit reports are available for all key assets and systems in Ut
- Hotline maintenance including bare hand work methods are implemented in urban areas
- Integrated view of all key assets on GIS maps which are monitored remotely and are integrated with ERP and are integrated with mobile workforce management system (MWFM) covering all urban areas
- Communication systems are upgraded at frequent intervals to support reliable performance of all IT and Automation systems deployed; new communication models include customer to Utility, customer to market, and smart equipment to equipment (M2M)
- Network model of the distribution grid up to DT level is regularly updated and modelling studies undertaken for assessing various scenarios of network upgrades to balance demand and supply most optimally
- Inventories are tracked remotely using appropriate systems which are integrated with the ERP, GIS and WAM systems
- Analytical tools for predictive maintenance are deployed on trial basis
- AMI integration with OMS – Last Gasp signals and restoration messages from smart meters are integrated with OMS for faster restoration and improved customer satisfaction
- AMI-GIS Integration to enhance the visualization of the network to provide safety, reliability and operational benefits

5. Technology

Maturity Level in 2020: 2; Target Maturity Level in 2025: 3

ISGF Recommendations for reaching Target maturity level of 3:

- Business processes in key LOBs where smart grid applications are implemented are aligned to the approved IT Architecture. Where ever required the business processes may be modified to align with the IT Architecture and systems
- Smart grid technologies implemented are leveraged in such a fashion that it improves the cross-LOB performances
- Uniform data communication strategies and tactics across LOBs are implemented
- Data collected from smart sensor network installed on distribution lines are leveraged by other applications for grid operations and customer services functions
- Cloud services are in place and all new applications are hosted on secured public cloud; existing applications are migrated to the cloud as the old hardware becomes redundant

- Systems in place for providing access to energy data to qualified academic researchers for research purposes, local government bodies for their climate action plans and other government agencies and regulators for specific use cases without compromising the privacy of customers personal data

6. Customer

Maturity Level in 2020: 2; Target level of maturity in 2025: 3

Following initiatives may be undertaken to achieve target maturity level of 3 by 2025:

- Smart grid programs may be tailored for different segments of customers in both urban and rural areas
- AMI may be deployed (with two-way communication and remote connect/disconnect features) to all urban customers
- Demand response systems for remote control of customer loads are deployed for select customers with loads >20kW
- Automatic outage detection and restoration systems are in place at substation level
- Customers can access their daily electricity consumption data through the customer portals (in urban areas where AMI has been implemented); Customers can receive alerts on monthly bills when it approaches the pre-set limits
- Customer engagement and education programs for leveraging the features of smart grid systems, prosumer enablement; and customer participation in peak load management programs; promotion of energy efficiency and system improvement programs on benefit sharing models
- Development of standards for security and privacy controls in all customer products and services
- Plans for enabling retail completion for energy supply is in place and initial trials undertaken
- Peer to Peer (P2P) trading of electricity from behind the meter devices (rooftop PV, batteries, EVs) are piloted successfully
- Actual residents (not building owners) are enrolled as UTILITIES's customers and new KYC norms and contacts information updated accordingly; and linked with their UID (Aadhar) Numbers
- Promotion of Diesel Generator set replacement program with Batteries (which can participate in load balancing) at customer premises
- Promotion of innovative Community Solar and Community Microgrid projects
- Pilots on Peer-to-Peer (P2P) trading of electricity from customer's behind the meter devices through smart contracts on real-time

7. Societal and Environmental

Maturity Level (In 2020): 0 (Default), Target Maturity Level (in 2025): 1

It is recommended to undertake following for reaching maturity level 1 by 2025

- Publish the smart grid roadmap with emphasis on:
  - Utilities role in environmental and societal issues with respect to smart grid vision and strategy
  - Utilities publicly promote the environmental benefits of using smart grid technologies
  - Organization role in protecting the nation's critical infrastructure

- Approved environmental compliance records may be available for public inspection

3.2.9.2.3 Bangladesh Smart Grid Roadmap 2025 – 2030

Bangladesh Smart Grid Roadmap 2030 defines the progressive trajectory of developments from present state (in 2025) to 2030 as expanded in all 8 domains below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, Utilities need to take following measures:

- Establish Smart Grid Governance Model for smart grid development and decision making Define roles, process and tools for the same
- Proper audit of all smart grid projects implemented across the country for better monitoring
- Designate a Single Smart Grid Leader in all key line of businesses with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap

2. Organization and Structure (OS)

Maturity Level (in 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, Utilities need to take following measures:

For achieving maturity level -3 by 2025 UTILITIES need to take following measures:

- Commitment and consistency of Leadership in communication and actions related to smart grid programs and projects
- Organization structure redesign to support smart grid initiatives - matrix organization structure or similar; also execute this in view of the DNO structure and retail competition era
- All changes in organizational structure and appointments/transfers/changes being made with the consideration that smart grid programs and projects are supported
- Performance rewards and compensations are linked to success of smart grid programs and projects
- Educational and training programs are aligned to build smart grid capabilities in UTILITIES
- Knowledge management framework to be put in place to capture the learnings from technology trials and new projects to be institutionalized rather than remain with individuals

3. Grid Operations (GO)

Maturity Level (in 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, Utilities need to follow below measures:

- Upgrade the electrical network to support the estimated peak load and energy requirements in 2025 through a combination of steps such as:
  - Building new substations and medium voltage (MV) and low voltage (LV) lines; and upgrading the capacity of existing substations
  - Increasing the transformation capacity at DT levels to approx.: 30,000 MVA
  - Replacement of existing DTs with higher capacity DTs where ever required
  - Addition of capacitor banks to regulate power quality where ever required
  - Peak load management through demand response (DR) at customer premises

- HT:LT ratio is brought to 1:2 in urban area and 1:4 in rural area
    - All old wire joints on overhead LV lines are replaced with proper crimped joints
    - All new grid equipment being installed are with remote monitoring capabilities
- Implementation of SCADA/DMS and Distribution Automation System (DAS) in smart cities
- Implementation of AMI across entire smart cities
- Extension of Outage Management System (OMS) to smart cities and its integration with SCADA/DMS, DAS and GIS
- Deployment of Energy Storage Systems (ESS) for grid balancing in urban areas with high rooftop PV penetration
- Rollout of EV charging infrastructure and Vehicle-Grid Integration solution in key locations in urban areas and national and state highways in Utility service area
- Deployment of Advanced Analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all LOBs; dash boards with relevant information are made available in each LOB; cross-LOB decision making is achieved efficiently through analytical inputs
- Grid operations data is being leveraged for grid planning using advanced analytical and planning tools
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real-time load and voltage data in all urban feeders and select rural feeders
- Installation of electronic wall map to assist distribution operations control centre consolidation (if not part of DA system) which assist operations personnel in managing and making operational decisions
- Establishment of a dedicated Smart Meter Operations Centre (SMOC) that will monitor and control smart meter operations; provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operations
- Advanced Ground Fault Detection by installing protective relays to detect high impedance (very low fault current) faults for faster isolation of downed conductors promoting enhanced safety and improved service reliability
- Systems for condition-based maintenance of Circuit Breakers and Power Transformers
- Extension of Voltage and Reactive Power (Volt-VAR) Optimization (VVO) systems to entire service area
- Systems for automated operation of Capacitor Banks (if not part of VVO solution)
- Implementation of state-of-the-art Security Operations Centre (SOC) to safeguard the system from cyber and physical threats

4. Work and Asset Management

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level-3 by 2030, Utilities need to undertake following measures:

- Asset performance trend analysis and event audit reports are available for all major assets and systems
- Integrated view of all major/ key assets on GIS system with remote monitoring facility and their further integration with ERP system and mobile workforce management system (MWFM) covering all major urban areas

- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals
- Network model of transmission and distribution grids up to DT level is regularly updated and modelling studies undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Analytical tools for predictive maintenance are deployed on trial basis
- AMI integration with OMS – restoration / disconnection messages from smart meters are integrated with OMS for faster restoration and improved customer satisfaction
- AMI- GIS integration to enhance the visualization of network to provide safety, reliability and operational benefits

5. Technology

Maturity Level in 2025: 3; Target Level in 2030: 4

ISGF Recommendations for reaching Target maturity level of 4:

- Business processes in key LOBs where smart grid applications are implemented are aligned to the approved IT Architecture. Where ever required, the business processes may be modified to align with the IT Architecture and smart grid systems
- Wide Area Monitoring Systems are implemented in the entire service area and event data are processed in analytical solutions with complex event processing (CEP) engines and artificial intelligence
- Smart grid technologies implemented are integrated with systems across the LOBs so that the cross-LOB system performances are enhanced
- Uniform data communication strategies and tactics across LOBs are implemented
- Wide Area Monitoring System is operational and the PMU data is leveraged by other applications supporting grid operations and customer support functions
- Security Operations Centre (SOC) is continuously upgraded with new tools and systems and complied with regulations and standards

6. Customer

Maturity Level in 2025: 3; Target level of maturity (in 2030): 4

Following initiatives may be undertaken to achieve target maturity level of 4 by 2030:

- Time of Use (ToU) tariff is introduced for all categories of customers including domestic customers; different tariff schemes are explained to all categories of customers and help them compare their electricity usage against different tariff plans
- AMI is deployed (with two-way communication and remote connect/disconnect features) to all customers (including rural) in Utility service area
- Automatic outage detection and notification is available at circuit level
- Price signals are communicated to customers on real-time basis so that customers can adjust their usage
- Customers in entire Utility service area can access their real-time usage data
- Residential customers are encouraged to participate in demand response programs; large customer's loads are remotely controlled from Utility control centre
- Retail competition for energy sales are successfully implemented and customers can choose their electricity provider

- Systems for participation in Peer to Peer (P2P) trading of electricity from behind the meter devices (rooftop PV, batteries, EVs) are available to all customers
- Keep constant watch of changing behavior of customers on social media and other artificial intelligence tools and ensure Utility systems and services meant for different categories of customers are available on all popular digital platforms

7. Societal and Environmental

It is assumed that Bangladesh is at default maturity level for this domain.

Present Level (in 2020): 0 (default), Target Maturity Level by 2025: 1

Recommendations for reaching maturity level 1 by 2025 are:

- Publish the smart road map with emphasis on:
    - Environment and societal issues with respect to smart grid vision or strategy
    - Promoting the environmental benefits of using smart grid technologies
- Approved environmental compliance records may be made available for public inspection

8. Value Chain Management (VCM)

Maturity Level (In 2025): 0 (Default), Target Maturity Level (in 2030): 1

Utilities should undertake following steps to reach maturity level 1 by 2030 on Value Chain Management:

- Formulation of a strategy for creating and managing a diverse resource portfolio

- Identification of:
    - Assets and programs for load management
    - Distributed generation resources, its locations and its capabilities
    - Security requirements to enable interactions with an expanded portfolio of value chain partners

The recommended Smart Grid Maturity Roadmap for Bangladesh Utilities are indicated in a phased manner below:

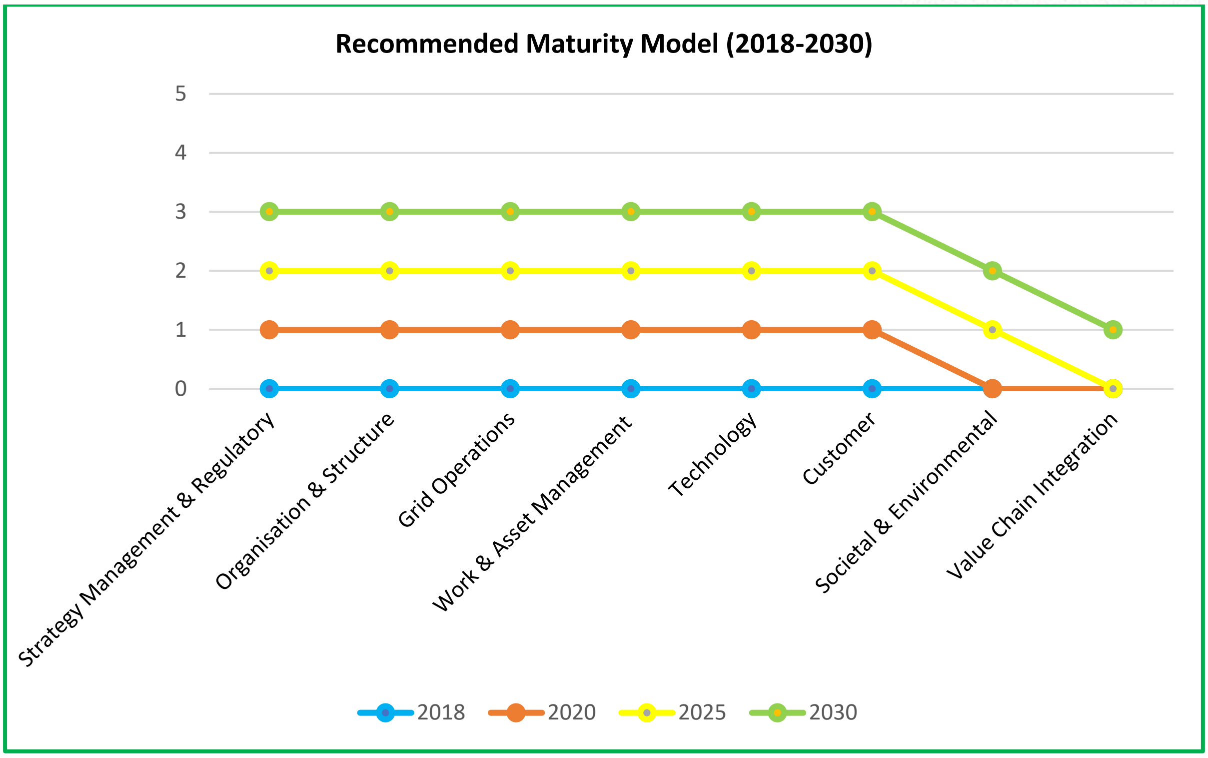


Figure 30: Recommended Smart Grid Maturity Levels (2018-2030)

3.2.10 Cost Benefit Analysis

3.2.10.1 Background

Bangladesh economy has undergone a major transformation since 2004 and has seen an annual growth of 6.5%. Over 90% of the population has access to electricity with the distribution system having a low 10% losses. It is Asia's 7th largest producer of natural gas (which the government now wants to conserve). Its 20,000 MW of generation (mostly old gas plants) is targeted to double by 2030. Solar PV penetration is low at 285 MW (but the most successful rural energy access in Asia), but 70% of rural lighting comes from kerosene. The major problem in the grid today is (1) overloading of systems equipment due to load growth; (2) No DSM (DR/Conservation) systems in place; (3) poor reactive power support and hence power quality problems; (4) old distribution network. Left unchecked, it will harm the economic growth and investments.

3.2.10.2 Project objective & Description

Autonomous decentralized DSM (DR+EC), power factor improvement and nodal voltage management using advanced devices. Alleviate 10 MW of capacity in a particular Distribution station and reduce energy consumption by 25% (all on LT load customer's side). Societal impact would be deferred Capex feeder investments on upgrades as more load/customers can be accommodated on the current given feeder with autonomous DSM capabilities.

Note in many parts of India the limit of 600 KVA DT is fast approaching in urban areas. Upgrading to a 11KV feed is very expensive (in the West we run 27.6 KV into each residential condo and step down (the customer pays for this Capex/transformer substation).

1. 5,000 unit of Advanced A/C Energy Saver (put on 2T-10T A/C units) - reduce av. 30 MWhr/day (USD $200 each)

2. 10,000 units of PF equipment - target 0.9pf at 2-10 KW load points and lower demand by 5MW or 15% (USD 150 each)
3. 10,000 units of autonomous load controller - target 2-10 KW load points and lower demand by 2.5MW or 7% (USD 300 each)
4. 500 units of Smart Inverter - target 5-10 KW load points/PV to autonomously regulate PCC voltage (USD 3000 each)
5. 500 units of Smart Meter + Telecom - target 5-10 KW Load points /PV to monitor harmonics (USD 100 each

Financial Data:

- Required rate of return (Govt. / IFI rates) - 8%
- Tax rate - 25%

Parameter	Cost
Equipment	$7,050,000.00
Engineering and Development	$150,000.00
Installation & Commissioning	$150,000.00
Total Initial Investments	**$7,350,000.00**

Benefits	YEAR	1	2	3
Diesel Fuel Saved (av. 250 KW x 6000 hrs x 0.28 L/KW x USD 1.75/L)		$735,000.00	$735,000.00	$735,000.00
Carbon Emissions Avoidance {(2.7kg/L x (1000-300 KW) x 0.28 L/KW x USD 25/ton)}		$79,380.00	$79,380.00	$79,380.00
Av. 5 MW Capacity/headroom improvement ($800/KW)		$4,000,000.00	$4,000,000.00	$4,000,000.00
DG maintenance savings (USD 1.00/hour/50 KW x (250 KW) x 6000 hours)		$30,000.00	$30,000.00	$30,000.00
av. 15 MWhr energy saving per day to customers (USD 0.10 /KWh)		$450,000.00	$450,000.00	$450,000.00
Total Benefits		**$5,294,380.00**	**$5,294,380.00**	**$5,294,380.00**

Evaluation Metrics		Cautionary Note
Net present value (NPV)	$1,628,254.52	All costs are budgetary for discussions purposes only
Internal rate of return (IRR)	19.90%	A detailed project report (DPR) needs to be done
Payback period (in years)	2.11	

Costs (Excluding Initial Capital Investments)	YEAR	1	2	3
Operations		$50,000.00	$50,000.00	$50,000.00
Maintenance		$40,000.00	$40,000.00	$40,000.00
Project management, customer support		$35,000.00	$35,000.00	$35,000.00
Capital Cost recovery from customers (10-year Amortization)		$1,014,228.46	$1,014,228.46	$1,014,228.46
Depreciation on capital expenditures (calculation uses 5-year period)		$1,470,000.00	$1,470,000.00	$1,470,000.00
Total Costs		**$2,609,228.46**	**$2,609,228.46**	**$2,609,228.46**

Totals	YEAR	1	2	3
Net Benefits (Costs)		$2,685,151.54	$2,685,151.54	$2,685,151.54
Tax		$671,287.88	$671,287.88	$671,287.88
Value after tax		$2,013,863.65	$2,013,863.65	$2,013,863.65
Depreciation added back		$1,470,000.00	$1,470,000.00	$1,470,000.00
Cash flow	-$7,350,000.00	$3,483,863.65	$3,483,863.65	$3,483,863.65

3.2.10.3 Relevance of CBA Analysis to SG transition

Bangladesh faces the challenge of meeting its surging demand as a result of its economic development. As a result, many of its circuits and equipment at the delivery points are overloaded. The cost of upgrading such equipment is not only expensive but time consuming as well. Prolonged delays in infrastructure upgrades will stall economic growth. New technologies in power management (power factor, load control, energy conservation and smart hybrid inverters), now allows for the cheapest solution in managing demand as a first step (rather than increase capacity). The current project is worthwhile exploring.

Benefits:

The CBA results look promising with a positive NPV and short payback and is worth implementing.

A detailed project report (DPR) with formal quotes will be required.

The following are the key benefits:

- Fuel savings in the order of USD $ 735,000 per annum is extremely beneficial for the economy
- A 5MW improvement in demand headroom, is worth USD $ 4 million per annum and a 15MWh energy savings at USD $450,000 p.a
- If successful, similar projects can be implemented in other urban clusters
- Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
- Local O&M services will also get a boost in operating and maintaining distributed devices
- All these are low power equipment and hence can be managed even in semi-urban areas

3.2.10.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions (temperature, humidity, dust, etc.)
2. Some special training/skills may be required for installation, calibration and commissioning of such equipment
3. CDM equipment installations require a coordinated planning for combined effects
4. It is important that the systems and architecture designs of this pilot project be supervised by global experts who are knowledgeable in this
5. Training of O&M personnel in new technology equipment (controllers, hybrid inverters, etc.)

3.3 Bhutan

3.3.1 Country Overview

Bhutan is a developing economy depending mostly on agriculture and forestry which involves almost 80% of the population. Their energy requirement is mainly met by biomass consisting of agriculture and forest residue. However, with hydropower having a huge resource potential of 30,000 MW provides Bhutan with an option to shift to electricity as their primary source of energy. In addition to hydropower, Bhutan also has an exploitable potential of solar and wind energy with few solar installations in place already. The existing installed capacity of Bhutan is 1614 MW with hydropower being the major source of generation and considering the electricity demand and run of river nature of most of the plants, Bhutan exports a substantial amount of its generation capacity to India in summer months and import electricity during winter.

Installed Capacity

- Installed Power Capacity - 1614 MW

Electrification Rate

- 100 %

Total Area

- 38,394 sq km

Total Population (2017)

- 807,670

Figure 31: Country Overview

Hydro power has become the most favorable element of Bhutan's economic growth as it contributes about 45 per cent of the national revenue which constitutes about 17.3% of the country's GDP. Bhutan is the only country in the South Asian region, which has a large amount of surplus power and the highest per capita electricity consumption of 2,572 kWh.

Table 10: Bhutan's Power Generation, Import, Export and Internal Demand Trends

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Net Production (in MU)	3,337	6,401	7,135	6,898	7,305	7,046	6,811	7,531	7,147
Imports	34	11	7	17	20	20	56	108	187
Exports	2,027	4,533	5,922	5,405	5,579	5,273	4,896	5,558	5,044
Energy Requirement (in MU)	738	973	1152	1442	1655	1714	1,854	1,924	2,085

3.3.1.1 Power Sector Structure and Institutional Framework

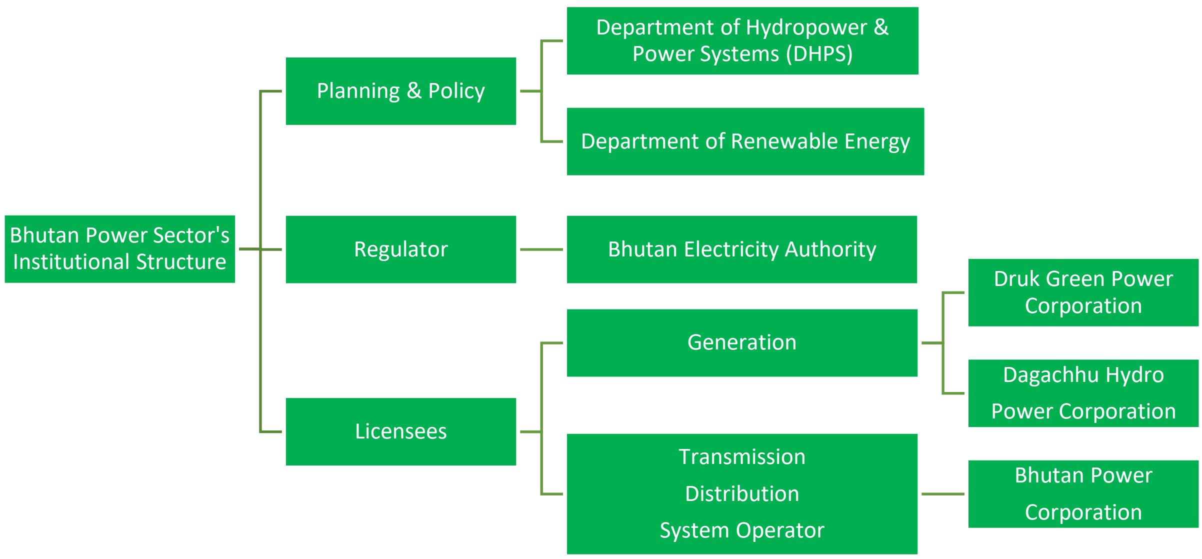


Figure 32: Bhutan Power Sector Institutional Structure

The power sector of Bhutan is mainly governed by Department of Hydropower and Power Systems and Department of Renewable Energy with policy and planning being their area of responsibility whereas the development of regulations and policy implementation stays with Bhutan Electricity Authority. On the other hand, electricity generation is mainly looked after by Druk Green Power Corporation and is responsible for both domestic supply as well as power export. Transmission and distribution are under the ownership of Bhutan Power Corporation along with supply functions including management and operations of embedded hydro and diesel generation units.

3.3.2 Generation

Bhutan is endowed with huge hydropower potential of 30,000 MW of which 23.700 MW is techno economically feasible to develop. It has existing generation capacity of 1,614 MW with generating stations like Basochhu-I and Basochhu-II catering to domestic demand whereas Chukha, Kurichhu, Tala and Dagachhu are providing for both power export as well as domestic supply. Moreover with the commissioning of Mangdechhu hydropower project, and expected completion of Punatsangchhu I & II hydropower project by 2021, electricity export will increase and it will also facilitate in reducing the amount of power import from India which will then only be used for meeting system requirement during contingencies (currently Bhutan is importing power from India during the months of December to February as the capacity of run of the river hydro plants decreases due to freezing of water in the rivers).

3.3.3 Transmission and Distribution

The electricity transmission network is under the ownership of Bhutan Power Corporation (BPC) which also owns and operates the electricity distribution sector in Bhutan. The existing transmission network has total line length of approx. 1098 km, and respective line voltages and their line lengths are given in Table 18.[21] Currently, majority of the transmission lines transmits electricity to various parts of the country through 132kV and 66kV transmission lines. Development of further high voltage transmission lines are expected to be implemented by 2020, and along with cross borders lines are also being planned for exporting power from Bhutan to India which can further be transmitted to Bangladesh. On the distribution side, BPC is catering to the domestic demand through its medium voltage distribution network of 33kV, 11kV, 6.6kV and low voltage network of 400V and 230V.

Line Voltage	Line Length (Ckt Km)
400 KV	74.14
220 KV	326.62
132 KV	344.54
66 KV	352.32
Total	**1097.62**

Table 11: Voltage Level and length of transmission Line

Consumer Served	Energy Consumption	Peak Load
• Total Customer -185130 • HV Customer - 16 • MV Customer - 59 • LV Customer - 778 (Bulk) • LV Customer - 184,277	• Year 2017 : 2185.75 MU • Year 2016 : 2008.90 MU • Rate of incerease - 8 %	• 14 Nov 2017 - 362.09 MW • 4 Nov 2016 - 335.87 MW

In order to improve the reliability and quality of supply and to ensure customer satisfaction, BPC is currently implementing Advanced Distribution Management System for the Thimpu region which includes SCADA, GIS integration, Volt/VAR control etc. which will also help in maintaining grid reliability with the increase in penetration of rooftop solar.

3.3.4 Renewable Energy

The renewable energy sector of Bhutan is not very well developed but with the advent of renewable energy policy and creation of a separate Department of Renewable Energy (DRE), progress in development of solar and wind pilot projects has been taken up. The first wind power pilot project was developed in 2015 in Rubesa which generates around 1.21 million units of energy per year. Two more sites for development of grid connected wind power projects have been identified by Department of Renewable Energy which will be of 1.5MW capacity. In addition, DRE is also looking after the development of solar power plant and is currently implementing a 30 MW solar power project in Singkhar in Bumthang and Longtoe and has distributed around 2000 solar home lighting systems to rural households across the country.

[21] Annual Report, 2017-2018, Bhutan Electricity Authority, Royal Government of Bhutan, Thimphu: Bhutan

3.3.5 Policies and Regulations

The electricity sector in Bhutan is mainly governed by the below mentioned policies which provides for the development of hydropower, renewable energy and private sector investment to ensure sustainability growth of the sector.

- Electricity Act of Bhutan, 2001
- Bhutan Sustainable Hydropower Development Policy, 2008
- Foreign Direct Investment Policy, 2010
- The Economic Development Policy of the Kingdom of Bhutan, 2010
- Bhutan Renewable Energy Policy, 2012

Figure 33: Key Policies of Bhutan

3.3.6 Key Drivers for Smart Grid in Bhutan

With the increase in hydropower generation, power export, growth of domestic demand and introduction of renewables, the grid needs to be reliable and efficient for which smart grid technologies will play a key role.

- **Improvement in Rural Electrification:** Introduction of stand-alone systems or microgrids with DERs as supply sources can help in improvement in the electricity supply in remote villages. **Renewable Energy Development:** Government is pushing for development of renewables and the DRE is currently in the process of developing a large solar power plant of 30 MW and also identified two wind power project sites for development. With the increase in rooftop solar and provision of net metering, grid reliability will require continuous monitoring and control and thereby will require technology intervention to facilitate the same.

- **Electric Vehicle:** With the Government of Bhutan's electric vehicle initiative to curb the fossil fuel import and the development of low emission strategy for the transport sector providing timeline for EV and charging infrastructure roll out, the number of EVs in the coming years is expected to increase. The integration of the EV charging load in the low voltage grid will pose challenges to grid reliability and will require technology intervention to ensure the stability of MV and LV grids. Vehicle-Grid integration can provide ancillary services for grid stability.

- **Grid Reliability:** The power interruption duration in the distribution system for the year 2017 is recorded to be 678,595 minutes by BPC.[22]. It has been observed that for several years, BPC continued to have serious problems with proper recording of power interruption data. This has resulted BEA to confront with severe challenges to calculate the accurate reliability indices. BEA calculated the reliability indices of BPC for the year 2017 as follows[23]:
  - SAIDI - 10.47 hours/customer/year
  - SAIDI - 29.42 times/customer/year
  - CAIDI - 0.57 hours/times

[22] Annual Report 2017-18,

[23] Annual Report 2017-18, Bhutan Electricity Authority, Royal Government of Bhutan, Thimphu: Bhutan

3.3.7 Smart Grid Initiatives

- Open Systems International, Inc. (OSI) has been awarded a contract by Bhutan Power Corporation Limited (BPC) of the Kingdom of Bhutan to deliver a state-of-the-art Advanced Distribution Management System (ADMS) based on OSI's monarch™ (Multi-platform Open Network Architecture) real-time automation and visualization platform. This ADMS system will be implemented for the distribution network in Thimphu, Bhutan's capital city, to manage the reliable delivery of electricity to the city's 115,000 inhabitants
- The OSI ADMS will include the following functionality: OSI's Graphical User Interface; Supervisory Control and Data Acquisition; Advanced Alarm Management System; Communications Front-end Processor; Real-time and Historical Trending; Inter-control Center Communications Protocol; Geographic Information Systems Interface; Load Shed and Restoration; Geographic Information Systems Interface; Distribution Mapping and Visualization; Distribution Power Flow; Volt/VAR control; Fault Location, Isolation, and Service Restoration; Dispatcher Training Simulator

3.3.8 Smart Grid Scenarios for Bhutan

As explained in the previous sections, the power sector in Bhutan need to develop the power system rapidly in order to:

- Ensure access to electricity for all citizen to promote a safe and reliable supply of electricity throughout the country as per objective of Electricity Act 2001
- Ensure 24x7 quality electricity supply to all customers
- Upgrading the hydroelectric power plants, transmission and distribution system to provide more efficient and reliable system with automation systems
- To be emission free by 2030 through development of renewable energy resources that can bring down the cost of power as well as CHG emissions

To ensure the fulfilment of the above objectives, utilities need to reorient their business strategy and improve their operational efficiency as recommended in the following section.

3.3.8.1 Smart Grid Roadmap for Bhutan

Based on the information gathered and analyzed a smart grid roadmap has been drawn for Bhutan with following key assumptions:

a. New policies and regulations will be recommended by 2020 for accelerated development and integration of renewable energy sources to grid by 2030 for achieving the national targets as per Paris Agreement
b. New initiatives and projects will be defined to integrate electric grid as one network by 2025
c. New projects and policies will be initiated for AMI, GIS, Integrated Billing System etc to reduce network losses and improved asset management by 2020
d. Growth of renewable energy resources including rooftop PV will accelerate in the coming years owing to policy mandates as well as cost reduction of PV systems making them economically attractive for larger sections of customers

The Smart Grid Roadmap recommended in this report are in 3 stages:

a. **Immediate Term (2018-2020):** proposes some immediate action items that can bring clear strategy and plan for power system development and grid modernization in Bhutan in alignment with the long-term goals set by the Government
b. **Near Term (2020-2025):** proposes a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction
c. **Medium Term (2025-2030):** proposes several measures that would transform the power utilities in Bhutan in to modern utilities using planning tools and advanced automation and IT systems and analytics to optimize their assets and operations

The above steps are described in detail in the following sections.

3.3.8.1.1 Bhutan Smart Grid Roadmap 2018 - 2020

The Bhutan Smart Grid Roadmap 2020 defines the progressive trajectory of developments from present state (in 2018) to 2020 in following areas: Strategy, Management and Regulatory (SMR), Organization Structure (OS), Grid Operation (GO) and Work and Asset Management (WAM). Elementary preparations have been observed as government has taken initiative to expand electrical infrastructure for transmission and distribution network and several new policies. Government has also taken initiative to install pre-paid metering at some of locations and have plans to expand the same.

1. Strategy, Management and Regulatory (SMR)

Present Maturity Level (in 2018): 0 (default); Target Maturity Level by 2020: 1

Bhutan should target to achieve maturity level 1 on Strategy, Management and Regulatory domain of SGMM by 2020. As per detailed evaluation of the existing systems and ongoing efforts in Bhutan, it is possible to reach maturity level-1 by undertaking following steps:

- Define Smart Grid Vision and Roadmap, strategy and policies in consultation with Ministry of Energy and Water
- Arrange training to key personnel to have common understanding about smart grid vision and technologies
- Initiate discussion with regulators on Bhutan's Smart Grid Roadmap
- Make departmental structure for smart grid implementation (DMS, SCADA, Substation Automation, AMI) and define their roles and responsibilities
- Define area load dispatch centre, regional load dispatch centre, central load dispatch centre and SCADA hierarchy for the country
- Identify areas for renewable energy growth and integration with grid
- Identify potential area for pilot project implementation for smart grid pilot projects Approval of funds for the pilot projects

2. Organization and Structure (OS)

Present Maturity Level (in 2018): default (0); Target Maturity Level by 2020: 1

Bhutan has restructured its power sector structure in 2008. Bhutan has taken steps to strengthen electrical network and achieve higher electrification rate. Smart Grid Vision and Roadmap and its importance need to be understood by all across the sector. There is a need to demonstrate their commitment towards implementing smart grid vision by creating a dedicated smart grid department headed by senior management official. So, organization need to be restructured in alignment with the Smart Grid Roadmap. Bhutan should target to achieve maturity level 1 by 2020 on Organization and Structure domain of SGMM by undertaking following steps:

- Organization should articulate (communicate) it's needs to build smart grid competencies in its workforce
- Organization structure and workforce need to align as per Smart Grid Vision and Roadmap
- Leadership should demonstrate a commitment to change the organization in support of achieving smart grid objectives and targets by assigning resources and budgets
- Conduct workshops/ awareness sessions of smart grid technologies and needs across multiple functions/line of business to support smart grid activities

3. Grid Operation (GO)

Present Maturity Level (in 2018): 0; Target Maturity Level by 2020: 1

Many projects are in progress for strengthening of electrical network across the country. Bhutan should target to achieve maturity level 1 on Grid Operations domain of SGMM by 2020 by undertaking following steps:

- Prepare a Smart Grid Roadmap (10-15 years) for Bhutan and get its approved by the management of the utilities or the Government
- Define Smart Grid as an important item in business plan, budget and annual revenue requirement (ARR) plan and define future work plan for the same
- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g., AMI with remote disconnect, SCADA / DMS, GIS etc.) may be undertaken
- Establish framework to calculate outages and reliability indices at distribution level
- Expand and upgrade the electrical network achieve 100 % rural electrification and strengthen transmission and distribution system in line with targets for 2020. Some of the suggested steps are:
    - Prepare plan for integration of grid as one network in the country by 2025
    - Building new substations and medium voltage (MV) and low voltage (LV) lines to meet demand growth
    - Addition of new DT's, feeders and bifurcation of existing feeders in order to increase transmission and distribution capacity
    - Upgrade the load dispatch centres with automation and control system
    - Replacement of existing DT by new higher capacity DT's wherever required according to load growth
    - Implementation of peak load management through demand response (DR) at distribution level
    - Installation of transformer monitoring units (TMU) on all power transformers and distribution transformers feeding to key customers and critical assets
    - Make plan to implement SCADA/DMS, substation automation and IT system in phased manner in urban areas by 2020
    - Make strategy and plan to implement pilot projects of AMI at select locations

4. **Work and Asset Management (WAM)**

Present Maturity Level (in 2018): 0; Target Maturity Level by 2020: 1

Bhutan could target for maturity level-1 on Work and Asset Management domain of SGMM by 2020 by undertaking following steps:

- Define business case for GIS and asset mapping of transmission and distribution assets and get approval for the same
- Perform consumer indexing at distribution level and map it on GIS
- Institute work flow for continuous updating of assets and customers on GIS map
- Implementation of ERP system
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

3.3.8.1.2 Bhutan Smart Grid Road Map (2020 – 2025)

The Bhutan Smart Grid Roadmap 2025 defines the progressive trajectory of developments from 2020 to 2025 in 7 domains as recommended in the following sections:

1. Strategy, Management and Regulatory (SMR)

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

For achieving maturity level – 2 in Strategy, Management and Regulatory domain of SGMM by 2025, Bhutan need to take following measures:

- Approval and acceptance of Smart Grid Roadmap from higher management across all multiple functions and line of business of utilities in Bhutan. Include the same in the Business Plan of utilities
- Approval of smart grid projects and investments as envisaged in the per Smart Grid Roadmap
- Update policies and regulations if needed to implement measures envisaged in the approved Smart Grid Roadmap
- Support from funding agencies for smart grid projects and make plan/ strategy to implement smart grid projects such as e.g. SCADA/DMS, AMI, OMS etc. and identify potential areas where new projects can be implemented

2. Organization and structure (OS)

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

For achieving maturity level-2 by 2025, utilities in Bhutan need to take following measures:

- Approval of Manpower Plan (including Training plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on approved Smart Grid Roadmap, restructure the organization hierarchy and its business process which can align end to end process for Smart Grid operations
- Create cross functional teams among all LOBs for implementation of smart grid initiatives as per approved Smart Grid Roadmap
- Plan workshop and train key personnel to develop smart grid competencies
- Plan for linking compensation and incentives with achievement of smart gird milestones

3. Grid Operations (GO)

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

Utilities in Bhutan can achieve maturity Level -2 in Grid Operations domain of SGMM by 2025 by undertaking following measures:

- Upgrade electrical network to support estimated peak load for 2025 targets in line with the overall estimated demand growth by 2025 through combination of steps such as:
  - Create new generation resources and transmission network, substations, medium voltage and low voltage lines as well as upgrading the transmission and distribution capacity
  - Replacement of existing / old DT's with new higher capacity DT's where ever required
  - Bifurcation and trifurcation of lines / feeders wherever required
  - Replacement of old wire / undersize conductors/ cables and replace old wire joints on overhead LV lines with proper crimped joints
  - Establish demand response (DR) for peak load management at customer level
- Establish SCADA/DMS in urban areas in phased manner by 2025
- Installation of Distribution Automation System in major towns
- Establish outage management system (OMS) for efficient outage restoration in order to reduce unplanned outages in Kabul
- Undertake pilot trials on smart microgrid for campuses, industrial parks etc
- Upgrade communication network to support automation and IT systems
- Implement AMI in one division in Bhutan
- Undertake pilot trials in energy storage for grid balancing on feeders with higher penetration of renewable energy
- Pilot installation on EV charging infrastructure in Thimpu and other urban areas

4. Work and Asset Management

Maturity Level in 2020: 1, Target Maturity Level by 2025: 2

Utilities in Bhutan can target maturity level-2 in Work and Asset Management domain of SGMM by 2025 by undertaking following measures:

- Systems for tracking inventory and event history of assets on GIS maps
- Implementation of enterprise resource planning (ERP) system and its integration with GIS and other IT and automation systems
- Develop and implement a communication system architecture to meet near term and long-term communications need adopting a multi-tier, multi-service telecommunication infrastructure architecture consisting of a core network and an edge network
- Develop network model for the distribution grid up to DT level so that modelling studies can be undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Plan for hotline maintenance – bare hand methods using trucks with insulated baskets and other hotline tools
- Prepare plan for mobile workforce management (MWFM) system
- System in place for load forecast every year and system upgrade plans to be reviewed and amended appropriately based on actual and expected load growth in each sub-division

5. Technology

Maturity Level in 2020: 0 (default), Target Maturity Level by 2025: 1

Utilities in Bhutan can target maturity level-1 in Technology domain of SGMM by 2025 by undertaking following measures:

- Enterprise IT Architecture: Utilities must develop an enterprise IT Architecture and start its implementation. Need to retire several IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated even through a middleware must be replaced with commercially available off the shelf (COTS) applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT Architecture should enable integration of new assets and applications acquired by different LOBs
- All IT applications should adopt change control process e.g. configuration management, patch management, remote updation of applications and integration capability for future integrations
- Implement one integrated billing system across Bhutan covering every type of customer
- Conduct audit for cyber security and adopt the recommendations to secure systems form cyber-attacks
- Prepare cloud strategy for future expansion

6. Customer

As Govt targets to increase electrification rate to 100 % and strength HV/ MV/LV transmission and distribution system, thousands of new customers will be added to the network. Customer needs and expectations must be at the centre of power development and operations.

Present Level (in 2020): 0 (default), Target Maturity Level by 2025: 1

It is recommended to take following steps to reach maturity level 1 on Customer domain of SGMM by 2025:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved Smart Grid Roadmap. These studies will identify customer benefits and satisfaction. Utilities may conduct these studies with input from different category of customers in urban and rural areas
- Conduct workshops to educate customers about Smart Grid Vision and Roadmap of Bhutan
- Conduct study or research work for security and data privacy implication of new technologies and business process/functions to be adopted which can enable customer participation to leverage smart grid functionalities
- Consult with public Utility commission and /or other government related organization regarding impact of technologies on different categories customers

7. Societal and Environmental

Present Level (in 2020): 0 (default), Target Maturity Level by 2025: 1

For reaching maturity level 1 on Societal and Environmental domain of SGMM by 2025 utilities may undertake following steps:

- Publish the smart road map with emphasis on:

- Bhutan role in environment and societal issues with respect to smart grid vision or strategy
- Bhutan publicly promote the environmental benefits of using smart grid technologies
- Organization role in protecting the nation's critical infrastructure

3.3.8.1.3 Bhutan Smart Grid Road Map (2025 – 2030)

Bhutan Smart Grid Roadmap 2030 defines the progressive trajectory of development from the state in 2025to 2030 as explained below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level in 2025: 2; Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2025, Bhutan need to undertake following measures:

- Establish Smart Grid Governance Model for smart grid development and decision making. Define roles, process and tools for the same
- Designate a Single Smart Grid Leader in all key line of businesses with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap
- Adopt smart grid vision, strategy and business case in the organization's vision and strategy
- Approval for smart grid investments for key initiatives envisaged in the approved Smart Grid Roadmap

2. Organization and Structure (OS)

Maturity Level in 2025: 2, Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, utilities in Bhutan need to take following measures:

- Redesign organization structure to support Smart Grid initiatives e.g. matrix organization structure or similar and also execute this structure in view of the new programs and projects for 2040
- Commitment and consistency of leadership in communication and actions related to smart grid programs and projects
- Performance awards and compensations are linked to success of smart grid programs and projects
- Conduct educational training programs which are aligned to build smart grid capabilities in organization
- All changes in organization structure, appointments / transfer / changes being made in consideration and support with smart grid program and projects
- Knowledge management framework to be put in place to capture the learnings from technology trials and new projects planned as per smart grid roadmap. This knowledge must be institutionalized

3. Grid Operation (GO)

Maturity Level in 2025: 2, Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, Bhutan need to take following measures:

- Upgrade electrical network to support estimated peak demand growth and energy requirement by 2030 and beyond

  - Building new generating plants, transmission lines, substations and medium voltage (MV), low voltage (LV) lines and upgrade the capacity of existing generation, transmission and distribution systems
  - Plan and execute bifurcation and trifurcation of distribution lines and expand distribution network to rural and urban areas ensuring to meet targets of electrification and increase in peak demand
  - Increase transformation capacity at DT level to meet the demand target of 2030
  - Replacement of exiting DTs with higher capacity DTs where ever required
  - Addition of new capacitor banks to regulate power quality where ever required
  - Peak load management through demand response (DR) at customer premises
  - HT: LT ratio is brought to 1:2 in urban area and 1:4 in rural area
  - Replace undersize / old conductors and old wire joints on overhead LV lines with proper crimped joints
- Integration of regional grids to enhance capacity of transmission and distribution and centralized scheduling and dispatch
- Expand renewable energy as per governments targets for 2032 and integration with grid
- Implementation of SCADA /DMS, distribution automation (DAS) and AMI across country or selected locations as per organization goals
- Implement outage management system (OMS) and its integration with SCADA /DMS, DAS and GIS in urban areas
- All new grid equipment being installed with remote monitoring capabilities
- Plan for rollout of EV charging infrastructure and Vehicle to Grid integration (VGI) in all urban areas.
- Deployment of advanced analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all lines of business (LOBs), dashboard with relevant information are made available in each LOB
- Grid operation data is being leveraged for grid planning using advanced analytical and planning tools
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real time load and voltage data on selected urban and rural feeders
- Establishment of dedicated Smart Meter Operation Centre (SMOC) that will monitor and control smart meter operations and provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operation
- Systems for condition-based maintenance of circuit breakers and power transformers
- Extension of voltage and reactive power (Volt-VAR) optimization (VVO) systems to entire country
- Automated operation of capacitor bank (if not part of VVO solution)
- Advanced ground fault detection by installing protective relays (or IEDs) to detect high impedance (very low fault current) faults for faster isolation of downed conductors/ section promoting enhanced safety and improved service reliability

4. Work and Asset Management

Maturity Level in 2025: 2, Target Maturity Level by 2030: 3

For achieving maturity level-3 by 2030, utilities in Bhutan need to undertake following measures:

- Asset performance trend analysis and event audit reports are available for all major assets and systems
- Integrated view of all major/ key assets on GIS system with remote monitoring facility and their further integration with ERP system and mobile workforce management system (MWFM) covering all major urban areas
- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals
- Network model of transmission and distribution grids up to DT level is regularly updated and modelling studies undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Analytical tools for predictive maintenance are deployed on trial basis
- AMI integration with OMS – restoration / disconnection messages from smart meters are integrated with OMS for faster restoration and improved customer satisfaction
- AMI- GIS integration to enhance the visualization of network to provide safety, reliability and operational benefits

5. Technology

Maturity Level in 2025: 1, Target Maturity Level by 2030: 2

For achieving maturity level-2 by 2030, Bhutan need to undertake following measures:

- Alignment of all line of business (LOB) with enterprise IT Architecture across entire organization. If required modify business process to align it with IT Architecture and systems
- Framework in process for change control of all IT applications and infrastructure
- Organization uses an informal common technology evaluation and selection process for smart grid activities including selection of vendors and external services
- Conduct pilot trials on wide area monitoring and distributed sensor network
- Smart grid technologies implemented are leveraged in such a fashion that it improves the cross-LOB performance
- Data collection from smart sensor network installed on distribution lines are leveraged by other applications for grid operation and customer service functions
- Cloud services are in place and all new applications are hosted on secured public cloud; existing applications are migrated to the cloud as the old hardware becomes redundant
- Cyber security systems in place

6. Customer

Maturity Level in 2025: 1, Target Maturity Level (in 2030): 2

For achieving maturity level-2 by 2030, utilities in Bhutan need to undertake following measures:

- Bhutan’s vision of the future grid is communicated to customers.
- Analyze electricity consumption behavior and pattern of residential customers area-wise and align systems to support their usage pattern and minimize outages; model the reliability of grid equipment
- Assess the impact of new smart grid systems and services on different categories of customers
- Measures for security and privacy requirements of customers and identify the specifications for new systems being procured as per measures

- Implementation of a state-of-the-art customer portal
- Prosumer enablement and net-metering plans available to all customers
- Leveraging social media for customer engagement effectively

7. Societal and Environmental

Maturity Level in 2025: 1; Target Maturity Level by 2030: 2

Utilities in Bhutan should undertake following steps to reach maturity level 2 by 2030:

- Finalize work plans for addressing the social and environmental issues through smarter technologies
- Offer smart grid supported energy efficiency programs for customers
- Adopt "Triple Bottom Line" (TBL) framework for key decisions – TBL method covers Social, Environmental and Financial aspects of every investment plans/projects
- Provide details of granular level energy consumption data to customers – from AMI system through customer portal
- Societal and environmental benefits are estimated in the detailed project report for each project
- Diesel Generator (DG) replacement with battery (that can be leveraged for load balancing) at customer premises is actively promoted through innovative business models
- Clean energy being moved to the core of organization business model

8. Value Chain Management (VCM)

Maturity Level in 2025: 0, Target Maturity Level by 2030:1

Bhutan utilities should undertake following steps to reach maturity level 1 by 2030 on Value Chain Management:

- Formulation of a strategy for creating and managing a diverse resource portfolio
- Identification of:
    - Assets and programs for load management
    - Distributed generation resources, its locations and its capabilities
    - Security requirements to enable interactions with an expanded portfolio of value chain partners

The recommended Smart Grid Roadmap for Bhutan:

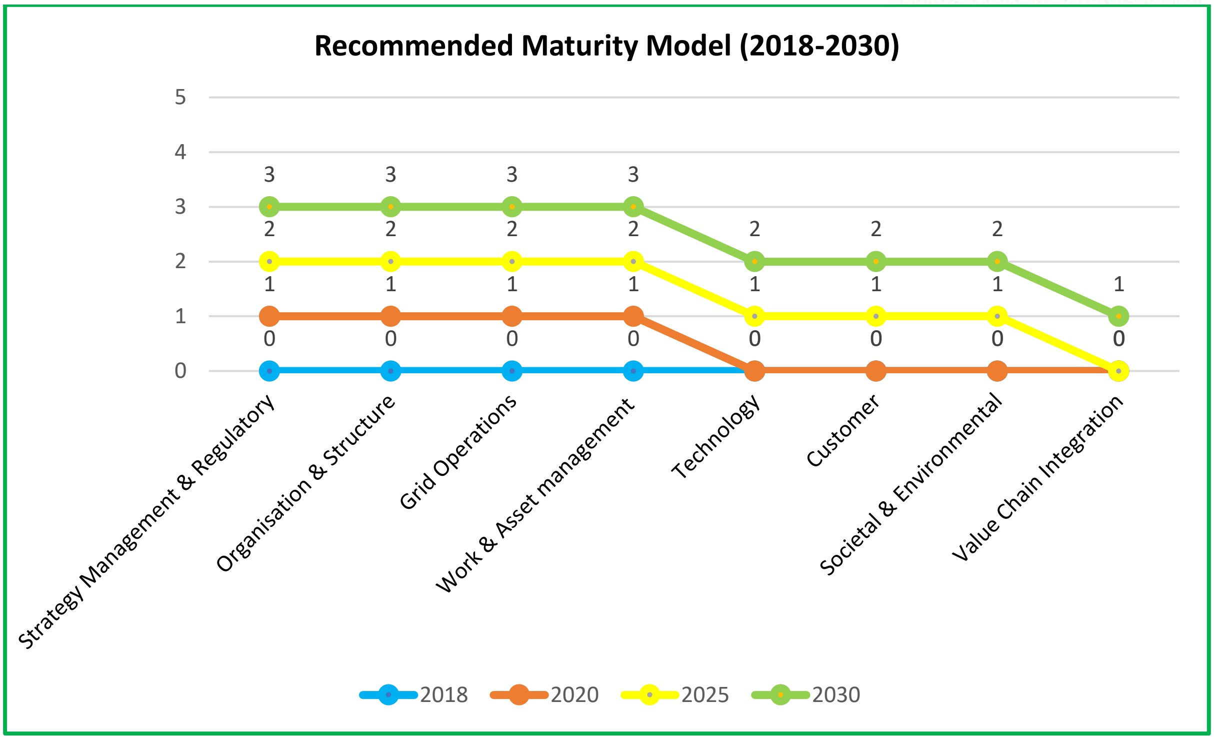
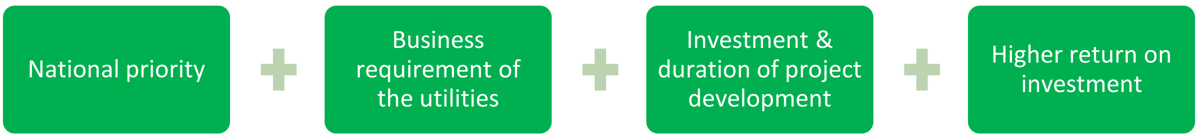


Figure 34: Recommended Maturity Model (2018 -2030)

3.3.9 Cost Benefit Analysis

Based on the above recommendations till 2030 in each of the eight domains, ISGF has identified various activities that need to be undertaken by the utilities in different phases and also identified one project for development in future based on the parameters mentioned below. These parameters have taken into account the envisaged or future targets of the governments in terms of electricity supply, renewable energy development, cross border power trading, operational performance of the utilities etc.



With the increase in renewable generation and roof top PV penetration, integration of these variable resources into low voltage grid poses serious concern to the grid reliability and increases the operational difficulties for the utilities. Therefore, load balancing and voltage control and mitigation measures need to be in place. The detailed cost benefit analysis for such a project has been done considering its priority and the huge amount of benefits it accrues compared to the investment needed.

3.3.9.1 Background

Bhutan is well endowed in hydroelectric power (5307 MW wheeled to India) and hence enjoys some of the lowest tariffs in Asia. It has a peak load of 362 MW. However, its distribution system (due to its forested and mountainous terrain) is prone to faults and lengthy restorations. Currently, the maximum period of power supply restoration is one day in urban and two days in rural areas. Monitoring/calculating reliability indices is also inaccurate but improving. For the year 2017 it was (1) SAIDI - 10.47 hours/customer/year; (2) SAIFI - 29.42 times/customer/year; (3) CAIDI - 0.57 hours

/times. Out of total outage-minutes of 678,595 minutes in 2017, 369,005 minutes is listed under 'Beyond the Control of BPC', which is 54% of total outages. A new data format was issued in 2017 and it is expected that more accurate data will be available in 2018. In any case, there is scope for significant improvement in Bhutan's reliability indices.

3.3.9.2 Project Objective and Description

Evaluate a simpler method to detect and report outages and/or correct erroneous reporting.

Line Monitoring Systems (MLIN) consisting of:

- 300 Line sensor units - 5 feeders in a station x (3 ph) x 20 sensors each feeder (USD $1800 each)
- 100 communications gateways (USD 3,500 each)
- Application Software - XNET (USD 700 each)
- PC Hardware/Software/Accessories (USD 10,000 lumpsum)
- Misc. (USD 10,000 lumpsum)

Financial Data:

Required rate of return (Govt. / IFI rates) - 8 %, Tax rate – 25 %

Initial Investment	YEAR	1	2	3
Equipment	$910,700.00			
Engineering and Development	$150,000.00			
Installation & Commissioning	$150,000.00			
Total Initial Investments	**$1,210,700.00**			
Benefits	**YEAR**	**1**	**2**	**3**
Fault location; Line Patrol saving (SAIFI 30 times x 100 cust x 10 hours x USD 20)		$600,000.00	$600,000.00	$600,000.00
Energy Revenue capture (2 days x 100cust x 1KW x USD 1.5NGU/73 tariff)		$98.63	$98.63	$98.63
Tourism promotion (long-term) estimate		$15,000.00	$15,000.00	$15,000.00
Total Benefits		**$615,098.63**	**$615,098.63**	**$615,098.63**
Costs (Excluding Initial Capital Investments)	**YEAR**	**1**	**2**	**3**
Operations		$20,000.00	$20,000.00	$20,000.00
Maintenance		$20,000.00	$20,000.00	$20,000.00
Project management, customer support		$5,000.00	$5,000.00	$5,000.00
Misc.		$10,000.00	$10,000.00	$10,000.00
Depreciation on capital expenditures (calculation uses 5 year period)		$242,140.00	$242,140.00	$242,140.00
Total Costs		**$297,140.00**	**$297,140.00**	**$297,140.00**
Totals	**YEAR**	**1**	**2**	**3**
Net Benefits (Costs)		$317,958.63	$317,958.63	$317,958.63
Tax		$79,489.66	$79,489.66	$79,489.66
Value after tax		$238,468.97	$238,468.97	$238,468.97
Depreciation added back		$242,140.00	$242,140.00	$242,140.00
Cash flow	-$1,210,700.00	$480,608.97	$480,608.97	$480,608.97
Cumulative cash flow	-$1,210,700.00	($730,091.03)	($249,482.05)	$231,126.92

Evaluation Metrics	
Net present value (NPV)	
Internal rate of return (IRR)	
Payback period (in years)	

Cautionary Note:

All costs are budgetary for discussions purposes only.

A detailed project report (DPR) needs to be done.

3.3.9.3 Relevance of CBA Analysis to Smart Grid Transition

As already indicated outage restoration in Bhutan takes long durations owing to geographical issues. Typical restoration times are about 24 hours in urban and 48 hours in rural areas. A big part of this problem is not being able to trace faults accurately, leading to long restoration times. The proposed pilot project helps identify the fault locations faster thereby maintenance crew could reach the fault location without patrolling the entire line.

Benefits:

The CBA results look promising with a positive NPV and short payback period and is worth implementing. A detailed project report (DPR) with formal quotes will be required. The following are the key benefits:

1. Accurate location and time saved by line patrol staff is about USD $ 600,000 in direct costs p.a.
2. Even a modest tourism improvement will likely amount to USD $ 15,000 annually at that location cluster (estimate)
3. If successful, similar projects can be implemented in other semi-urban and remote clusters
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Utility O&M services will also get a boost in operating and maintaining distributed devices
6. All these are distribution voltage power equipment and hence can be managed by the Utility

3.3.9.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions (temperature, altitude, etc.)
2. Some special training/skills may be required for installation, calibration and commissioning of such equipment
3. Line sensor and associated equipment installations require coordinated planning for good outcomes
4. It is important that the systems and architecture designs of this pilot project be supervised by global experts who are knowledgeable on the subject

3.4 India

3.4.1 Introduction

3.4.1.1 Indian Power Sector Overview

Indian power system is the third largest in the world with 346 GW of installed capacity and close to 300 million customers covering an area of over 3 million Sq Km. Peal load met during the current year 2018 is about 175.5 GW. India has successfully completed village electrification having bought electricity to citizens in over 5, 98,000 villages. Still there are about 30 million household that are not connected to the grid.

Table 12: Installed Capacity (MW) & % Share

Source	Installed Capacity (MW)	% Share
Thermal	221,767	64.08
Hydro	45,487	13.14
Nuclear	6780	1.95
Renewables	72,012	20.88
Total	**3,46,046**	**100**

The Indian power system operates with ± 800 kV HVDC and ±500 kV HVDC lines; and 765 kV, 400 kV, 230 kV (or 220 kV in some states), 132 kV (or 110 kV in some states) and 66 kV AC lines.24

The objective of capacity addition in generation and transmission domains will be fruitful only if the power distribution segment is also strengthened to carry the generated electricity to customers connected on the low voltage distribution network. To address the problems in the distribution sector, Government of India (GoI) has implemented various schemes like Accelerated Power Development and Reform Program (APDRP), Restructured APDRP (R-APDRP), Rajiv Gandhi Grameen Vidyutkaran Yojana (RGGVY), Integrated Power Development Scheme (IPDS) and Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) with the objective to improve the sub-transmission and distribution network, separation of agricultural feeders and rural electrification. GoI has established National Electricity Fund to promote investment in distribution segment. In 2017, GoI launched a new scheme called "Saubhagya" for electrification of remaining households in the country on fast track. Along with these, GoI has also launched Ujwal DISCOM Assurance Yojana (UDAY) scheme to ensure financial revival of the electricity distribution companies by taking over 75% of their debts and issuing bonds (by the DISCOM) for the rest 25% debt. UDAY also envisaged reduction of Aggregate Technical and Commercial (AT&C) losses in distribution sector and reduce the gap between Average Cost of Supply (ACS) and Average Revenue Requirement (ARR) and installation of smart meters. Large scale rollout of smart meters has already commenced.

3.4.1.2 Power Sector Structure

The institutional framework of the power sector in India is depicted below:

Table 13: Institutional Framework

Framework	Centre	State/Private
Policy	Ministry of Power (and Ministry of New and Renewable Energy for Renewables)	State Government
Planning	Central Electricity Authority	

[24] https://powermin.nic.in/en/content/overview

Regulations	Central Electricity Regulatory Commission (CERC)	State Electricity Regulatory Commission (SERC)
Generation	Central Government owned Generation Companies; Ultra Mega Power Plants (UMPPs)	State Government owned GENCOS; Independent Power Producers (IPPs)
Transmission	Central Transmission Utility (CTU); Transmission Licensees	State Transmission Utilities (STU)
System Operations	National Load Dispatch Centre (NLDC); Five Regional Load Dispatch Centres	State Load Dispatch Centres (SLDC)
Distribution		Distribution Licensees (72 numbers)
Trading	Indian Energy Exchange; Power Exchange of India Ltd, Trading Licensees	
Appeal	Appellate Tribunal	

3.4.2 Generation

In 2017, 1,160 billion units were produced that was 4.7 % higher than 2016[25]. In 2018, it is expected that the growth rate will be same coupled with growth in generation from renewable energy resources.

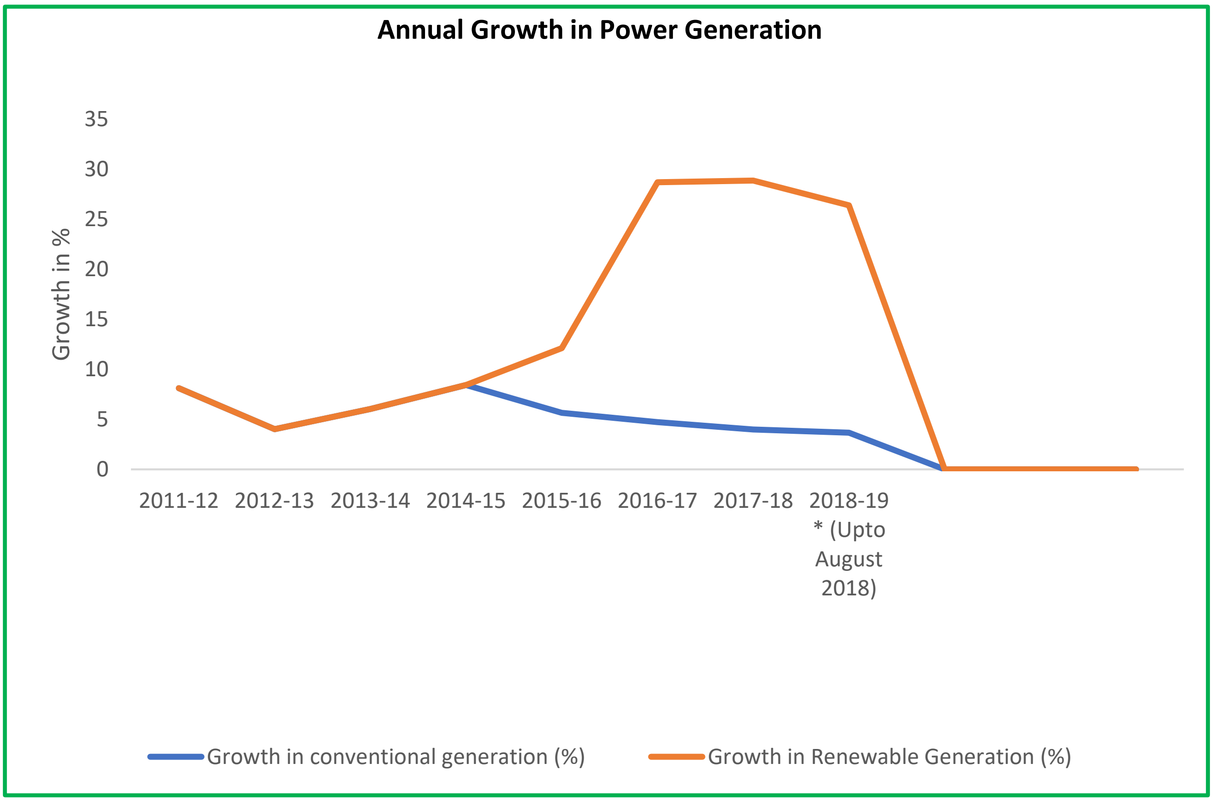


Figure 35: Annual Growth in Power Generation

[25] http://www.eprmagazine.com/cover-story/is-2018-the-turnaround-year-for-indian-power-gen-sector/

3.4.2.1 Overall Demand-Supply Scenario

Although 347 GW of generation capacity is available many regions in India face frequent power outages owing to constraints in transmission and distribution networks. Some thermal plants suffer from shortage of coal and gas. Hydropower stations are affected from variations in rainfall in the catchment areas.

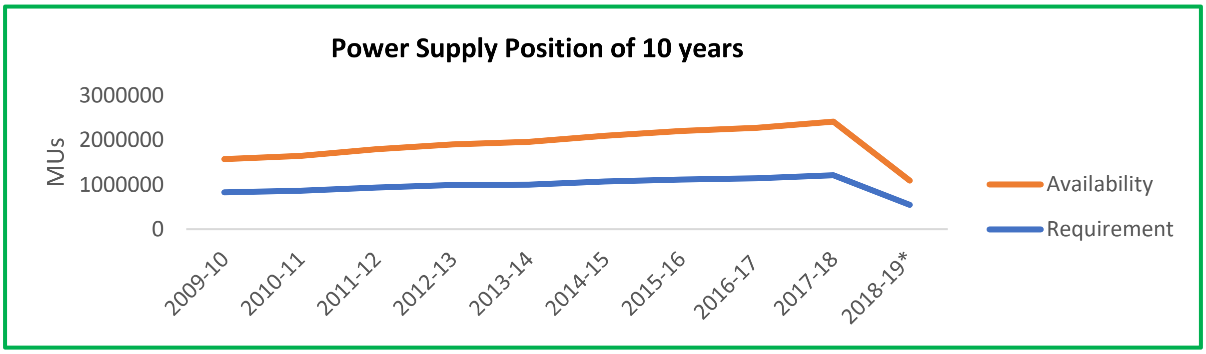


Figure 36: Power Supply Position

3.4.3 Transmission and System Operation

India operates a relatively modern transmission grid consisting of extra high voltage (EHV) AC and DC lines. Power Grid Corporation of India Ltd (POWERGRID) owns and operates the nationwide EHV network. In each of the states there are state transmission companies owned by the respective state governments also own and operate EHV transmission systems in the states including state load dispatch centres (SLDC). POWERGRID's network and most of the state transmission networks are equipped with modern SCADA/EMS systems and a large wide area monitoring system (WAMS) with 1170 PMUs is also being commissioned.

Indian power system is operated as 5 regional grids interconnected synchronously. System operation is managed by Power System Operation Corporation Ltd (POSOCO) which owns and operates the national load dispatch centre (NLDC) and five regional load dispatch centres (RLDC). SLDCs are managed from the respective RLDCs.

3.4.3.1 Cross Border Interconnections and Trading

India has interconnections with neighbouring countries like Bhutan, Bangladesh and Nepal and is a net exporter of electricity. While India imports electricity from large hydroelectric plants in Bhutan, India exports electricity to Nepal, Bangladesh and to Bhutan (during winter months). Also, India supplies electricity to few remote locations in Pakistan and Myanmar through 11kV lines. The details of the transmission interconnections of Indian power system with neighbouring countries are presented in table below:

Table 14: Cross Border Interconnections

S. No	Cross Border Interconnection	Transmission Lines
Existing International exchange with Bhutan, Nepal, Bangladesh and Myanmar		
1	India – Bhutan	400 kV Tala - Binaguri D/C Line
		400 kV Tala – Binaguri S/C Line
		400 kV Binaguri - Malbase
		220 kV Bipara - Chuka D/C Line
		220 kV Birpara - Malbase

		132 kV Rangia - Motanga
		132 kV Salakati - Gelephu
2	India – Bangladesh	400 kV Bherhampur - Bheramara D/C Line
		132 kV Surjyamaninagar - Comilla D/C Line
3	India - Nepal	132 kV Tanakpur - Mahendranagar
		132 kV Muzaffarpur - Dhalkeba
4	India - Myanmar	11 kV Moreh Tamu
Planned International exchange with neighbouring Countries 2021-2022		
1	India - Bhutan	220 kV Birpara – Chukha D/C line
		220 kV Birpara – Malbas S/C Line
		400 kV Siliguri – Tala D/C Line
		400 kV Siliguri – Tala S/C Line
		Siliguri – Malbas S/C line
		400 kV Alipur – Punatsan D/C Line
		400 kV Alipur – Punatasan S/C Line
		400 kV Alipur – Jigmeling D/C Line
2	India – Bangladesh	400 kV Behrampur – Bheramara D/C Line

Presently, all the power trade is being conducted through bi-lateral government to government agreements. High efforts are carried out to establish interconnection of all SAARC countries for the creation of a SAARC Grid and SAARC Market for Electricity (SAME). [26]

Augmentation of existing transmission connections with Bhutan through HVDC transmission link will increase the capacity to 5,000 MW by 2020. It is envisaged that total electricity import will be in range of 55 to 101 BU across various scenarios by 2046-47.

3.4.3.2 Institutions related to Transmission

Table 15: Institutional Framework for Transmission Sector

Power Grid Corporation of India Ltd (PGCIL)	State owned Utility that transports about 50% of total power generated in India. It is also a central transmission Utility under Ministry of Power.
Power System Operation Corporation Ltd (POSOCO)	Handles power management for power grid. It also provides open access in its transmission system for use by a license
Indian Energy Exchange (IEX)	A trading platform for physical delivery of electricity consisting segments such as Day ahead market, Term ahead market, Renewable energy certificates (RECs). About 4000 participants & 3000 open access consumers are leveraging IEX to manage their power portfolio.
Power Exchange India Ltd (PXIL)	PXIL, another power exchange is promoted by National Stock Exchange of India and National Commodity & Derivatives Exchange Ltd
Power Traders	Trading License are issued by Central Electricity Regulatory Commission

[26] https://sari-energy.org/program-activities/cross-border-electricity-trade/country-energy-data/

3.4.3.3 Transmission Capacity Constraints

Over the next four years (by 2021-22), more than 85,000 circuit km of transmission lines and 230,000 MVA of transformation capacity are expected to be added to the Indian grid. New designs and technologies are being adopted to address right of way issues that includes multi-circuit and narrow base towers, gas insulated substations (GIS) and EHV XLPE cables. Digitalization of substations in the network has greatly increased system efficiency, safety and visibility.

India issued a national Smart Grid Vision and Roadmap in August 2013. In order to achieve the objectives of this Smart Grid Roadmap transmission utilities are advised to formulate state/Utility specific policies and programs in alignment with Ministry of Power (MoP)'s overarching policy objective of Access, Availability and Affordability of Power for All. Some of the key highlights are:

Development of a reliable, secure and resilient grid supported by a strong communication infrastructure that enables greater visibility and control of efficient power flow between all sources of production and consumption by 2027.

a. Implementation of Wide Area Monitoring Systems (WAMS, using Phasor Measurement Units, or PMUs) for the entire transmission system
b. 50,000 km of optical fibre cables to be installed over transmission lines to support implementation of smart grid technologies
c. Enabling programs and projects in transmission utilities to reduce transmission losses to below 4% by 2017 and below 3.5% by 2022
d. Implement power system enhancements to facilitate evacuation and integration of 30 GW renewable capacity by 2017, 80 GW by 2022, and 130 GW by 2027 – or targets mutually agreed between Ministry of New and Renewable Energy (MNRE) and MoP. These numbers have been revised in 2015 with launch of the renewable energy program of 175 GW by 2022

3.4.4 Distribution

Distribution sector in India is plagued by numerous problems as over 95% of the country, the power distribution network is owned and operated by state government owned distribution companies. There are total 72 distribution licensees in India of which 10 are private companies which are in Delhi, Mumbai, Kolkata and Gujarat. The major problem in the distribution domain are:

- Huge AT&C losses – nationally about 23% with several states reporting over 30% despite focused programs to reduce AT&C losses in the last two decades
- Poor quality of distribution network which was planned for very low demand of individual customers initially and unable to augment the capacity with rapidly increasing demand of customers
- Very long 11kV lines and low voltage (LV) lines
- Skewed tariff with revenue gap of Rs 0.27 (USD 0.0039) per kWh between Average Cost of Supply (ACS) and Average Revenue Requirements (ARR). That is ARR-ACS = 0.27 rupees per kWh
- The distribution companies (DISCOMs) in most of the states are in financial losses for several years leading to poor investment in network upgradation and employee skill developments

In order to achieve the Smart Grid Vision, DISCOMs were advised to formulate state/Utility specific policies and programs in alignment with MoP's overarching policy objective of Access, Availability and

Affordability of Power for All. Some of the key highlights as per the Smart Grid Roadmap issued by MoP in 2013 are:

a. Completion of on-going programs which will lay the basic building blocks of smart grids such as SCADA/DMS in large cities, GIS maps for asset mapping and consumer indexing, automated meter reading (AMR) for all feeders, integrated billing and customer care systems, data centres (DC) and disaster recovery centres (DR) in all states as part of RAPDRP, and planning for integration of such systems into future smart grid deployments
b. Enabling programs and projects in distribution utilities to reduce AT&C losses to below 15% by 2017, below 12% by 2022, and below 10% by 2027
c. Integrated technology trials through a set of smart grid pilot projects by 2015; and based on outcome of the pilots, full rollout of smart grids in pilot project areas by 2017; in major urban areas by 2022 and nationwide by 2027
d. Working with other stakeholders, building the National Optical Fibre Network (NOFN) by connecting 2,50,000 village Panchayats in the country by Optical Fibre Cable and extending the fibre link to all the 33/11 kV and above substations to build a backbone communications network for the power sector
e. Development of smart microgrids, storage options, virtual power plants (VPP), solar photovoltaic to grid (PV2G), and building to grid (B2G) technologies in order to manage peak demand, optimally use installed capacity and eliminate load shedding and black-outs
f. EV charging facilities may be created in all parking lots, institutional buildings, apartment blocks etc; and quick/fast charging facilities to be built in fuel stations and at strategic locations on highways

3.4.4.1 Restructured Accelerated Power Development and Reforms Programme (R-APDRP)

R-APDRP was launched on July, 2008 by the Ministry of Power (MoP) as a part of reform in the power sector which was focused on the demonstrable performance in terms of AT&C loss reduction, establishment of the reliable and automated sustainable systems for collection of baseline data, adoption of information technology in the areas of energy accounting, consumer care and strengthening of distribution network of state power utilities. The total program outlay was of Rs 51,577 Crore where Power Finance Corporation Limited (PFC) was designated as the Nodal Agency for operationalization of the program. R-APDRP covered 1411 towns with population above 30,000 services by all state government owned DISCOMS. Program was structured in to two parts. While Part-A was primarily focused on IT intervention for automated baseline data for proper energy accounting, Part-B was for electrical network refurbishment and upgradation. Part –A was a complete grant from GoI to DISCOMs and Part-B was 50% grant and 50% loan with low interest. Originally R-APDRP was envisaged to be completed by March 2012. However, owing to a variety of reasons the program took over 5 years in some of the front running states and in few states, it is still in progress. As of November 2018, 1,346 towns out of 1411 towns have gone-live with R-APDRP systems.

Key Highlights of R-APDRP

Coverage: 1411 towns with population of over 30,000

Part-A

- GIS maps for asset mapping and consumer indexing. Automated Meter Reading (AMR) on Distribution Transformers and Feeders
- Integrated billing and customer care systems
- Data Centres (DC) and Disaster Recovery Centres (DR) in every state
- Computerization of all field offices of the DISCOMS – LAN and WAN
- Energy Accounting and Auditing Systems
- SCADA/DMS in cities with population above 300K or annual energy sales above 100 MU

Part -B

- Renovation, Modernization and Strengthening of 11 kV Substations, Transformers/ Transformer Centres
- Re-Conducting of lines at 11kV and below
- Load Bifurcation, Load Balancing, HVDS (11kV)

3.4.4.2 Integrated Power Development Scheme (IPDS)

The IPDS Scheme was approved in 2014 to extend the R-APDRP systems to another 6000 towns with population of over 5000. IPDS had an outlay of Rs 32,612 crore which includes a budgetary support of Rs 25,354 crore from GoI. IPDS is now in the advanced stages of implementation. IPDS also allotted money for smart metering in several towns.

3.4.4.3 Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)

The DDUGJY is the re-christened rural electrification program that was being undertaken under RGGVY. DDUGJY was approved in 2014 with a total outlay of Rs 44,033 crore which includes a budgetary support of Rs 33,453 crore from Govt. of India. The objectives of scheme are:

- Separation of agricultural and non-agricultural feeders
- Strengthening of sub-transmission and distribution networks in rural areas
- Metering of distributing transformers/feeders/consumers in rural areas
- Rural electrification
- In April 2018, India completed electrification of all the 597,464 villages.

3.4.5 Renewable Energy

In the Indian power renewable energy resources totaling about 74 GW accounts for 20% of total installed capacity. At the Copenhagen climate summit in 2009, India made a voluntary commitment of emission reduction by 20-25% by 2025. As part of the initiatives to achieve this goal, GoI ed the Jawaharlal Nehru National Solar Mission (JNNSM) in January 2010 with a target of 20 GW of grid connected solar power by 2020. This program was re-launched in February 2015 with an ambitious target of 175 GW of renewable energy (100 GW solar, 60 GW wind and 15 GW small hydro and bioenergy) by 2022. The solar and wind energy industry has been a highly competitive market with the solar tariffs which started at Rs 17/kWh in 2010 dripping to as low as Rs 2.44/kWh in 2018 in the reverse tariff bidding auctions. The present installed capacity of wind is 34.65 GW and solar is about 24 GW. Ministry of New and Renewable Energy (MNRE) has been vested with the responsibility of developing all the renewable energy projects in the country.

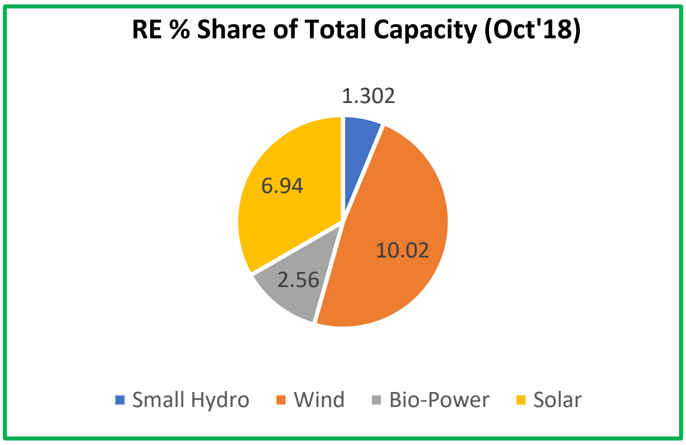


Figure 37: RE Installed Capacity

3.4.6 Policy and Regulations

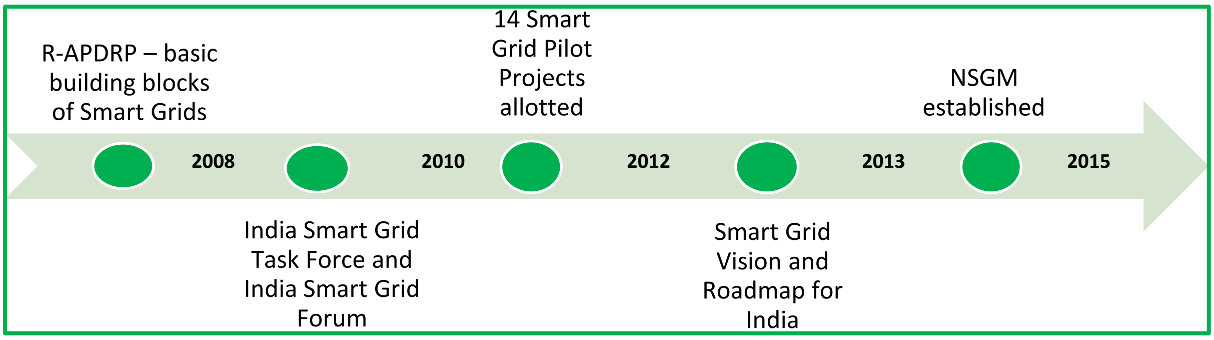
In 1998 through a special Act, GoI introduced electricity regulatory commissions in India which was previously undertaken partly by the Ministry of Power, Central Electricity Authority and respective state governments. India follows the US model of a Central Electricity Regulatory Commission (CERC) and separate electricity regulatory commissions (SERC) in each state. There are 27 SERCs, 2 Joint electricity regulatory commissions and once CERC. Chairpersons of all the 30 commissions forms a statutory body called Forum of Regulators (FOR) which is chaired by the chairperson of CERC. Some key policies, regulations and legislations in the electricity sector are given below:

Table 16: Policies and Regulations

Electricity Act, 2003	Sector reorganization and competitive markets, provide legal frame work for making theft of electricity an offence
National Electricity Policy	Overall sector development
National Tariff Policy	Performance based regulation
Guidelines for Competitive Bidding	Transparent tariff-based bidding for new generation
Rural Electrification Policy	Electrification of villages & remote areas
Indian Electricity Grid Code Regulations	Grid operations with competitive markets and renewables
REC Regulations	Trading of renewable energy certificates
Power Market Regulations	Transparent power market operations
Guidelines for Cross Border Trade of Electricity 2016 (draft regulation)	Guidelines regarding cross border trade of electricity between India and neighbouring countries
Renewable Energy Policy	A target of 175 GW Renewables by 2022; Net metering policies in all states
Power for All	Focus on universal access to electricity and measures to incorporate modern energy sources to supply round the clock electricity to all.

License Regimes	Increased private investments to simplify & deregulate business environment
Model Smart Grid Regulations	Issued by FOR in October 2015
Ancillary Services Regulations	Issued by CERC in August 2015

In 2010, GoI established India Smart Grid Task Force (ISGTF) an inter-ministerial task force and India Smart Grid Forum (ISGF), a public private partnership of governments, utilities, regulators, industry and academia and research. ISGF was mandated to assist GoI, state governments, utilities and regulators on grid modernization policies and programs. ISGF recommendations were to be vetted by ISGTF and submit to GoI and state governments for appropriate actions. ISGF in consultations with ISGTF prepared the Smart Grid Vision and Roadmap which was issued by GoI in August 2013.



3.4.7 Key Drivers for Smart Grids in India

The drivers for smart grid for different stakeholders in India are:

Utilities:

- Reduction of T&D losses in all utilities as well as improved collection efficiency
- Peak load management – multiple options from direct load control to consumer pricing
- incentives
- Reduction in power purchase cost
- Better asset management
- Increased grid visibility
- Self-healing grid
- Renewable integration

Customers:

- Expand access to electricity – "Power for All"
- Improve reliability of supply to all customers – no power cuts, no more DG sets and inverters
- Improve quality of supply – no more voltage stabilizers
- User friendly and transparent interface with utilities
- Increased choices for consumers, including green power
- "Prosumer" (producer and consumer) enablement
- Options to save money by shifting loads from peak periods to off-peak periods

Government and Regulators:

- Satisfied customers
- Financially sound utilities
- Tariff neutral system upgrade and modernization
- Reduction in emission intensity

It is evident that the far-reaching goals of the Indian power system can be enabled by smart grids which can help improve the efficiency and optimize performance within the Indian power sector Utilities.

Smart Grid Pilot Projects:

In order to kick-start deployment of smart grid technologies in the country, the MoP allocated 14 smart grid pilot projects to different distribution utilities in various states in 2012. Half the project cost of these projects was offered as grant from MoP under the then ongoing R-APDRP. Most projects covered a customer base of 8000 to 23000 and comprised of applications such as:

1. AMI – residential and industrial customers
2. Peak load Management
3. Power Quality Improvement
4. SCADA/DMS
5. Outage Management System
6. RE Integration on Low voltage grid

The smart grid pilot projects were scheduled for completion by 2015. Due to various reasons the projects are delayed. Four projects were cancelled. 3 projects have been completed in 2018. A snapshot of the status of the smart grid pilot projects is given below:

The detailed status of Smart Grid Pilot Projects given in section 4.8 Volume 2.

Table 17: Status of Smart Grid Pilot Projects

Pilot Project	Status
IIT Kanpur Smart City Pilot	Project Completed in March 2018
CESC, Mysore	Project completed in 2018
UHBVN, Haryana	Project completed in 2018
HPSEB, Himachal Pradesh	Project completed in 2018
UGVCL, Gujarat	All meters and DCUs installed and communicating to data center
TSECL, Tripura	31,044 meters and 267 DCUs installed
APDCL, Assam	13,895 smart meters and 200 DCUs installed 9,319 meters communicating to Control Center
PED, Puducherry	25,535 smart meters and 253 DCUs installed; Integration testing in progress
WBSEDCL, West Bengal	5,112 meters and 80 DCU installed. 2387 meters communicating

TSSPDCL, Telangana	5000 single phase meters installed. 4,475 meters communicating

3.4.8 Smart Grid Scenario

As already indicated, the EHV transmission grid in India is "smart" with state-of-the-art automation and control systems. In the distribution sector the private DISCOMs who operate in large cities of Delhi, Mumbai, Kolkata, Ahmedabad, Surat and NOIDA have been traditionally deploying latest technologies. Several of the smart grid solutions are successfully implemented in Delhi, Mumbai and Kolkata.

Table 18: List of Private Distribution Companies and their Smart Grid Initiatives

S. No	Name of the DISCOM, Service Area and Number of Customers	Smart Grid Applications Implemented	Smart Grid Applications under Implementation/Planned
1	Tata Power Company Ltd Southern parts of Mumbai, 0.6 million Customers	1. SCADA/DMS 2. Distribution Automation 3. Sub-station automation 4. GIS map; asset mapping and customer indexing 5. AMI for 15K customers 6. ERP and Integrated Billing Systems and Customer Care 7. Transformer Monitoring Systems 8. Gas Insulated Substations 9. Rooftop PV Integration 10. Outage Management System 11. Customer Portal and Mobile App 12. Chatbot and Voice Bot	1. Extension of AMI for balance customers 2. Extension of Sub-station Automation 3. EV Charging Infra 4. Rooftop PV Integration - continuation 5. Battery Energy Storage
2	Adani Electricity Mumbai Ltd (formerly known as Reliance Infra) Northern parts of Mumbai; 2.9 million Customers	1. SCADA/DMS 2. GIS map; asset mapping and customer indexing 3. AMI pilot based on 6LoWPAN and AMR for HT consumers and grid metering 4. Transformer Monitoring System for remote monitoring of transformer parameters 5. Analytics for predictive maintenance, asset health monitoring 6. Sub-station Automation, 7. Rooftop PV Integration 8. Pilot on Power Quality Management (PQM) 9. Pilot on EV Charging Station	1. Roll out of AMI for all customers 2. Extension of Substation Automation 3. EV Charging Infra 4. Rooftop PV Integration - continuation 5. Transformer Monitoring System for all transformers 6. Demand Response System for 100 MW 7. Advanced Analytics 8. Extension of Sub-station automation-continuation 9. Chat Bots & Voice Bots

		10. Pilot on 1MW Demand Response System 11. Customer Portal and Mobile App 12. ERP and Integrated Billing Systems and Customer Care	
3	Tata Power Delhi Distribution Ltd (formerly known as NDPL) North and Northwestern parts of Delhi; 1.64 million customers	1. SCADA/DMS in all sub-stations 2. Advanced Distribution Management System 3. Distribution Automation 4. GIS map; asset mapping and customer indexing 5. AMI Pilot 6. ERP and Integrated Billing Systems and Customer Care 7. Sub-station Automation 8. Transformer Monitoring Systems 9. Outage Management Systems 10. Customer Portal and Mobile App 11. Pilot on Automated Demand Response (ADR) and integration of Smart Meters 12. Electric Vehicle Charging Infrastructure	1. Roll out of AMI for 300,000 customers 2. Extension of Sub-station Automation 3. EV Charging Infra 4. Rooftop PV integration - continuation 5. Roll out of Demand Response for 40 MW 6. Extension of Transformer Monitoring for all units 7. 10MWh Battery Energy Storage System 8. Chat Bots & Voice Bots
4	BSES Rajdhani Power Ltd South and Southwestern parts of Delhi; 2.4 million Customers	1. SCADA/DMS in all sub - stations 2. GIS map; asset mapping and customer indexing 3. AMI pilot based on 6LoWPAN communication technology 4. Smart Pre-paid Meter 5. Intelligent Group Metering System for High Loss Clusters based on RF Mesh and GPRS communication technology 6. Smart Transformer Monitoring System 7. Roof Top PV Integration 8. ERP and Integrated Billing Systems and Customer Care 9. Customer Portal and Mobile App	1. Roll out of AMI for 300,000 customers 2. EV Charging Infra 3. Rooftop PV Integration - continuation 4. Extension of Transformer Monitoring for all units 5. Sub-Station Automation 6. Chat Bots & Voice Bots
5	BSES Yamuna Power Ltd Eastern and Northeastern parts of Delhi; 1.6 million customers	1. SCADA on complete sub-transmission network 2. Distribution Automation in 60 sub-stations 3. Sub-station Automation	1. Extension of Distribution Automation 2. Roll out of AMI for 200,000 customers 3. EV Charging Infra

		4. Intelligent Group Metering for theft reduction 5. Smart metering pilot based on LoRa & RF-Mesh communication technology 6. Intelligent Outage Management System with integration of SCADA, GIS and OMS and Mobile Workforce Management 7. GIS map; asset mapping and customer indexing 8. ERP and Integrated Billing Systems and Customer Care 9. Customer Portal and Mobile App	4. Rooftop PV Integration - continuation 5. Extension of Transformer Monitoring for all units 6. Sub-station monitoring for all sub-stations 7. Chat Bots & Voice Bots
6.	CESC, Kolkata Central parts of Kolkata; 2.9 million Customers	1. SCADA/DMS 2. Self-Healing Distribution System 3. Distribution Automation – 10% Feeders 4. AMI based on RF Mesh, for 30,000 customers 5. AMR for Feeders 6. Net Metering 7. Transformer Monitoring System 8. Customer Portal and Mobile App 9. GIS & GPS integrated Consumer Complaint Management System 10. Condition Based Monitoring 11. Automated Demand Response System of 1.5 MW 12. EV Charging Stations (Pilot)	1. Extension of AMI to balance customers 2. EV Charging Infra 3. Rooftop PV integration - continuation 4. Extension of Demand Response 5. Sub-station Automation 6. Energy Storage pilot 7. Upgradation of SCADA/DMS
7.	Torrent Power Ltd Ahmedabad, Gandhi Nagar and Surat in Gujarat; 3 million customers	1. SCADA 2. Distribution Automation in 91 distribution sub-stations 3. ERP and Integrated Billing Systems and Customer Care 4. Customer Portal & Mobile App 5. Rooftop PV Integration	1. AMI Pilot 2. Rooftop PV Integration - continuation 3. Sub-station Automation 4. Transformer Monitoring

3.4.9 Smart Grid Roadmap for India

As indicated, Government of India (GoI) issued a Smart Grid Vision and Roadmap for India way back in August 2013. This is a high-level roadmap that prescribed the trajectory of smart grid development based on the IT and automation systems implemented under R-APDRP and given broad targets to all stakeholders. GoI had advised all states and utilities to prepare their own state and Utility specific smart grid roadmaps. Since all the utilities are not in the same level, the roadmaps for each Utility will be different as their starting points are different.

For example, the DISCOMs in Mumbai, Kolkata and Ahmedabad have AT&C losses below 10%, there are many states the losses are above 30% and few with losses as high as above 70%. Similarly, the percapita consumption of electricity in India is about 1000 kWh per person per year, there are several urban areas where this number is 3000 – 4000; and we have few states where the percapita consumption is below 200 kWh per person per year. Disparity with in the country being huge, Utility's business priorities and government's objectives are also differing widely. While few states are ready for large rollout of smart meters, some states are struggling to complete household electrification and other basic necessities.

Out of 72 electricity distribution licensees in India, about 60 of them will not measure up to Level-1 on the smart grid maturity model (SGMM) on any of the domains. Only few private DISCOMs have their Utility specific smart grid roadmap. Amongst the state government owned DISCOMs, Bangalore Electricity Supply Company Ltd (BESCOM) was the first one to prepare a smart grid roadmap. When SGMM compass survey was conducted for BESCOM in 2017, it was noticed that they scored 2 in Strategy, Management and Regulatory domain and 1 on Organization and Structure. Rest of the 6 domains BESCOM did not reach maturity level-1. This is considering the fact that BESCOM has successfully completed R-APDRP Part-A, SCADA/DMS and Distribution Automation System in Bangalore City. BESCOM is clearly a leader amongst the state government owned DISCOMs in terms of technology deployment and organizational maturity.

In view of the above it is recommended that all DISCOMs in India should prepare their Utility specific smart grid roadmaps. Some of the higher-level recommendations for all the DISCOMs in India are summarized below:

1. **Smart Grid Maturity Model (SGMM)**: SGMM cover entire operations of a Utility from strategy and management, organizational structure and grid operations to customers and societal and environmental related functions. These are classified as 8 domains and, in each domain, there are six levels of maturity – Level 0 to Level 5. Many utilities have not even reached level -1 in certain domains such as value chain integration, societal and environmental etc. Hence a ZERO (or default) level was introduced to the model in its latest version.

It is suggested that all DISCOMs should target to achieve maturity levels in in different domains as indicated below:

Table 19: Targets and Timelines for Smart Grid Maturity Model

Target and Timelines	2020	2025	2030	2035
SGMM Survey and Utility Specific Smart Grid Roadmaps	ALL Discoms should complete			
Smart Grid Maturity Levels				

Strategy, Management & Regulatory	Level-1	Level-2	Level-3	-
Organization & Structure	Level-1	Level-2	Level-3	-
Grid Operations	Level-1	Level-2	Level-3	Level-4
Work & Asset Management	Level-1	Level-2	Level-3	Level-4
Technology	Level-1	Level-2	Level-3	-
Customer	Level-1	Level-2	Level-3	-
Value Chain Integration	-	Level-1	Level-2	Level-3
Societal & Environmental	-	Level-1	Level-2	Level-3

2. **Peak Load Management:** Peak Load Management is one of the key smart grid objectives which can be achieved through a combination of following methods:
    a. Time of Use (ToU) Tariff
    b. Critical Peak Pricing
    c. Demand Response

The **ToU tariff** will help to move towards separation of peak and off-peak tariffs which would help in reducing consumption as well as costly power purchase by DISCOMs at the peak time. The tariff can be set in such a way that it inherently provides incentives and disincentives for the use of electricity in different time periods.

During peak hours when demand–supply balance is critical for grid stability, critical peak pricing (CPP) is an effective tool for controlling electricity demand by calling critical events during a specified time period, the price for electricity during these time periods is substantially increased. Two variants of this type of rate design exist: one where the time and duration of the price increase are predetermined, when events are called and another where the time and duration of the price increase may vary based on the electric grid's need to have loads reduced. In response to CPP strategies, customers may change their patterns of electricity usage. Detailed studies on the customer loads, usage pattern and behavior need to be undertaken before a CPP regime can be designed.

Demand Response (DR) stands for end-use electric customers reducing their electricity usage in a given time period, or shifting that usage to another time period, in response to a price signal, a financial incentive, an environmental condition or a reliability signal. This is normally operated by the Utility from their control room. DR will enable DISCOMs to avoid buying expensive power during the peak hours of the day by reducing the demand during those particular times of the day. DR can also provide system and local reliability benefits that will enable DISCOMs to avoid the use of rolling blackouts when there is not enough generation to satisfy demand. Typically, large customers such as industries, commercial buildings, shopping malls, water and sewage pumping stations etc are enrolled in a DR program. Utilities usually offer benefits to customers participating in the DR program.

3. **Microgrids:** Microgrids are considered a key component of the 21st century grids for a variety of reasons. The primary focus on microgrids (grid connected smart microgrids) is to ensure reliability of supply for critical loads (with in the microgrid) in the event of a grid failure or extreme weather (or terror/natural disaster) events. While cyber-attacks on the control centre of a Utility can cause

grid failure, hundreds of microgrids that can island from the affected Utility's grid can still function independently ensuring reliable supply to critical loads – airports, railway stations, water and sewerage pumping stations, fire services, data centres, military establishments, weapon systems etc.

India should consider large scale implementation of both grids connected smart microgrids as well as stand-alone microgrids for remote villages/communities and islands on priority. The Smart Grid Roadmap of 2013 envisages 31000 microgrids. There are over 7000 railway stations in India which are ideal candidates for smart microgrids – the solar PV can be installed on the long platforms, loads with the railway station as well as the loads in the nearby areas can be clubbed to form a smart microgrid around the railway stations.

4. **Distribution Automation and Substation Automation:** Distribution Automation and Substation Automation are independent systems but mostly undertaken together in many utilities.

Distribution Automation involves employing automation elements at various places on the electricity grid such as motorized Ring Main Units (RMU), sectionalizers, auto-reclosers and fault passage indicators (FPI) – all with communication systems. This centralizes the monitoring and control of the distribution network which further improves the reliability and efficiency of the electrical network. In case a feeder trips owing to a fault in one section, that portion can be isolated and supply to rest of the network can be restored immediately. Moreover, the exact location of the fault is known in the control centre and crew can be dispatched straight to that location instead of patrolling the entire feeder.

Substation Automation (SA) involves equipping the substation with digital relays and connecting them through reliable and secured communication systems with the control centre so that the substation can be remotely monitored and operated.

It is recommended that DISCOMs should undertake DA and SA in urban areas on fast track which will help controlling the EV charging as well as variability in rooftop PV generation.

5. **Integration of New Smart Grid Systems with R-APDRP Systems:** Through R-APDRP program (Part-A) all DISCOMs in India today have basic IT infrastructure and a set of IT applications. Any new smart grid applications implemented need to be integrated with the R-APDRP systems such as Billing & Customer Care, GIS Maps, Energy Accounting Module etc. In order to achieve this, the DISCOMs need the assistance of the System Integrator who has implemented the R-APDRP systems. This is already an issue in DISCOMs implementing the smart grid pilot projects. Typical integration points are:
    a. Smart Meter Data to Billing System
    b. Smart Meter Data to Energy Accounting Module
    c. SCADA and Outage Management System Data with GIS
    d. OMS Data with Customer Care Centre (call centre)
    e. Other Advanced Smart Grid Applications with R-APDRP Systems

Where ever standard applications (SAP-ISU, Oracle CC&B) are in place under R-APDRP, the integration process may be smooth as skills are available in the market. But in utilities where home-grown billing systems are in use (for example: MSEDCL, TANGEDCO, KSEB, 4 Discoms in Gujarat, Himachal, Rajasthan etc) such integration efforts will be humungous.

DISCOMS should address this key challenge and prepare mitigation measures failing which no new applications can be integrated with R-APDRP systems.

6. **One Billing System in a DISCOM:** Most DISCOMs in India are using more than one billing system: RAPDRP Billing System, Non-RAPDRP Billing System, HT Billing System etc. Billing System is the heart of a distribution Utility's operations and there is a burning need to bring all billing activities under ONE integrated billing system. It is the first step towards efficient energy accounting and loss reduction.

As mentioned in the previous section, some of the large DISCOMs are still using their home-grown billing systems. It will be almost impossible to integrate these applications with Meter Data Management Systems (MDMS) that is a key element of AMI and smart grid architecture.

It is recommended that all DISCOMs should make a plan for moving to ONE BILLING SYSTEM. Ideally, it should be a Commercial Off-The Shelf (COTS) billing system for which skilled personnel are easily available in the market.

7. **Business Process Re-Engineering (BPR):** With more and more automated systems being implemented, there is an urgent need for business process reengineering (BPR) and changes in organizational structure in DISCOMs. For example, once the GIS map of a feeder has gone live, all new connections/modifications on the electrical network should be undertaken on ground only after the proposed changes are incorporated in the GIS map and materials issued accordingly.

Smart Grid Roadmap Recommendations for DISCOMs in India: As indicated majority of the DISCOMs in India are in initial stages with regard to smart grids, the following detailed roadmap is prepared for DISCOMs to move from default level to Level-1 and beyond in a phased manner.

The Smart Grid Roadmap recommended in this report are in 3 stages:

a. **Immediate term (2018-2020):** Proposed some immediate action items that can add clear strategy and plan for power system development and grid modernization in India in alignment with long term goals set by the Government

b. **Near Term (2020-2025):** Proposed a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction

c. **Medium Term (2025-2030):** Proposed several measures that would transform DISCOMs in to a modern DISCOMs using planning tools and advanced automation and IT systems and analytics to optimize the assets and operations

The above steps are described in detail in the following sections:

3.4.9.1.1 India Smart Grid Roadmap 2018 – 2020

The India Smart Grid Roadmap 2020 defines the progressive trajectory of developments from present state (in 2018) to 2020 in following areas: Strategy Management and Regulation (SMR), Organization Structure (OS), Grid Operations (GO), Work and Asset Management (WAM).

It is assumed that India is seen to be at initial level in all domains of SGMM. Elementary preparation has been observed as government has taken initiative to expand electrical infrastructure for transmission and distribution network, policy recommendation, National Energy supply program and other projects for 2020 and 2030 targets. Government has also taken initiative to install pre-paid metering at some of locations and looking forward for advancement.

1. Strategy, Management, and Regulatory (SMR)

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level to achieve in 2020: 1

Although DISCOMs vision, policies and other projects are already in progress in India, they require a Smart Grid vison and Roadmap. Planning need to be done to achieve targets for 2020 and 2030. In ISGF's view, DISCOMs should target to achieve Maturity level 1 on SGMM by 2020.

India DISCOMs will target to achieve maturity level-1 by 2020 and level-2 by 2025. As per detailed evaluation of the existing systems and ongoing efforts in India, it is possible to reach maturity Level-1 by undertaking following steps:

- Define smart grid vision, strategy and policy in consultation with Ministry of Power
- Arrange training to key personals to have common understanding about smart grid vision and technologies
- Initiate discussions with regulators on DISCOMs Smart Grid Roadmap
- Make departmental structure for smart grid implementation (DMS, SCADA, Substation automation), AMI and their role and responsibilities
- Define area load dispatch center, regional load dispatch centre, central load dispatch centre and SCADA hierarchy from across the country
- Identify potential are a for Pilot project implementation for Smart Grid Pilot Projects, Substation automation and AMI

2. Organization and Structure (OS)

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level (In 2020): 1

As per data analyzed as a part of the study, India to be at default level as per Smart Grid Maturity Level "Organization and structure". ISGF recommends DISCOMs should target to achieve Maturity level 1 by 2020 by undertaking following steps:

- Organization should articulate (communicate) it's needs to build smart grid competencies in its workforce
- Organization structure and workforce need to align as per Smart Grid Vision and Roadmap
- Leadership should demonstrate a commitment to change the organization in support of achieving smart grid by assigning resources and budgets
- Conduct workshops/ awareness session of Smart Grid technology and needs across multiple functions/line of business to support smart grid activities

3. Grid Operations (GO)

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level to achieve in 2020: 1

Many projects are in progress by DISCOMs for strengthening of electrical network across country. In the realm of Grid Operations, DISCOMs must undertake following steps to reach maturity level 1:

- Prepare a Smart Grid Roadmap for (10~15 years) DISCOMs and get it approved by the Board of directors
- Define Smart Grid as an important item in business plan, budget and annual revenue requirement (ARR) plan and define future work plan for the same

- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g. AMI, with remote disconnect, SCADA/DMS, GIS etc.) may be undertaken
- Define strategy and plan for proof of concept projects and/or component testing for grid monitoring and control underway related to smart grid technologies
- Establish framework to calculate outages and reliability indices at distribution level
- Integration of Grid as one network through the country
- Building new substation and medium voltage (MV) and low voltage (LV) lines
- Addition of new DT's feeders and bifurcation of existing feeder in order to increase transmission and distribution capacity
- Replacement of existing DT by new higher capacity DT's wherever required according to load growth

4. Work and Asset Management

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level (in 2020): 1

As per present situation and data provided to ISGF, assume that DISCOMs are at default level (i.e. 0 level) in work and asset management domain. Looking into present progress of work, it is expected that DISCOMs could target for Level-1 by 2020 by undertaking following steps:

- Define business case for GIS and asset mapping at Transmission and Distribution levels and get approval for the same
- Perform consumer indexing at distribution level and map it to GIS
- Institute work flow for continuous updating of assets and customers on the GIS map
- Implementation of ERP (Enterprise resource level) system
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

5. Technology

Maturity Level in 2018: 0 (default), Target Maturity Level by 2020: 1

For achieving maturity level-1 by 2020, DISCOMs need to take following measures:

- Enterprise IT Architecture: DISCOMs must develop an enterprise IT Architecture and start its implementation. Need to retire several IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated (even through a middleware) must be replaced with commercially available off the shelf (COTS) applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT Architecture should enable integration of new assets and applications acquired by different LOBs
- Implement one integrated billing system across DISCOMs covering every type of customer
- Conduct audit for Cyber Security and adopt the recommendations to secure systems form cyber-attacks
- Prepare cloud strategy for future expansion

6. Customer

Present Level (in 2018): 0 (default), Target Maturity Level by 2020: 1

For achieving maturity level-1 by 2020, DISCOMs need to take following measures:

Recommendations for reaching maturity level 1 by 2020 are:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved Smart Grid Roadmap. These studies will identify customer benefits and satisfaction. DISCOMs may conduct these studies with input from different category of customers in urban and rural areas
- Conduct workshops to educate customers about Smart Grid Vision and Roadmap of DISCOMs
- Conduct study or research work for security and data privacy implication of new technologies and business process/functions to be adopted which can enable customer participation to leverage smart grid functionalities
- Consult with public Utility commission and /or other government related organization regarding impact of technologies on different categories customers

3.4.9.1.2 India Smart Grid Roadmap 2020 – 2025

The India Smart Grid Roadmap 2025 defines the progressive trajectory of developments from present state (in 2020) to 2025 in 7 domains as recommended below:

1. Strategy, Management, and Regulatory (SMR)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025):2

For achieving maturity level-2 by 2025, India need to following measures:

- Approval and acceptance of smart grid roadmap from higher management and ministry across all multiple functions and line of business of DISCOMs. Include the same in the business plan of DISCOMs
- Approval of smart grid projects/investments as per smart grid roadmap
- Establish smart grid governance model and define its hierarchy by keeping in view smart grid roadmap
- Designate and make hierarchy of smart grid leaders in all key line of business (LOB’s) with authority / responsibilities to implement measures envisaged as per approved smart grid roadmap
- Support from funding agencies for smart grid projects and make plan / strategy to implement smart grid projects in coming year e.g. SCADA, NMS, AMI, OMS etc. identify potential areas where projects can be implemented

2. Organization and Structure (OS)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

For achieving level-2 by 2025, DISCOMs need to take following steps:

- Approval of a Manpower Plan (including Training Plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on smart grid roadmap, restructure the organization hierarchy and its business process which can align end process for smart grid operations
- Create cross functional teams among all LOBs for implementation of smart grid initiatives as per Smart Grid Roadmap

- Plan workshop and training to key personnel to develop smart grid competencies

3. Grid Operations (GO)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

As per analysis of available data, it is assumed that DISCOMs can achieve maturity level 2 by 2025. For achieving maturity level 2 by 2025, DISCOMs need to take following measures:

- Create a new generation and transmission network, substations, medium voltage and low voltage lines by upgrading the transmission and distribution capacity
- Establish demand response (DR) for peak load management at customer level
- Establish outage management system (OMS) for efficient outage restoration
- Undertake pilot trials on smart microgrids for campuses, industrial parks etc
- Implement AMI in DISCOMs
- Pilot install EV charging infrastructure in required areas

4. Work and Asset Management

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

As per ISGF analysis of available data, it is assumed that DISCOMs can target to maturity level 2 by 2025. For achieving maturity level 2 by 2025, DISCOMs need to take following steps:

- Systems for tracking inventory and event history of assets on GIS maps
- Implementation of enterprise resource planning (ERP) system and its integration with GIS and other IT and automation systems
- Develop and implement a communication systems architecture to meet near term and long-term communications need adopting a multi-tier, multi-service telecommunication infrastructure architecture consisting of a core network and an edge network
- Development of network model for the distribution grid up to DT level so that modelling studies can be undertaken for assessing various scenarios of network upgrades to balance demand and supply most optimally
- Plan for hotline maintenance – bare hand methods using trucks with insulated baskets and other hotline tools
- Prepare plan for mobile workforce management (MWFM) systems

5. Technology

Present Level (In 2020): 0 (Default), Target Maturity Level (in 2025): 1

As per ISGF analysis on available data, it is assumed that DISCOMs can target maturity level 1 by 2025. For achieving maturity level 2 by 2025, DISCOMs need to take following measures:

- An Enterprise IT Architecture: DISCOMs must develop an enterprise IT architecture and start its implementation. Need to retire several IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated even through a middleware must be replaced with COTS applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT architecture should enable integration of new assets and applications acquired by different LOBs

- All IT applications should adopt change control process e.g. configuration management, patch management, remote updating of applications and integration capability for future integrations
- Implement one integrated billing system areas DISCOMs covering every type of customer
- Conduct audit for cyber security and adopt the recommendation to secure systems from cyber attacks
- Prepare cloud strategy for future expansion

6. Customer

As per data analyzed by ISGF, it is assumed that DISCOMs are at default level in this domain.

Present Level (In 2020): 0 (Default), Maturity Level (in 2025): 1

ISGF recommendations for reaching maturity level 1 by 2025 are:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved smart grid roadmap. These studies will identify customer benefits and satisfaction. Utility may conduct these studies with input from different category of customers in urban and rural areas
- Conduct workshops to educate customer about smart grid vision and roadmap of DISCOMs
- Consult with public DISCOMs commission and / or other government related organization regarding impact of technologies on different categories of customers

7. Societal and Environmental

As per data provided to ISGF and online available data, it is assumed that India is at default level for this domain.

Present Level (In 2020): 0 (Default), Maturity Level (in 2025): 1

ISGF recommendation for reaching maturity level 1 by 2025 are:

- Publish the smart grid roadmap with emphasis on:
  - DISCOMs role in environment and societal with respect to smart grid vision or strategy
  - DISCOMs publicly promote the environmental benefits of using smart grid technologies
  - Organization role in protecting the nation's critical infrastructure
- Approved environmental compliance records may be available for public inspection

3.4.9.1.3 India Smart Grid Roadmap 2025 – 2030

India Smart Grid Roadmap 2025-2030 defines the progressive trajectory of developments from present state (in 2018) to 2030 as expanded below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2025, DISCOMs need to take following measures:

- Establish Smart Grid Governance Model for smart grid development and decision making. Define roles, process and tools for the same

- Designate a Single Smart Grid leader in all key line of businesses with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap
- Approval for smart grid investments for key initiatives envisaged in the approved Smart Grid Roadmap

2. Organization and Structure (OS)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, India need to take following measures:

- Redesign organization structure to support Smart Grid initiatives e.g. matrix organization structure or similar and also execute this structure in view of the new programs and projects for 2040
- Conduct educational training programs which are aligned to build smart grid capabilities in organization
- All changes in organization structure, appointments / transfer / changes being made in consideration and support with smart grid program and projects

3. Grid Operations (GO)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, DISCOMs need to following measures:

- Building new generating plants, transmission lines, substation and medium voltage (MV), low voltage (LV) line and upgrade the capacity of existing generation, transmission and distribution system
- Plan for rollout of EV charging infrastructure and Vehicle to Grid integration solution in key locations
- Deployment of advanced analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all lines of business (LOBs), dashboard with relevant information are made available in each LOBs
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real time load and voltage data on selected urban and rural feeders
- Establishment of dedicated Smart Meter Operation Centre (SMOC) that will monitor and control smart meter operations and provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operation
- Automated operation of capacitor bank (if not part of VVO solution)
- Advanced ground fault detection by installing protective relays (or IEDs) to detect high impedance (very low fault current) faults for faster isolation of downed conductors/ section promoting enhanced safety and improved service reliability
- Implementation of state of art Security Operation Centre (SOC) to safeguard the system from cyber and physical attacks

4. Work and Asset Management

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

As per data analyzed by ISGF it is assumed that DISCOMs will target to achieve level 1 by 2020, level 2 by 2025, level 3 by 2030.

For achieving maturity level 3 by 2030, DISCOMs need to take following measures:

- Asset performance trend analysis and event audit reports are available for all major assets and systems
- Integrated view of all major/ key assets on GIS system with remote monitoring facility and their further integration with ERP system and mobile workforce management system (MWFM) covering all major urban areas
- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals
- Network model of transmission and distribution grids up to DT level is regularly updated and modelling studies undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally

5. Technology

Maturity Level (In 2025): 1, Target Maturity Level (in 2030): 2

As per data analyzed by ISGF, it is assumed that DISCOMs will target to achieve level 1 by 2025, level 2 by 2030.

For achieving maturity level 2 by 2030, DISCOMs need to following measures:

- Alignment of line of business with enterprise IT Architecture across entire organization. If required modify business process to align it with IT Architecture and systems
- Framework in process for change control of all IT applications and infrastructure
- Organization uses an informal common technology evaluation and selection process for Smart Grid activities including selection of vendors and external services
- Conduct pilot trails on wide area monitoring and distributed sensor network

6. Customer

Maturity Level (In 2025): 1, Target Maturity Level (in 2030): 2

As per data analyzed by ISGF, it is assumed that DISCOMs will target to achieve level 1 by 2025 and level 2 by 2030. For achieving maturity level 2 by 2030, DISCOMs need to take following measures:

- Carry out research studies on enhancing customer experience and benefits through smart grid technologies envisaged in the approved Smart Grid Roadmap. These studies may be conducted for different categories of customers in both urban and rural areas
- DISCOMs vision of the future grid is being communicated to customers

7. Societal and Environmental

Maturity Level (In 2025): 1, Target Maturity Level (in 2030): 2

DISCOMs should undertake following steps to reach maturity level 2 by 2030:

- Finalize work plans for addressing the social and environmental issues through smarter technologies

- Undertake proof of concept projects that can demonstrate the environmental benefits of smart grid technologies and applications
- Offer smart grid supported energy efficiency programs for customers
- Adopt “Triple Bottom Line” (TBL) framework for key decisions – TBL method covers Social, Environmental and Financial aspects of every investment plans/projects
- Diesel Generator replacement with battery (that can be leveraged for load balancing) at customer premises is actively promoted through innovative business models

8. Value Chain Management (VCM)

Present Level (In 2025): 0 (Default), Target Maturity Level (in 2030): 1

DISCOMs should undertake following steps to reach maturity level 1 by 2030.

- Formulation of a strategy for creating and managing a diverse resource portfolio
- Identification of:
    - Assets and programs for load management
    - Distributed generation resources, its locations and capabilities
    - Security requirements to enable interactions with an expanded portfolio of value chain partners
- Evaluate and identify the security requirement to enable interaction with expanded portfolio of value chain partners

The above maturity levels can be achieved in a phased manner as indicated in the chart below:

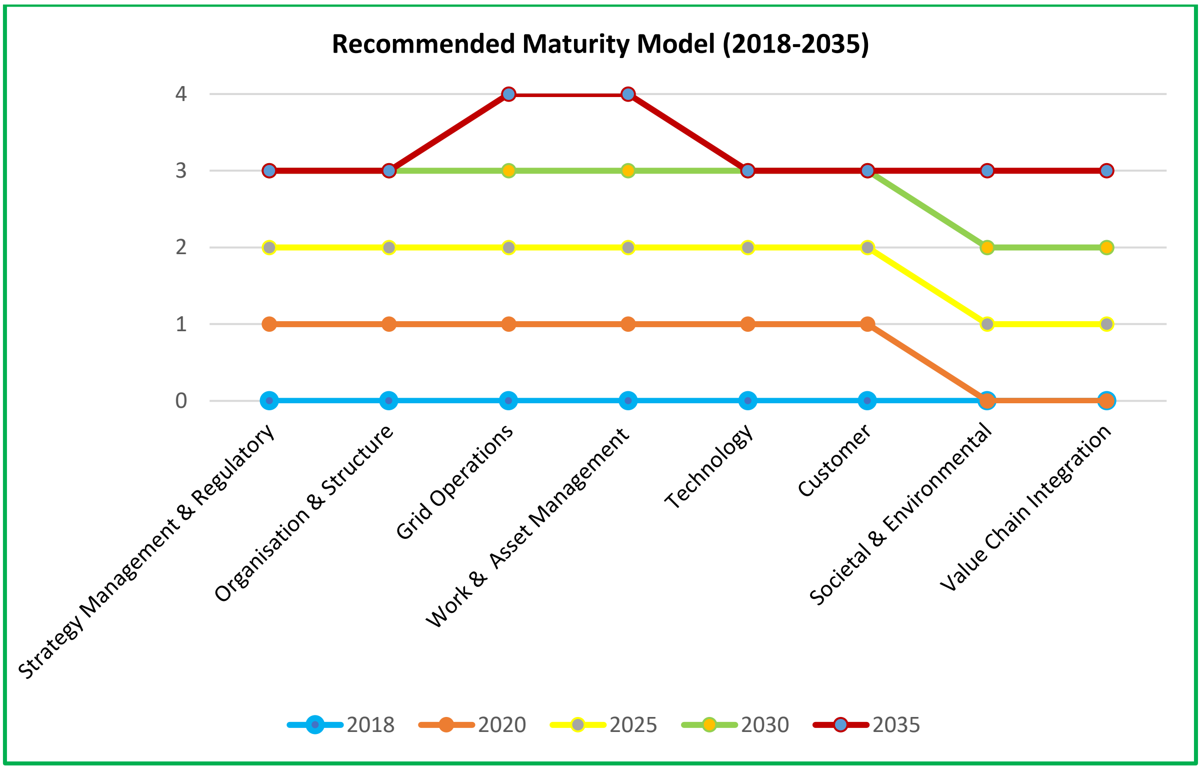


Figure 38: Recommended Smart Grid Maturity Levels (2018-2030)

3.4.10 Cost Benefit Analysis

3.4.10.1 Background

India has an installed generation capacity of 346 GW (65% thermal; 13% hydro; 20% Renewable; 2% Nuclear). The average PLF over the past 5 years has declined from 70% to 60%. The peak demand is 172.4 GW. A 10-year energy blueprint published in 2016 predicts 57% of India's total electricity capacity will come from non-fossil fuel sources by 2027. The Paris climate accord target is 40% by 2030. Most of this RE addition will be solar PV (170 GW PV of which 40 GW will be Rooftop PV on MV and LT voltages). Currently, four states are generating over 50% of load from solar PV/Wind and RE curtailments take place regularly (particularly wind). The addition of such large solar PV on MV and LT levels will likely cause power quality issues. Multiple active/reactive power and load control mitigation measures will be needed to manage this well at higher targeted penetration levels.

3.4.10.2 Project Objective & Description

Evaluate near-autonomous load-following of variable-generation on an Urban distribution station (MV+LT)

A 10 MW station with 6+ MW Rooftop PV on MV feeders and LT Voltages:

1. 250 units of Smart Inverter with BESS (target 5-10 KW LT prosumer points) to autonomously regulate PCC voltage and load-balancing (USD 18,000 each)
2. 2 units of above ground containerized 2 x 60 KW flywheels for inertia and PQ mitigation (USD 3,000/KW each)
3. units of distributed 250KW x 4 hr BESS on MV Feeders (USD 240/kWh)
4. 10,000 units of distributed A/C set-point controller (raise/lower set temp by 3°C) (USD 150 each)
5. 5500 units of Smart Meter + Telecom (at strategic points to monitor PQ (USD 150 each)

It is novel in the sense, globally only very few pilots in the 50MW range have been undertaken in this area. India will need to manage this if its aggressive RE targets are met. Already it curtails wind in 4 states (not very good). Machine learning is an integral part of this near-autonomous approach. Cyber-security is of course implied.

Financial Data:

- Required rate of return (Govt. / IFI rates) - 8%
- Tax rate – 25%

Initial Investments:

Parameter	Cost
Equipment	$7,995,000.00
Engineering and Development	$200,000.00
Installation & Commissioning	$250,000.00
Total Initial Investments	**$8,445,000.00**

Benefits	YEAR	1	2	3
Avoided Fossil power costs (6 MW x 0.04cents diff tariff x 6000 hrs)		$1,440,000.00	$1,440,000.00	$1,440,000.00
Urban Pollution Avoidance {(0.95 t/MWh CO2) x 6 MW x 6000 hrs x USD 50/t value)		$1,710,000.00	$1,710,000.00	$1,710,000.00
PQ Improvement Impact (2multiple x 3 MW av. x 0.10cents x 1000 hr)		$600,000.00	$600,000.00	$600,000.00
Time-shifting/Demand Reduction (1 MW x USD 8/KW/Mth x 5days/mth x 12 mths)		$480,000.00	$480,000.00	$480,000.00
Total Benefits		**$4,230,000.00**	**$4,230,000.00**	**$4,230,000.00**

Costs (Excluding Initial Capital Investments)	YEAR	1	2	3
Operations		$50,000.00	$50,000.00	$50,000.00
Maintenance		$40,000.00	$40,000.00	$40,000.00
Project management, customer support		$35,000.00	$35,000.00	$35,000.00
Misc.		$10,000.00	$10,000.00	$10,000.00
Depreciation on capital expenditures (calculation uses 5-year period)		$1,689,000.00	$1,689,000.00	$1,689,000.00
Total Costs		**$1,824,000.00**	**$1,824,000.00**	**$1,824,000.00**

Totals	YEAR	1	2	3
Net Benefits (Costs)		$2,406,000.00	$2,406,000.00	$2,406,000.00
Tax		$601,500.00	$601,500.00	$601,500.00
Value after tax		$1,804,500.00	$1,804,500.00	$1,804,500.00
Depreciation added back		$1,689,000.00	$1,689,000.00	$1,689,000.00
Cash flow	-$8,445,000.00	$3,493,500.00	$3,493,500.00	$3,493,500.00
Cumulative cash flow	-$8,445,000.00	($4,951,500.00)	($1,458,000.00)	$2,035,500.00

Evaluation Metrics		Cautionary Note
Net present value (NPV)	$558,088.32	All costs are budgetary for discussions purposes only
Internal rate of return (IRR)	11.63%	A detailed project report (DPR) needs to be done
Payback period (in years)	2.42	

3.4.10.3 Relevance of CBA Analysis to SG transition

India's plan to target 170 GW of PV and Wind (of which 40GW will be rooftop PV on MV and LT voltages), requires special attention to manage these variable energy resources (VRE) effectively and not lead to deteriorating power quality (PQ) for customers. At today's levels, four states already exceed 50% of their load regularly, and VRE curtailments are taking place (particularly Wind power). This pilot project attempts to mitigate PQ effects of high VRE (mostly PV) penetration, particularly in urban MV and LT circuits where its impact will be felt most.

Benefits:

The CBA results look promising with a positive NPV and short payback and is worth implementing.

A detailed project report (DPR) with formal quotes will be required.

The following are the key benefits:

1. Avoided fossil power costs are about USD $ 1.44 million p.a. and avoided air pollution effect is about USD 1.71 million annually
2. Avoided PQ effects amounts to USD $600,000 annually and demand reduction (due to time shifting) about USD $ 480,000 per annum
3. If successful, similar projects can be implemented in other urban and semi-urban areas having high VRE
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Local and Utility O&M services will also get a boost in operating and maintaining distributed devices
6. All these are medium and low distribution voltage power equipment and hence can be managed by the Utility and external contractors

3.4.10.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions (temperature, humidity, dust, etc.)
2. Some special training/skills may be required for installation, calibration and commissioning of such equipment
3. Associated equipment installations require coordinated planning for good outcome.
4. It is important that the systems and architecture designs of this pilot project be supervised by global experts

In most of our project implementation in emerging markets, these common factors play a crucial role in success versus failures. Hence the repetition. Differing infrastructure issues are often de-risked in planning, investments and technology. Training of O&M personnel in new technology equipment (BESS, Inverters, Flywheels, etc.). In most of our project implementation in emerging markets, these common factors play a crucial role in success versus failures. Hence the repetition. Differing infrastructure issues are often de-risked in planning, investments and technology.

3.5 Maldives

3.5.1 Introduction

Maldives has a population of around 436,330 people dispersed across 188 islands. The country has been enjoying robust economic growth and infrastructure development including connectivity. Maldives has the highest percapita GDP amongst the SAARC nations. Tourism and fisheries are the main industries in Maldives. It has also been providing high quality and affordable public services for its citizen. Maldives has a literacy rate close to 100%, and life expectancy of over 77 years which are highest among the SAARC nations.

3.5.2 Power Sector

Maldives is highly dependent on imported oil. The state-owned electric company, STELCO supplies electricity to the country's capital Male' and another 32 islands representing 60% of the population.

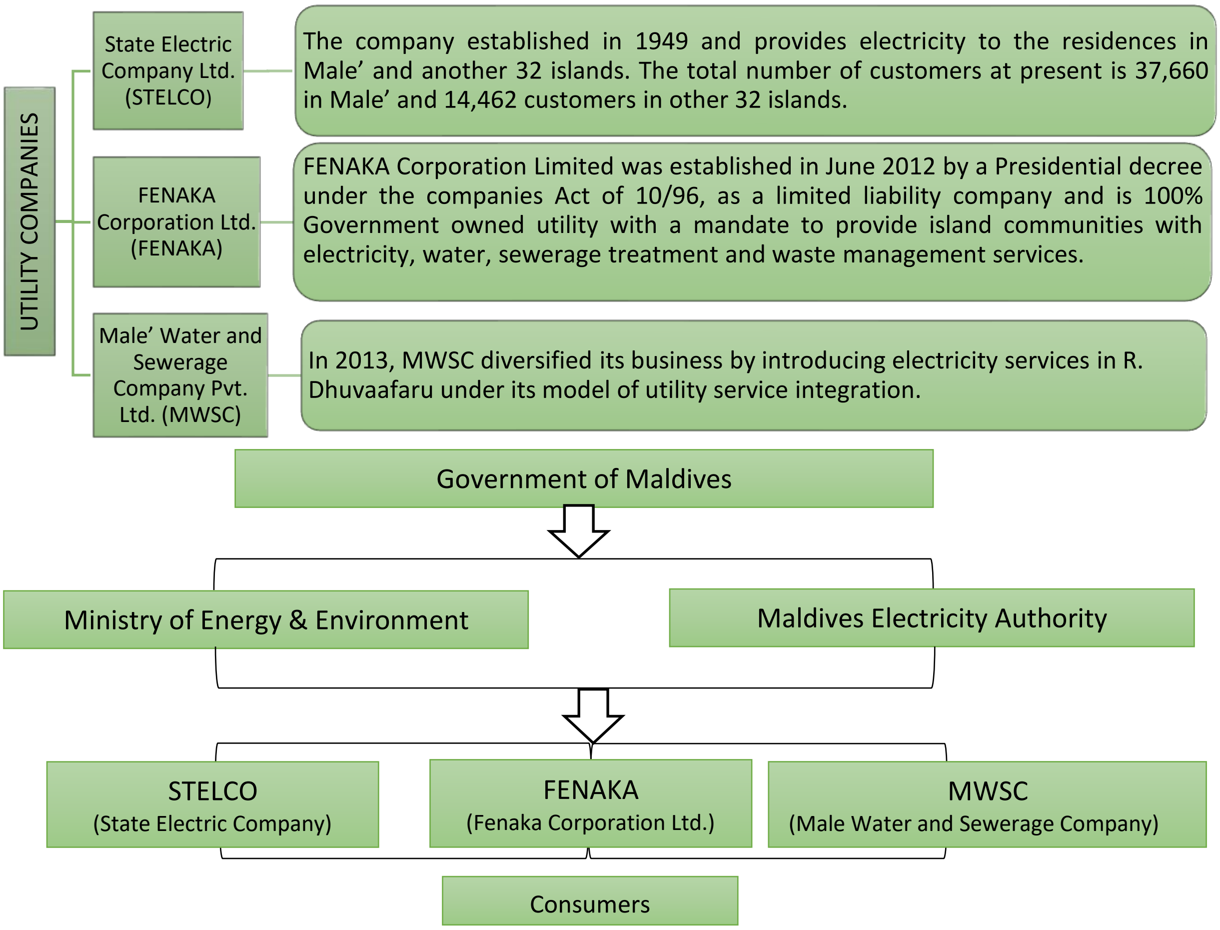
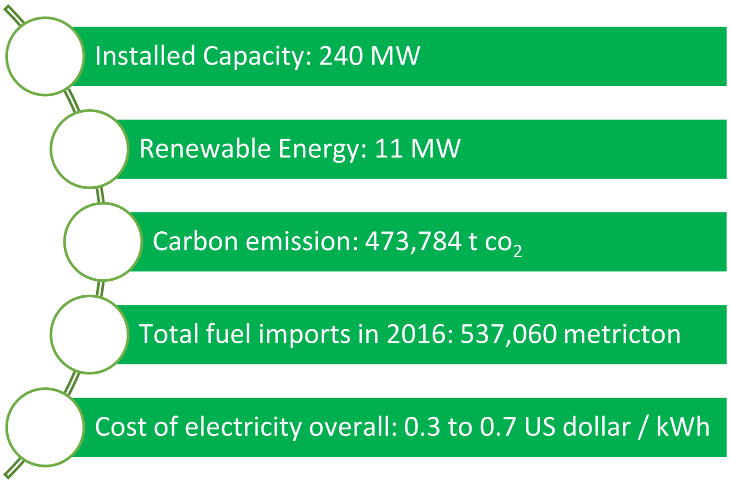


Figure 39: Institutional Framework of Maldives Power Sector

Maldives has no conventional energy resource that it can utilize to meet its energy needs. STELCO is wholly owned by the government. Its core business includes power generation, distribution, and retail. It operates 28 power systems in 33 islands, providing electricity to 60% of the country's population. The STELCO's largest operation is in Malé, the capital of Maldives. The installed capacity on the capital island is 80.32 MW as of 2018 which includes 27 generator sets. The size varies from 1 MW to 8.9 MW. Peak demand in 2017 was 56 MW. Maldives has total land area of 298 sq km; but Malé, the capital island has an area of 5.8 sq km only where almost 25% of the country's population reside.

3.5.3 Generation Sector

The [27]total installed capacity of Maldives is 240 MW. During 2017, Maldives consumed 704 GWh. Electricity is mainly produced from imported fuel oil. Over reliance on fossil fuel imports leaves Maldives highly vulnerable to global fuel price hikes. In addition, it results in increased carbon emissions which reached to 473,784 tonnes of CO_2 in 2016. Currently, fuel storage capacity of the country is very small, approximately 28 MT, which only lasts for 10 days. Hence, fuel needs to be imported twice or thrice per month adding to the price instability.



3.5.1.1 Energy Supply and Demand Status

Electricity consumption in Malé island was about 336 GWh in 2017. While the demand in Male is from the residential sector followed by manufacturing and commercials and government buildings, in other islands it is mostly tourist resorts that consume electricity. The forecast for the next 20 years with the maximum demand of 562 GWh in year 2037 is displayed in the figure below.

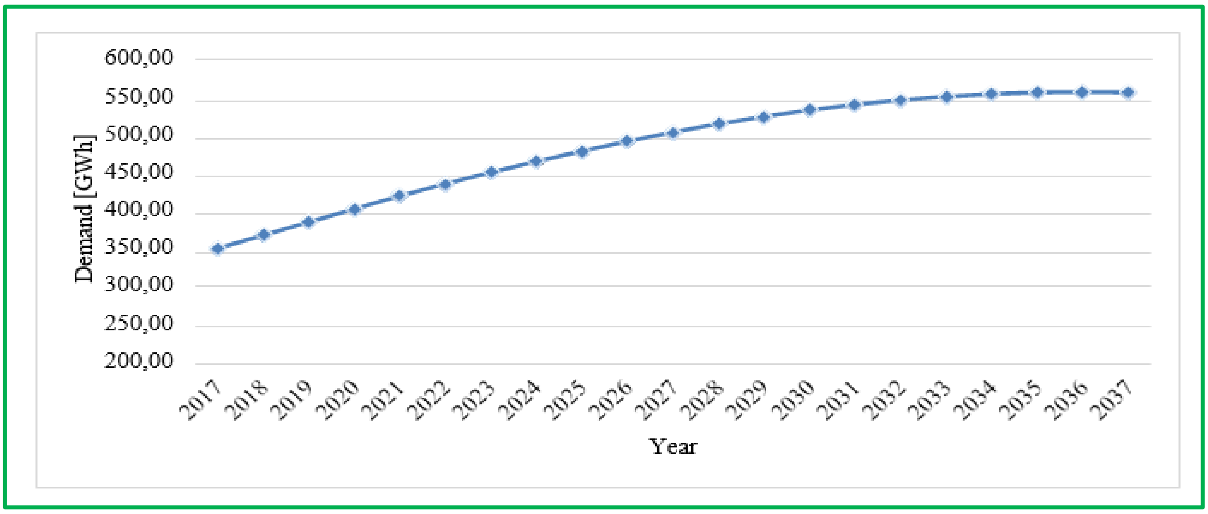


Figure 40: Forecast for Electricity Demand until 2037 in Male

[27] MALDIVES ENERGY SECTOR & SREP IP 4 TH DECEMBER 2017, ABUJA, NIGERIA

3.5.4 Renewable Energy

In Maldives, renewable energy sources are: solar, wind and biomass. Other upcoming technologies like marine current, wave, tidal, OTEC are yet to be deployed. The country has already identified an initial set of some 8 pilot renewable energy projects that include wind and solar hybrids totaling some 47.8 kW of solar and 93.4 kW of wind. Total RE capacity as of 2018 is 11 MW.

The other feasible options for renewable energy sources in the country include the development of hybrid mix of solar-diesel, wind-diesel and solar-wind-diesel projects.

In Male and Hulhumale islands there is a good potential for solar and wind generation which can be deployed to increase installed capacity and achieve targets for 2020.

Table 20: Comparison of 2020 Renewable Energy Deployment Potential and Grid Stability

Comparison Of 2020 Renewable Energy Deployment Potential and Grid Stability			
Islands	**Solar PV potential (MW)**	**Wind Power (MW)**	**Grid Stability Limit (solar PV (MW)**
Male	5.11	-	5.11
Hulhumale and Hulhule	11.81	-	8
Thilafushi	4.09	20	-
Villingili	0.57	-	0.57
Gulhifalhu	1.91	-	1.2
Total renewable energy potential	**23.49**	**20**	**14.88**

Source: Renewable Energy Roadmap: The Republic of Maldives- IRENA

3.5.1.2 Energy Policy 2016 summary

Maldives Energy Policy and Strategy 2016 consist of revised policies derived from Maldives Energy Policy and Strategy 2010. The 9 policies are reduced to 5 key policy statements, which are:

Policy 1: Strengthen the institutional capacity and regulatory framework of the energy sector

Policy 2: Promote energy conservation and efficiency

Policy 3: Promote renewable energy technologies

Policy 4: Improving the reliability and sustainability of electricity service

Policy 5: Increase national energy security

3.5.5 Key Drivers for Smart Grid in Maldives

Despite diesel being the major energy resource, the country possesses a good potential of renewable energy resources due to its geographical location. In the year 2016 fuel imports reached 5,37,060 metric tons. The peak electricity demand in Male' is likely to double in the next 7 years, requiring major investments, incurring high operating costs and increased GHG emission. [28]Maldives Government is now focusing on the development of energy sector through renewable energy sources. As per "Policy 3: promote renewable energy technologies", Maldives is trying minimize electricity expenses by Introducing hybrid systems that use renewable energy, promote installation of rooftop PV on government and large private buildings, facilitate research in wind, solar, ocean currents, and wave energy[29] by 2030.

Following are the key drivers for smarter technologies in Maldives' power sector[30]:

Reduce Dependence on Fuel Imports: Maldives has no indigenous reserve energy resources like petroleum, gas, or coal and there is no hydropower potential as well. Diesel for power generators is entirely imported and is subject to fluctuation in prices. Other forms of indigenous energy (such as solar and biomass) are not significant in the supply mix so far. Maldives receives over 120 days of sunshine a year. Solar energy, while used to provide heating water in some resorts and pilot tested for rooftop installations in Malé, is making progress with some projects in greater Malé.

Improve Energy Efficiency: The dispersed islands with small populations increases the costs of providing electrical services owing to poor economies of scale. Fuel conversion efficiency is very low and distribution losses are very high in these smaller islands. The way forward is to install smart microgrids with state-of-the-art energy storage and control systems.

Attract Investments: Investments in the energy sector is not forthcoming presently. Transition to low carbon electricity regime could attract international investment in the energy sector. However institutional strengthening and capacity building in the new technologies must be taken up on priority for development of modern microgrids in islands.

Inter-connection of nearby Islands: In Maldives, every island is a micro grid but some of the islands are not far away and have shallow water in-between them which can be connected to each other via submarine cables. By doing this, many micro grids can be merged together and reliability of supply and optional use of energy resources can be achieved. Grouping of separate microgrids and interconnected operation require smarter technologies.

3.5.6 Smart Grid Initiatives

- Maldives expected to accommodate 2,40,000 residents within a land mass of over 400 hectares in Hulhumalé island which is planned as a smart city and will incorporate a smart microgrid to provide better electricity and related services to the inhabitants. This island is promoted as a global tourist hub offering world class resorts with beaches and diving spots. The project is managed by the government owned Housing Development Corporation Ltd (HDC)
- Another transport master plan has been developed to include smart city components such as smart traffic management systems, automatic surveillance, ERP systems, as well as more efficient and a smart public transportation system

[28] Maldives Energy Policy & Strategy 2016

[29] Maldives Climate Change In-Depth Technology Needs Assessment - Energy Sector

[30] Sector Assessment (Summary): Energy, Interim Country Partnership Strategy: Maldives, 2014–2015

3.5.7 Smart Grid Roadmap Recommendations

As described, there is no major electric grid in existence in Maldives and owing to its unique geography no transmission and large distribution grids will be feasible in future as well.

It is recommended that Maldives should undertake following steps in energy transition from an economy driven by imported fuel to one primarily depending on clean energy from solar and wind resources with battery energy storage systems. The Smart Grid Roadmap recommended in this report are in stages:

a. **Immediate term (2018-2022):** Proposed some immediate action items to reduce diesel consumption for power generation and thereby reduce both emissions and foreign exchange outflow
b. **Medium Term (2022-2030):** Proposed several measures that would transition the energy scenario in Maldives

The above steps are described in detail in the following sections.

3.5.7.1 Maldives Smart Grid Roadmap 2018 – 2022

A) Following measures are recommended for STELCO in Male' Island:

a. Prepare plan and install at last 5 MW of rooftop Solar PV in Male' Island – government buildings, airports, schools, colleges, hospitals (Male' island has a total area of 1433 Acre and 5 MW require about 125 Acre roof space – survey of rooftop to be conducted to assess the feasibility; but not an un-achievable target)
b. Install Battery Energy Storage Systems for minimum 10 MWh capacity – this could be distributed across different locations in the island
c. Identify locations in Male' Island where large campuses or building complexes can be grouped together to make smart microgrids and select one good location and convert that to a 1 MW advanced hybrid microgrid capacity with solar (and wind also if feasible) generation, battery energy storage and demand control systems (as proposed in the next section on Cost Benefit Analysis)
d. Convert one DG Set as a hybrid power station with solar (and wind if feasible) and study the behavior and upgrade the control systems to operate to efficiently

B) Following measures are recommended for STELCO and FENAKA on other islands they serve:

- Identify one island each by STELCO and FENAKA for converting to a smart microgrid with solar, wind and DG sets as well as Battery Storage and implement the system on fast track
- Undertake feasibility studies to identify groups of nearby islands whose power systems can be connected through undersea cables; and undertake the interconnection of one such island group on pilot basis. Study the results and prepare techno-economic analysis for replicating the interconnection for other feasible island groups
- Study the feasibility of deploying floating solar panels in sea water with appropriate wave-breakers (floating solar plants have been installed in several places in the recent past including dams in India)
- Study the feasibility of deploying floating wind mills (Electricity de Portugal has installed floating wind mills in sea water which are working since 2013)

- Undertake feasibility studies for deploying wave energy (in the recent past different designs of wave energy plants have been installed successfully – Australia, Denmark, Israel, Turkey etc)
- Launch energy efficiency programs – LED bulbs, LED street lights, star labelled appliances etc
- Introduce and test solar boats for inter-island transport between nearby islands

C) Male Water and Sewerage Company (MWSC) should setup a waste to energy plant in Male' running primarily on municipal solid waste (MSD)

D) Housing Development Corporation (HDC) to finalize the plan for the Smart City in Hulhumale Island; and undertake pilots on select domains including electricity

3.5.7.2 Maldives Smart Grid Roadmap 2022-2030

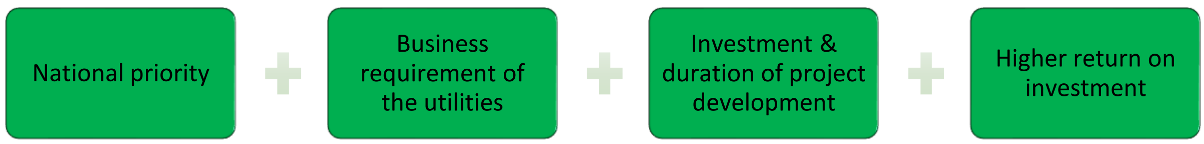
- Implement policies to prevent addition of DG Sets capacity. Demand growth to be met from cleaner sources
- Explore techno-economic feasibility for replication/scaling up of:
    - Microgrids with solar PV, wind turbines and battery storage in maximum number of islands where feasible
    - Interconnection of nearby islands through undersea cables with centralized control of generation and dispatch
    - Floating solar plants
    - Floating wind mills
    - Waste to Energy plants in islands where feasible

- Launch programs for replacement of DG sets smaller than 100 kW with batteries and other sources of generation
- Scale up energy efficiency programs (LED bulbs, LED street lights, star labelled appliances etc) – fine tune the program based on the experience from Male' island
- Rollout solar boats for inter-island transport between nearby islands

Introduce electric and solar planes for inter-island transport (A company called Amphere based in Los Angeles has already introduced short flights with electric planes for short flights)

3.5.8 Cost Benefit Analysis

Based on the above recommendations till 2030 in each of the eight domains, ISGF has identified various activities that need to be undertaken by the utilities in different phases and also identified one project for development in future based on various parameters as mentioned below. These parameters have also taken into account the envisaged or future targets of the governments in terms of electricity supply, renewable energy development, cross border power trading, operational performance of the utilities etc.



With the increase in renewable generation and roof top PV penetration, integration of these variable resources into low voltage grid poses serious concern to the grid reliability and increases the operational difficulties for the utilities. Therefore, load control mitigation measures need to be in place with the increase in roof top PV penetration in the urban areas. The detailed cost benefit analysis for the project has been done considering its priority and the huge amount of benefits it accrues compared to the investment it needs.

3.5.8.1 Project Objective

Evaluate diesel fuel displacement and carbon emissions benefits with advance micro-grid architectures for a 1 MW hybrid in Male (PV potential 1250 KW).

1 MW hybrid micro-grid consisting of:

1. 3 x 100 KW Variable Speed DG sets (USD $1250/KW each)
2. Above ground containerized 2 x 60 KW flywheels for inertia and solar PQ mitigation (USD 3,000/KW each)
3. 250KW x 4 hr BESS (USD 240/KWh)
4. 1 MW Solar PV Plant (USD 1000/KW)
5. Microgrid controller and substation (USD 750,000)

Financial data: Required rate of return (Govt. / IFI Rates) – 8 %, Tax Rate -25

Initial Investment	YEAR	1	2	3
Equipment	$2,725,000.00			
Engineering and Development	$150,000.00			
Installation & Commissioning	$150,000.00			
Total Initial Investments	**$3,025,000.00**			

Benefits	YEAR	1	2	3
Diesel Fuel import Saved {1000 KW - 300KW) x 6000 hrs x 0.28 L/KW x USD 1.75/L}		$2,058,000.00	$2,058,000.00	$2,058,000.00
Carbon Emissions Avoidance {(2.7kg/L x (1000-300 KW) x 0.28 L/KW x USD 25/tonne)		$79,380.00	$79,380.00	$79,380.00
Tourism promotion (long-term reduced pollution) estimate		$50,000.00	$50,000.00	$50,000.00
DG maintenance savings (USD 1.00/hour/50 KW x (1000-300 KW) x 6000 hours)		$84,000.00	$84,000.00	$84,000.00
Total Benefits		**$2,271,380.00**	**$2,271,380.00**	**$2,271,380.00**

Costs (Excluding Initial Capital Investments)	YEAR	1	2	3
Operations		$50,000.00	$50,000.00	$50,000.00
Maintenance		$40,000.00	$40,000.00	$40,000.00
Project management, customer support		$35,000.00	$35,000.00	$35,000.00
Misc.		$10,000.00	$10,000.00	$10,000.00
Depreciation on capital expenditures (calculation uses 5-year period)		$605,000.00	$605,000.00	$605,000.00
Totals		**$740,000.00**	**$740,000.00**	**$740,000.00**

Totals	YEAR	1	2	3
Net Benefits (Costs)		$1,531,380.00	$1,531,380.00	$1,531,3
Tax		$382,845.00	$382,845.00	$382,84
Value after tax		$1,148,535.00	$1,148,535.00	$1,148,5
Depreciation added back		$605,000.00	$605,000.00	$605,00
Cash flow	-$3,025,000.00	$1,753,535.00	$1,753,535.00	$1,753,5
Cumulative cash flow	-$3,025,000.00	($1,271,465.00)	$482,070.00	$2,235,6

Evaluation Metrics		Cautionary Note:
Net present value (NPV)	$1,494,029.77	All costs are budgetary for discussions purposes only.
Internal rate of return (IRR)	33.73%	A detailed project report (DPR) needs to be done.
Payback period (in years)	1.73	

3.5.8.2 Relevance of CBA Analysis to SG transition

Maldives consists of many islands and each island has its own grid (micro-grid) and are not inter-tied into one grid. The cost of linking the islands into one national grid using undersea cables is likely very expensive for a national total generation of only 363 MW. With the advent of new technologies that support better variable generation, the current project is worthwhile exploring.

Benefits:

The CBA results look promising with a positive NPV and a quick payback and worth implementing. A detailed project report (DPR) with formal quotes will be required:

The following are the key benefits:

1. Fuel savings in the order of USD $ 2 million per annum is extremely beneficial for the economy
2. Eco-tourism will get a boost as a result of less carbon emissions
3. If successful, similar projects can be implemented in other islands
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Local O&M services will also get a boost in operating and maintaining new technology devices
6. This will be a continued step from the recent ADB cleantech projects implemented a few years ago

3.5.8.3 Potential Barriers to Success

Need to ascertain these new technology devices can be operated in the environmental conditions of the island (temperature, humidity, etc.)

1. Some special training/skills may be required for installation and commissioning of Flywheels, and BESS systems
2. Unless planned well with good lead times, the supplies/delivery of such heavy equipment may get held up in sea transport to Maldives
3. It is important that the systems and architecture designs of this pilot project be supervised by global experts
4. Training of O&M personnel in new technology equipment (BESS, Variable Speed DGs, Flywheels, etc.)

3.6 Nepal

3.6.1 Introduction

Table 21: Socioeconomic Data

Socioeconomic Data	2017
GDP (billion $)	20.6
GDP Growth Rate, Annual (%)	3

Agriculture remains Nepal's principal economic activity, employing about 65% of the population and providing 31.7% of GDP. The main sources of primary energy in Nepal is traditional biomass including fuelwood accounting for around 80% of total energy consumption. At end of 2017-18, about 70% population have access to electricity. Nepal power sector is governed by the Ministry of Energy, Water Resources and Irrigation (MoEWRI) with Department of Electricity Development (DoED) functioning as the main implementing agency for promotion and implementation of Government policies and programs in the sector. At the operational level, Nepal Electricity Authority (NEA), a vertically integrated state-owned utility is the key institution responsible for ownership, planning and operation of generation, transmission and distribution assets. In addition, the other concerned bodies engaged in the various activities for electricity sector development are Water and Energy Secretariat and Electricity Tariff Fixation Committee (ETFC).[31]

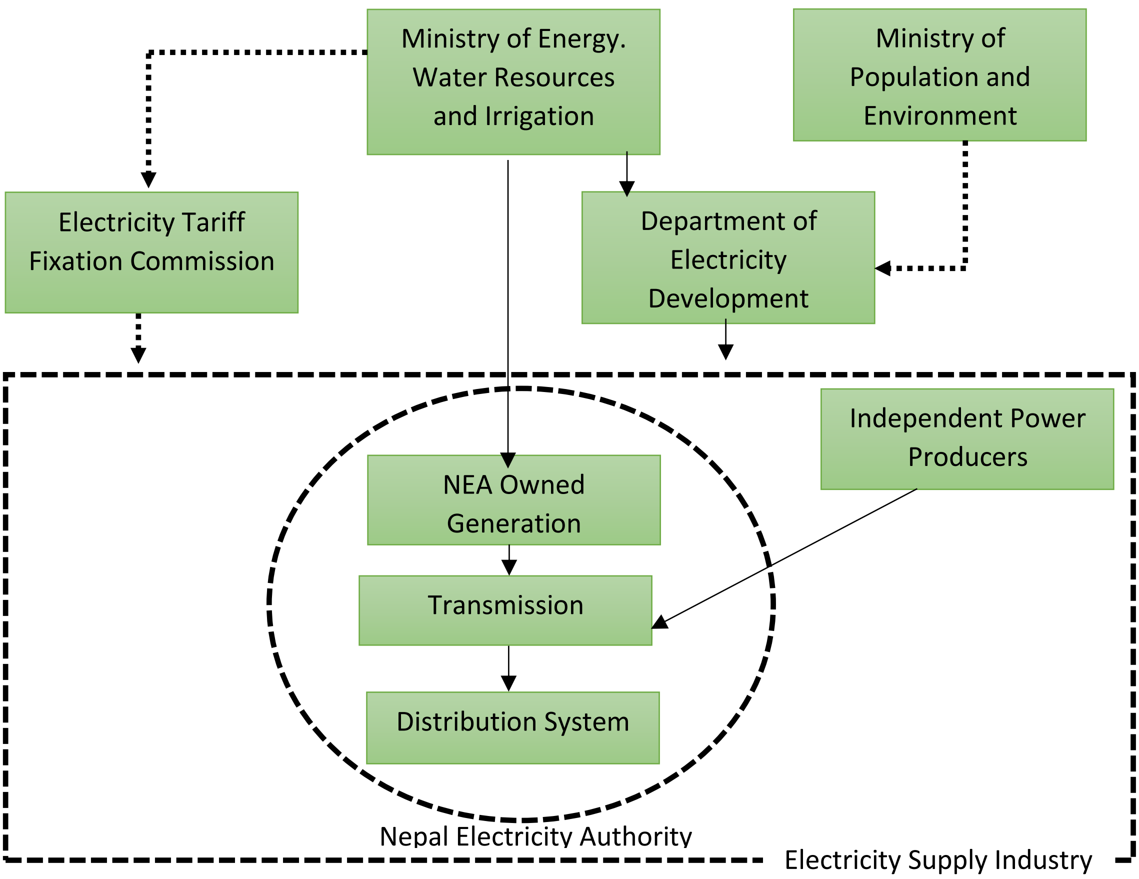


Figure 41: Institutional Framework of Nepal Power Sector

[31] Nepal Electricity Authority Annual Report, August 2017

3.6.2 Generation

Nepal has no known deposits of oil, gas, or coal except for some lignite deposits. Biomass, hydroelectricity and imported oil products and coal are its main sources of primary energy. The largest share of energy consumption goes to the residential sector. The share of industry and transport is now small, but the sectors are growing fast.

Table 22: Installed Capacity

Generation Source		Capacity (MW)
Hydro	NEA Grid Connected	504
	NEA Small Hydro	4
	IPP	512
	Subtotal	1,020
Thermal	NEA	54
Solar	NEA	0.1
Total Installed Capacity		**1,074**

Nepal is considered to be the second richest country in the world in terms of inland water resources and accounts for 2.27% of the water resources in the world. The perennial nature of Nepali rivers and the steep gradient of the country's topography provide ideal conditions for the development of some of the world's largest hydroelectric projects. The estimated hydro potential is over 80,000 MW of which 43,000 MW is considered economically viable. However actual installed hydropower capacity so far is only 1020 MW. Peak demand for electricity in FY 2016 was 1385 MW with 534 MW of load shedding. This resulted in daily load shedding of up to 11 hours during the dry months of January –April.

3.6.2.1 Energy Mix

Besides the 1020 MW of hydroelectric plants which are run-off the river (ROR) plants, NEA has 54 MW thermal capacity (mostly DG sets). Renewable energy so far is limited to 100 kW of solar. In 2015, Nepal and the World Bank signed an agreement to develop a 25 MW solar project that will be connected to the national grid and the work at the site in Devighat is in progress. Solar and Wind Energy Resource Assessment project has estimated wind potential at 3,000 MW. Techno-economically feasible capacity of peaking and storage type of hydropower plant (PROR) is not yet assessed exactly, though various studies present different pictures. Upper Arun (725 MW0 and Tamakoshi V (100 MW) PROR type projects are in the initial stages of development by NEA.

Presently the deficit in domestic generation is met by import of electricity from India. During FY 2018, while NEA (2,308 GWh) and IPPs (2,167 GWh) combined generation with in Nepal was 4,475 GWh, the imports from India was 2,582 GWh.

Currently, hydroelectric projects with a total capacity of 547 MW are under various stages of construction. NEA projects account for the major share (500 MW) of it. Planned and proposed projects would increase the capacity by 1,422 MW. But considering the past record of very slow development of new projects in Nepal, it looks that until 2025, Nepal will have to import power during dry months of January to April when the rivers go dry. Though, several initiatives are being taken to augment domestic generation capacity, current situation of load-shedding is likely to persist and may even get worse in the near future. Considering the estimated growth of energy demand, capacity will hardly meet peak demand even after completion of the ongoing projects.

Out of the 112 existing plants in Nepal having a cumulative installed capacity of 2,091 MW, only 4 are owned by NEA with a capacity of 244 MW and 11.7% of the total share while the rest are owned by IPPs.

3.6.2.2 Electricity Load Forecast

According to the NEA's load demand forecast, peak system demand will increase from 1,292 MW in FY2015 to 2,379 MW by FY2022. If all power plants are built as planned, there will be a supply margin of nearly 600 MW in FY2022.

According to estimations of the NEA, energy demand will grow in the next 17 years with an average annual rate of 8.34 %. The current demand of 4430 GWh annually is expected to exceed 17,400 GWh by 2027. Along with the growing demand it is projected that system peak load will increase with similar annual growth rates, reaching 3679 MW in 2027.[32]These estimations require an immense increase in the exploitation of the vast hydropower resources in Nepal. Of the 42,000 MW of economically feasible hydropower resources a miniscule has been tapped. Despite long term development plans targeting to reach 10,000 MW of installed capacity by 2020 (according to the 10-years hydropower development plan), current development of the sector draws a rather different picture.

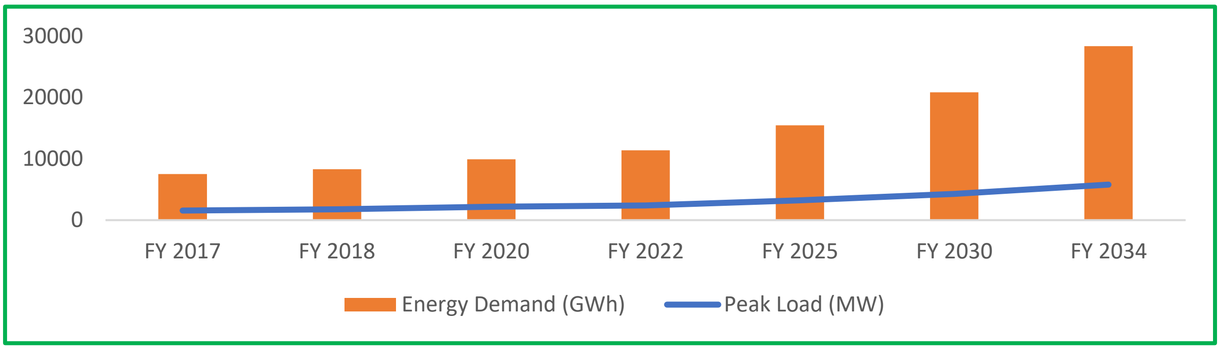


Figure 42: NEA Load Forecast till 2034

3.6.2.3 Demand - Supply Gap

In the last 5 years, the annual energy requirement of Integrated Nepal Power System (INPS) grew at 7.9% CAGR and in FY2017 stood at 5,560 GWh. On the other hand, energy supply grew at only 5.9% CAGR and in FY2017 energy supplied was 4,632 GWh. In addition to supply from domestic sources, NEA has existing 237 MW of available quantum of import from India through bilateral treaties or contracts. [33]

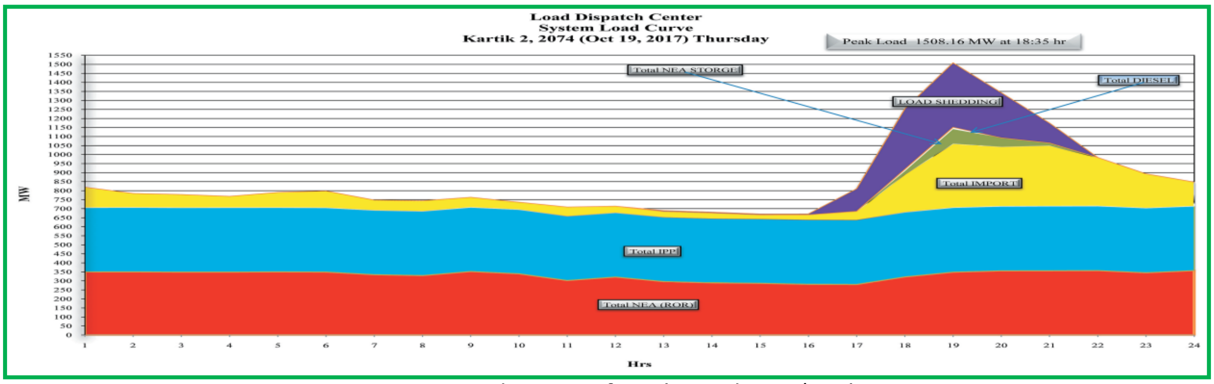


Figure 43: System Load Curve of Peak Load Day (19th Oct, 2017)

[32] Power Sector Overview Nepal, 2017
[33] Power Sector Overview Nepal, 2017

Coping with load-shedding is challenging in both the industrial and commercial sectors. Despite preferential treatment of the industrial sector (which is partly spared from load-shedding), manufacturing suffers hard from the power crisis.

3.6.3 Transmission and System Operation

The NEA is responsible for planning, developing and operating the transmission system in Nepal. NEA constructs transmission lines and substation facilities to evacuate power generated by NEA and IPP owned power plants, and undertakes transmission system reinforcements. The main load center in Nepal is in the central zone, which includes Kathmandu Valley. The main transmission system consists of 66 kilovolt (kV) and 132 kV transmission lines running from east (Anarmani) to west (Mahendranagar), parallel to the Indian border, and major substations are located in Hetauda, Syuchatar, and Balaju.[34]

Table 23: Transmission Lines Overview

Voltage	Transmission Line (Circuit km)		
	Existing	Under Construction	Planned & Proposed
66 kV	511		
132 kV	2,416	1427	1,400
220 kV		5782	950
400 kV		740	6,496

Table 24: Substations and Transformation Capacities

Substations	Existing (Nos./Capacity)	Under construction (Nos./Capacity)	Planned (Nos./Capacity)
66/11 kV	13 Nos 509 MVA		
132/66 kV	28 Nos 1622 MVA	10 Nos 506 MVA	21 Nos 917 MVA
220/132 kV			18 Nos 3,876 MVA
400/220 kV			5 Nos 2,025 MVA

To improve power trading with India, Nepal is building a major 400 kV cross-border transmission link. The hydropower sector relies on this expanded network to progress more rapidly. Transmission line losses in Nepal are relatively high. In FY2017, it amounted to 5.63% which should ideally be reduced to around 2-3%.

[34] Nepal Electricity Authority Annual Report 2017-18

Cross Border Transmission Infrastructure:

Nepal has cross border connections with India on 400 kV, 132 kV, 33 kV and 11 kV.

Voltage	Transmission Lines	Capacity	Remarks
400 kV	Muzaffarpur – Dhalkebar D/Ckt Quad Conductor line operated at 220kV	1000 MW (present transfer capacity is 150 MW)	Presently operated at 220 kV as 400kV substation in Nepal is not ready
132 KV	1. Duhabi-Kataiya 2. Gandak-Ram Nagar 3. Mahendra Nagar-Tanakpur 4. Kataiya – Kusaha (one circuit completed on D/Ckt towers) 5. Raxaul – Parwanipur	70 MW	
33 kV	Several interconnections between Boarder Towns operating on radial mode	50 MW	
11 kV	Several interconnections between Boarder Towns operating on radial mode		

Another 400 kV HVDC line is currently in planning stage. With the commissioning of these lines, the total cross border transmission capacity will increase to 2460 MW which will give an option to optimize power import from India by shifting the load from existing lines to the more efficient HVDC lines.

Transmission System Master Plan (TSMP) covering 2015 to 2035 that optimizes projected load flows within Nepal and between Nepal and India

- Prepared by Consultant EdF with WB grant in 2015
- Generation scenario in consultation with DOED and NEA Engineering/PTD
- Load Scenario – System Planning department
- Transmission line development divided into four tranches – 2015-2020, 2020-2025, 2025-2030, 2030-2035

3.6.4 Distribution

The NEA has a de facto monopoly on the distribution of electricity in Nepal, and manages the distribution services and networks. In FY 2017/18, total number of consumers under Distribution and Consumer Service Directorate (DCSD) reached 3.55 million, an increase of 9.17% over the previous year. Industrial and Commercial consumers constitute only 1.98% of the total number of consumers but shared 44.91% of total revenue [35].

[35] Nepal Electricity Authority Annual Report 2017-18

Table 25: Electricity Consumers

Consumer Category	Total Consumers (2017)	No. of Consumers (% of total)	Sales (%)	Revenue (%)
Domestic	30,62,995	93.83	43.5	40.29
Non-Commercial	19,257	0.59	3.11	4.78
Commercial	19,574	0.61	7.38	10.57
Industrial	46,343	1.37	37.53	37.25

Distribution Sector Developments

The distribution segment in Nepal power sector is undergoing significant development in the field of technical and non-technical loss reduction. Some important steps have already been initiated in these areas, such as digital metering, implementation of computerized billing system, removal of loss prone feeders, meter reading for high-value consumers by senior staff, etc. Following steps were taken to reduce the technical and non-technical losses.

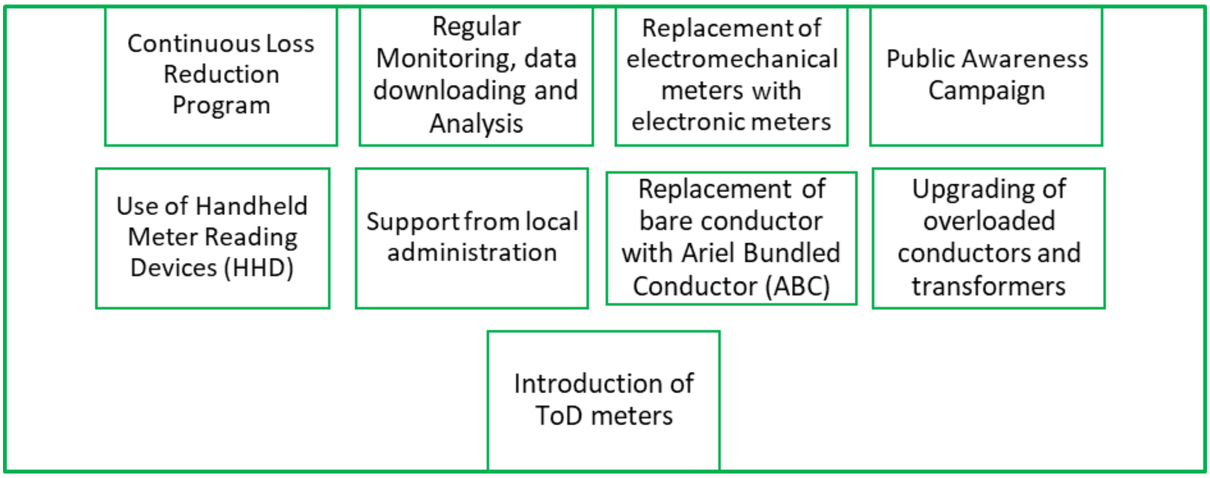


Figure 44: Loss Reduction Techniques

In addition, NEA has already started implementation of smart metering in Kathmandu. These continued efforts and measures taken to control losses brought fruitful results by bringing down the distribution system losses to 14.82% except certain hilly areas.

3.6.5 Renewable Energy

According to the estimation made by Solar and Wind Energy Resource Assessment (SWERA), Nepal has a potential of 3000 MW of Wind, 1830 MW from Solar PV and an additional 2100 MW from grid connected PV. [36] The Ministry of Environment, Science and Technology and the Alternative Energy Promotion Centre (AEPC) under this ministry are the main entities for the promotion and development of renewable energy technologies. The centre provides the financial and technical support to local

[36] Nepal Power Investment Summit 2018

organizations for promoting and developing decentralized rural energy through technology transfer and research and development activities. Presently, AEPC is implementing different programs and projects to promote the renewable energy systems in the country like mini and micro hydropower, improved water mill, solar photovoltaic and solar thermal, biogas, biomass and bio-fuels and wind energy.

As of 2018, around 15 MW of electricity generation came from Micro Hydro schemes, 32 MW from Solar photovoltaic (PV) systems, and less than 20 kilowatts (kW) from Wind energy. Nepal should transform its energy supply system into a more sustainable system using clean and renewable energy resources, given the high costs of grid connection, the low consumption rate, and the scattered population, especially in remote areas. Decentralized renewable energy supply systems, such as Micro Hydro, Solar PV and Biogas can provide feasible and environment-friendly supply options.[37]. Key policies and initiatives for RE development are listed below.

Rural Energy Policy, 2006

- Reduce dependency on traditional energy and conserve environment by increasing access to clean and cost effective energy in rural areas
- Increase employment and productivity through the development of rural areas

Nepal Subsidy Policy for Renewable Energy, 2018

- Accelerate renewable energy service delivery with better quality compromising of various technologies to households and communities
- Benefit men and women from all social groups, leading to more equitable economic growth

National Rural and Renewable Energy Programme, 2012-17

- Central Renewable Energy Fund
- Business Development for Renewable Energy and Productive energy use

3.6.6 Policy and Regulatory Environment

The important policies for development of power sector are: Hydropower Policy 2001, Electricity Act 1992 and Electricity Tariff Fixation Rule 1993. Other acts and regulations governing the sector are Electricity Theft Control Act 2002 and Foreign Investment and One Window Policy 1992.

3.6.7 Key Drivers for Smart Grids in SAARC Member States

The important drivers for smart grid in Nepal are described in this section.

[37] Energy Scenarios: Harnessing Renewable Energy for Sustainable Development and Energy Security in Nepal

3.6.7.1 Energy Access

Per capita consumption of electricity in Nepal stands at 161 kWh (2013) which is one of the lowest among South Asian countries. About 30% of the population lack access to electricity and majority of the unserved population are in the rural areas. Extension of grid to remote locations are technically and financially unviable. These remote communities could be electrified trough microgrids with solar and wind power as well as battery storage. The customers connected to the grid experience several hours of outages, particularly during the winter months. The load-shedding can be avoided by demand response and other smart grid solutions.

3.6.7.2 Renewable Energy Integration

Although present capacity of RE in Nepal is miniscule, the Government plan to develop RE sector aggressively. Integration of RE resources on the grid which is already weak would require better visibility and control as well as flexibility. Large scale wind and solar farms should be planned with systems for flexibility and remote monitoring and control.

3.6.7.3 Quality of Supply

Power quality suffers badly owing to supply-demand imbalances and frequent tripping of feeders. The situation can be managed better with demand side management through smart grid technology interventions.

3.6.7.4 Transmission and Distribution Loss Reduction

Network losses at both transmission and distribution losses are very high in Nepal. Transmission losses which is about 5.67% can be brought down below 3% by modernization of substations and transmission lines. The losses at distribution level consists of technical losses as well as non-technical losses including theft. Increased visibility of power flows through smart grid solutions could facilitate to identify segments of the distribution grid where losses are high. Once locations of losses can be identified the reasons and mitigation measures becomes easier.

3.6.7.5 Electric Mobility

Transportation sector in Nepal is dependent on the imported petroleum products which is expensive and prone to frequent price fluctuations in the international oil market. The Government has taken initiatives for introduction of electric vehicles. As per electric vehicle association of Nepal (EVAN), there e are around 300 electric cars and 2000 electric scooters in use at present.[38] Since Nepal has abundant hydropower potential, it would be environmentally and financially beneficial for them to transition the transport sector from imported oil to clean hydropower. For vehicle grid integration smart grid technologies are required.

In 2017, the Global Green Growth Institute (GGGI) supported the Government of Nepal to develop a National Action Plan for Electric Mobility.

[38] https://thehimalayantimes.com/business/nepal-electricity-authority-promote-electric-vehicles/

3.6.8 Smart Grid Scenario

As briefed above, Nepal power system is facing acute shortage of power during winter months and peak hour shortage almost throughout the year. Besides poor quality of supply and high network losses badly affects the financial health of the sector. Many of the challenges can be aggressed to a great extent by smart grid technologies.

Nepal Electricity Authority (NEA) has started implementing Smart Electricity meters in Kathmandu. The implementation comes into effect as a part of a project called Kathmandu Valley Smart metering project (KVSM). AMI incorporates the smart meters along with the Information and Communication Infrastructure. First phase of the project covers around 100,000 smart electricity meters. NEA will also deploy prepaid billing where the system reduces the available credit based on consumption.

Another important project is the distribution improvement project funded by the Asian Development Bank (ADB). ADB has approved a $150 million loan to help improve the reliability and efficiency of Nepal’s electricity supply and distribution system. The project will enhance the distribution capacity and improve reliability and quality of electricity supply in the Kathmandu Valley by reducing distribution system overloads and technical and commercial losses.

3.6.8.1 Smart Grid Roadmap for Nepal

The smart grid roadmap recommended for NEA is described in this section. The key assumptions behind the proposed roadmap are:

a. New Policies and regulations will be recommended by 2020 for expansion and integration of renewable energy sources to grid by 2030
b. Growth of Renewable Energy (RE) resources including rooftop PV will accelerate in the coming years owing to policy mandates as well as cost reduction of PV systems making them economically attractive for larger sections of customers
c. New initiatives/projects and policies will be initiated for AMI, GIS, SCADA/DMS, integrated billing system etc to improve operational efficiency and asset utilization

The Smart Grid Roadmap recommended is in 3 stages:

a. Immediate term (2018-2020): Proposed some immediate action items that can add clear strategy and plan for power system development and grid modernization in Nepal in alignment with long term goals set by the Government

b. Near Term (2020-2025): Proposed a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction

c. Medium Term (2025-2030): Proposed several measures that would transform NEA to a modern utility using planning tools and advanced automation and IT systems and analytics to optimize the assets and operations

The above steps are described in detail in the following sections:

3.6.8.1.1 Nepal Smart Grid Roadmap 2018 – 2020

Nepal Smart Grid Roadmap 2020 defines the progressive trajectory of developments from present state (in 2018) to 2020 in following areas: Strategy Management and Regulation (SMR), Organization Structure (OS), Grid operations (GO), Work and Asset Management (WAM).

1. Strategy, Management, and Regulatory (SMR)

Present Maturity Level (In 2018): 0; Target Maturity Level in 2020: 1

Although NEA's vision, policies and initial projects are already visible, they require a Smart Grid Vison and Roadmap approved by their Board. NEA should undertake following steps to achieve Maturity Level-1 on Strategy, Management and Regulatory domain by 2020:

- Define smart grid vision, strategy and policy in consultation with the Ministry
- Arrange training to key personnel to have common understanding about smart grid vision and technologies
- Initiate discussions with regulators on NEA's Smart Grid Roadmap
- Make departmental structure for smart grid implementation (DMS/SCADA, Substation Automation, AMI) and their role and responsibilities
- Identify potential are a for Smart Grid Pilot Projects such as substation automation and AMI
- Define area load dispatch center, regional load dispatch centre, central load dispatch centre and SCADA hierarchy from across the country
- Identify area for renewable energy development and integration with grid

2. Organization and Structure (OS)

Present Maturity Level (In 2018): 0; Target Maturity Level (In 2020): 1

NEA should target to achieve Maturity Level 1 by 2020 by undertaking following steps:

- Organization should articulate (communicate) needs to build smart grid competencies in its workforce
- Organization structure and workforce need to align as per Smart Grid Vision and Roadmap
- Leadership should demonstrate commitment to change the organization in support of achieving smart grid by assigning resources and budgets
- Conduct workshops/ awareness sessions of Smart Grid technology and needs across multiple functions/line of business to support smart grid activities

3. Grid Operations (GO)

Present Maturity Level (In 2018): 0; Target Maturity Level in 2020: 1

Many projects are in progress by NEA for strengthening of electrical network across country. In the realm of Grid Operations, NEA must undertake following steps to reach Maturity Level 1 by 2020:

- Prepare a Smart Grid Roadmap for (10~15 years) and get it approved by the Board of NEA
- Define Smart Grid as an important item in business plan, budget and annual revenue requirement (ARR) plan and define future work plan for the same
- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g. AMI with remote connect/disconnect, SCADA/DMS, GIS etc.) may be undertaken
- Strengthening of the transmission grid and installation of Wide Area Monitoring Systems to improve reliability of the EHV network
- Building new substations and medium voltage (MV) and low voltage (LV) lines to meet projected demand growth
- Replacement of existing DTs by new higher capacity DTs wherever required according to load growth

- Define strategy and plan for proof of concept projects and/or component testing for grid monitoring and control underway related to smart grid technologies
- Establish framework to calculate outages and reliability indices at distribution level
- Implementation of peak load management through demand response (DR) at distribution level
- Installation of transformer monitoring units (TMU) on all power transformers and distribution transformers feeding to key customers and critical assets
- Make plan to implement SCADA/DMS, substation automation and outage management systems in phased manner in Kathmandu and other urban areas
- Make strategy and plan to implement pilot projects of AMI at select locations
- Implementation of Cyber security measures such as:
  - Identity and access management system
  - Implement relevant recommendation of statutory authorities in the country (if any)
  - Compliance with IEC or country specific cyber security standards

4. Work and Asset Management

Present Maturity Level (In 2018): 0; Target Maturity Level in 2020: 1

NEA should undertake following measures to achieve Maturity Level-1 by 2020 in Work and Asset Management domain:

- Define business case for GIS and asset mapping at transmission and distribution levels and get approval for the same
- Perform consumer indexing at distribution level and map it to GIS
- Institute work flow for continuous updating of assets and customers on the GIS map
- Implementation of ERP system
- Establish communication system architecture to meet near and long-term communication needs
- Upgrade the communication system architecture to meet near and long-term communication needs
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

3.6.8.1.2 Nepal Smart Grid Roadmap 2020 – 2025

The Nepal Smart Grid Roadmap 2025 defines the progressive trajectory of developments from the state in 2020 to 2025 in 7 domains as recommended below:

1. Strategy, Management, and Regulatory (SMR)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025):2

For achieving maturity level-2 by 2025, NEA need to undertake following measures:

- Approval and acceptance of smart grid roadmap from higher management and ministry across all multiple functions and line of business of NEA. Include the same in the business plan of NEA
- Approval of smart grid projects/investments as per approved Smart Grid Roadmap
- Establish smart grid governance model and define its hierarchy by keeping in line with the Smart Grid Roadmap

- Designate and make hierarchy of smart grid leaders in all key line of business (LOB's) with authority / responsibilities to implement measures envisaged as per approved Smart Grid Roadmap
- Update policies / regulations if needed to implement measures envisaged in the approved Smart Grid Roadmap
- Support from funding agencies for smart grid projects and make plan / strategy to implement smart grid projects in coming year e.g. SCADA/DMS, AMI, OMS etc; identify potential areas where projects can be implemented

2. Organization and Structure (OS)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

For achieving Maturity Level-2 by 2025 on Organization and Structure domain, NEA needs to undertake following steps:

- Approval of a Manpower Plan (including Training Plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on the Smart Grid Roadmap, restructure the organization hierarchy and its business process which can align end to end processes for smart grid operations
- Create cross functional teams among all LOBs for implementation of smart grid initiatives as per Smart Grid Roadmap
- Plan workshops and training programs to key personnel to develop smart grid competencies
- Plan for linking of compensation and incentive programs with achievement of smart grid milestones

3. Grid Operations (GO)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

NEA should undertake following steps to achieve Maturity Level 2 on Grid Operations by 2025:

- Create a new generation and transmission network, substations, medium voltage and low voltage lines; and upgrade capacity of existing network to meet the demand growth most efficiently
- Replacement of existing / old DT's with new higher capacity DT's where ever required
- Installation of Distribution automation systems in major towns
- Replacement of existing / old Distribution Transformers (DTs) with new higher capacity DTs where ever required
- Replacement of old cable / undersize conductors and replace old wire joints on overhead LV lines with proper crimped joints
- Upgrade the existing SCADA/EMS in the transmission system and extend the WAMS to cover entire EHV network
- Establish outage management system (OMS) for efficient outage restoration in urban areas
- Undertake pilot trials on smart microgrids for campuses, industrial parks etc
- Upgrade communication network to support automation and IT systems
- Rollout of EV charging infrastructure in urban areas and highways
- Implement AMI in all urban areas

- Undertake pilot trails in energy storage for grid balancing on feeders with higher penetration of renewable energy

4. Work and Asset Management

Maturity Level (In 2020): 1, Target Maturity Level in 2025: 2

For achieving Maturity Level 2 by 2025, NEA need to undertake following steps:

- Systems for tracking inventory and event history of assets on GIS maps
- Implementation of enterprise resource planning (ERP) system and its integration with GIS and other IT and automation systems
- Develop and implement a communication systems architecture to meet near term and long-term communications needs by adopting a multi-tier, multi-service telecommunication infrastructure architecture consisting of a core network and an edge network
- Development of network model for the distribution grid up to DT level so that modelling studies can be undertaken for assessing various scenarios of network upgrades to balance demand and supply most optimally
- Plan for hotline maintenance – bare hand methods using trucks with insulated baskets and other hotline tools
- Prepare plan for mobile workforce management (MWFM) systems in urban areas
- Systems in place for load forecast every year and system upgrade plans to be reviewed and amended appropriately based on actual and expected load growth in each sub-division

5. Technology

Present Level (In 2020): 0; Target Maturity Level in 2025: 1

For achieving Maturity Level 2 by 2025, NEA needs to take following measures:

- Enterprise IT Architecture: NEA must develop an enterprise IT architecture and start its implementation. Need to retire several IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated even through a middleware must be replaced with COTS applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT architecture should enable integration of new assets and applications acquired by different LOBs
- Conduct pilot trials on wide area monitoring and distributed sensor network
- All IT applications should adopt change control process e.g. configuration management, patch management, remote updating of applications and integration capability for future integrations
- Implement one integrated billing system covering all type of customers
- Conduct audit for cyber security and adopt the recommendations of statutory agencies in Nepal to secure systems from cyber attacks
- Prepare cloud strategy for future expansion

6. Customer

Present Level (In 2020): 0; Target Maturity Level (in 2025): 1

For achieving Maturity Level 1 on Customer domain by 2025, NEA needs to undertake following steps:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved Smart Grid Roadmap. These studies will identify customer benefits and satisfaction. Utility may conduct these studies with input from different categories of customers in urban and rural areas
- Conduct workshops to educate customer about smart grid vision and roadmap of NEA
- Conduct study or research on security and data privacy implication of new technologies and business process / functions to be adopted which can enable customer participation to leverage smart grid functionalities
- Consult with regulators and / or other government related organizations regarding impact of technologies on different categories of customers

7. Societal and Environmental

Present Level (In 2020): 0; Target Maturity Level in 2025: 1

It is recommended to undertake following measures to achieve Maturity Level 1 by 2025:

- Publish the smart grid roadmap with emphasis on:
    - NEA's role in environmental and societal aspects with respect to Smart Grid Vision and Roadmap
    - NEA should publicly promote the environmental benefits of using smart grid technologies
    - NEA's role in protecting the nation's critical infrastructure
- Approved environmental compliance records may be available for public inspection

3.6.8.1.3 Nepal Smart Grid Roadmap 2025 – 2030

Nepal Smart Grid Roadmap 2025-2030 defines the progressive trajectory of developments from present state (in 2018) to 2030 as expanded below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2025, NEA needs to undertake following measures:

- Establish Smart Grid Governance Model for smart grid development and decision making. Define roles, process and tools for the same
- Designate a single smart grid leader in all key line of businesses with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap
- Adopt smart grid vision, strategy and business case in organization vision and strategy
- Approval for smart grid investments for key initiatives envisaged in the approved Smart Grid Roadmap

2. Organization and Structure (OS)

Maturity Level (In 2025): 2, Target Maturity Level in 2030: 3

For achieving maturity level 3 by 2030, Nepal need to take following measures:

- Redesign organization structure to support smart grid initiatives e.g. matrix organization structure or similar and also execute this structure in view of the new programs and projects for 2040

- Commitment and consistency of leadership in communication and actions related to smart grid programs and projects
- Performance awards and compensations are linked to success of smart grid programs and projects
- Conduct educational training programs which are aligned to build smart grid capabilities in organization
- All changes in organization structure, appointments / transfer / changes being made in consideration and support with smart grid program and projects
- Knowledge management framework to be put in place to capture the learnings from technology trails and new projects planned as per smart grid roadmap. This knowledge must be institutionalized

3. Grid Operations (GO)

Maturity Level (In 2025): 2, Target Maturity Level in 2030: 3

For achieving Maturity Level 3 by 2030, NEA needs to undertake following measures:

- Building new generating plants, transmission lines, substation and medium voltage (MV), low voltage (LV) lines; upgrade the capacity of existing generation, transmission and distribution systems to meet demand growth most optimally
- Plan and execute bifurcation and trifurcation of long distribution lines and expand distribution network to rural and urban areas ensuring to meet targets of electrification rate and increase in peak demand
- Increase transformation capacity at DT level to meet estimated demand in 2030
- Replacement of exiting DTs with higher capacity DTs where ever required
- Addition of new capacitor banks to regulate power quality where ever required
- Peak load management through demand response (DR) at customer premises
- HT: LT ratio is brought to 1:2 in urban area and 1:4 in rural area
- Replace undersize / old conductors and old wire joints on overhead LV lines with proper crimped joints
- Implementation of SCADA /DMS, distribution automation (DAS) and AMI across country on selected locations as per NEA goals
- Implement outage management system (OMS) and its integration with SCADA /DMS, DAS and GIS in urban areas
- All new grid equipment being installed with remote monitoring capabilities
- Deployment of advanced analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all lines of business (LOBs), dashboard with relevant information are made available in each LOBs
- Grid operation data is being leveraged for grid planning using advanced analytical and planning tools
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real time load and voltage data on selected urban and rural feeders
- Establishment of dedicated Smart Meter Operation Centre (SMOC) that will monitor and control smart meter operations and provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operation
- System for condition-based maintenance of circuit breakers and power transformers

- Extension of voltage and reactive power (Volt-VAR) optimization (VVO) systems to entire service area
- Automated operation of capacitor bank (if not part of VVO solution)
- Advanced ground fault detection by installing protective relays (or IEDs) to detect high impedance (very low fault current) faults for faster isolation of downed conductors/ section promoting enhanced safety and improved service reliability
- Implementation of state of art Security Operation Centre (SOC) to safeguard the system from cyber and physical attacks

4. Work and Asset Management

Maturity Level (In 2025): 2, Target Maturity Level in 2030: 3

For achieving Maturity Level 3 by 2030, NEA needs to undertake following measures:

- Asset performance trend analysis and event audit reports are available for all major assets and systems
- Integrated view of all major/ key assets on GIS system with remote monitoring facility and their further integration with ERP system, outage management system and mobile workforce management system (MWFM) covering all major urban areas
- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals
- Network model of transmission and distribution grids up to DT level is regularly updated and modelling studies undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Analytical tools for predictive maintenance are deployed on trial basis
- AMI integration with OMS – restoration / disconnection messages from smart meters are integrated with OMS for faster restoration and improved customer satisfaction
- AMI- GIS integration to enhance the visualization of network to provide safety, reliability and operational benefits

5. Technology

Maturity Level (In 2025): 1, Target Maturity Level (in 2030): 2

For achieving Maturity Level 2 on Technology domain by 2030, NEA needs to undertake following measures:

- Alignment of line of business with enterprise IT Architecture across entire organization. If required modify business process to align it with IT Architecture and systems
- Framework in process for change control of all IT applications and infrastructure
- Organization uses an informal common technology evaluation and selection process for smart grid activities including selection of vendors and external services
- Smart grid technologies implemented are leveraged in such a fashion that it improves the cross-LOB performance
- Data collection from smart sensors network installed on distribution lines are leveraged by other applications for grid operation and customer service functions
- Cloud services are in place and all new applications are hosted on secured public cloud; existing applications are migrated to the cloud as the old hardware becomes redundant
- Cyber security systems in place

6. Customer

Maturity Level (In 2025): 1, Target Maturity Level in 2030: 2

For achieving Maturity Level 2 by 2030, NEA needs to undertake following measures:

- Carry out research studies on enhancing customer experience and benefits through smart grid technologies envisaged in the approved Smart Grid Roadmap. These studies may be conducted for different categories of customers in both urban and rural areas
- Studies are conducted on the implications of data privacy and protection of customers
- Assess the impact of new smart grid systems and services on different categories of customers
- Measures for security and privacy requirements of customers are built in the specifications for new systems being procured
- Implementation of a state-of-the-art customer portal
- Prosumer enablement and net-metering plans available to all customers
- Leveraging social media for customer engagement effectively

7. Societal and Environmental

Maturity Level (In 2025): 1, Target Maturity Level (in 2030): 2

NEA should undertake following steps to reach Maturity Level 2 by 2030:

- Finalize work plans for addressing the social and environmental issues through smarter technologies
- Provide details of granular level energy consumption data to customers – from AMI system through customer portal
- Societal and environmental benefits are estimated in the detailed project report for each project
- Diesel Generator replacement with batteries (that can be leveraged for load balancing) at customer premises is actively promoted through innovative business models
- Clean energy being moved to the core of NEA's business model

8. Value Chain Management (VCM)

Present Level (In 2025): 0; Target Maturity Level in 2030: 1

NEA should undertake following steps to reach Maturity Level 1 by 2030:

- Formulation of a strategy for creating and managing a diverse resource portfolio
- Identification of:
    - Assets and programs for load management
    - Distributed generation resources, its locations and capabilities
- Evaluate and identify the security requirement to enable interaction with expanded portfolio of value chain partners

The above maturity levels can be achieved in a phased manner as indicated in the chart below:

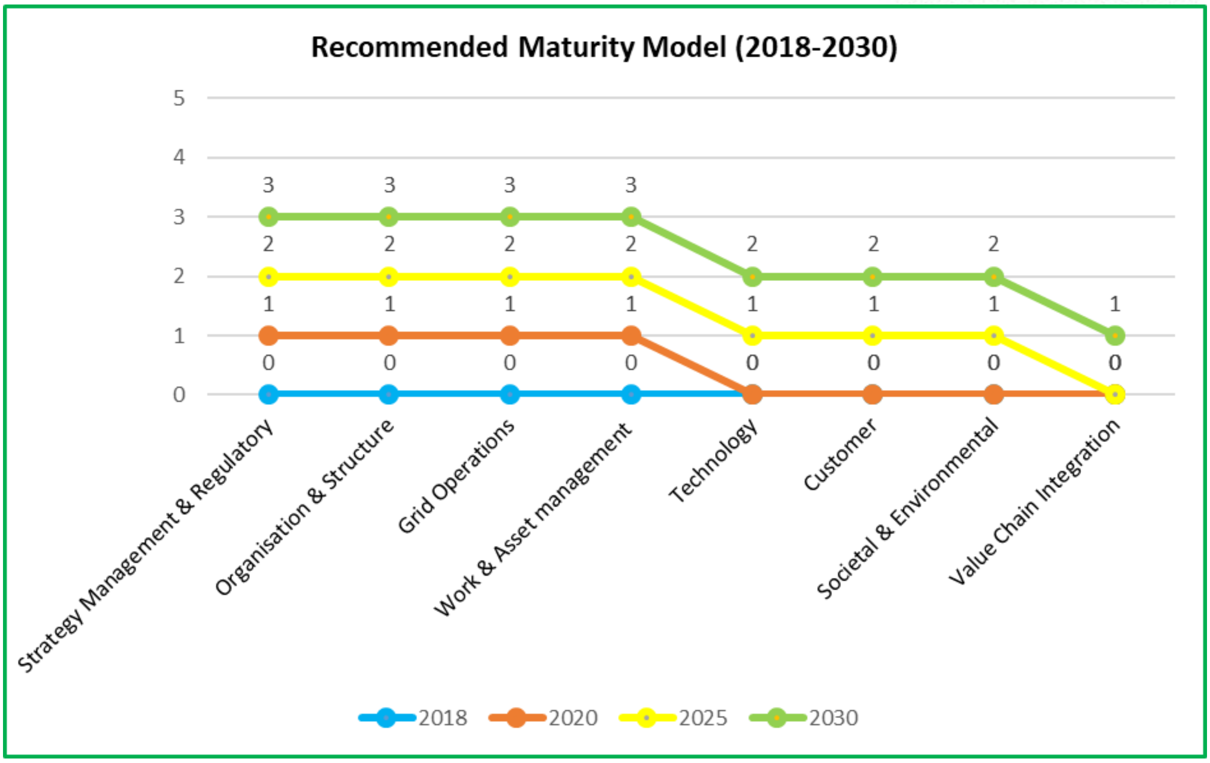


Figure 45: Recommended Smart Grid Maturity Levels (2018-2030)

3.6.9 Cost Benefit Analysis

3.6.9.1 Background

Nepal is among the countries that are most vulnerable to climate change. Its power sector is interwoven with overlap between the roles of various institutions which are impeding the development of the sector. Inadequate investments have led to a very slow pace of hydropower development, resulting in a widening demand-supply gap, low customer satisfaction and low energy access. Peak demand in Nepal in FY2016 was 1,385 MW, with 534 MW of load shedding, resulting in daily load shedding of up to 11 hours during the dry months of January –April. Of the 42 GW of feasible hydropower, only a small share of 1.7 % is tapped.

3.6.9.2 Project Objective and Description

Evaluate diesel fuel displacement and power shortfall with DSM and Distributed Clean Power during Jan-Apr shortfall months. 10 MW distributed Supply-demand management consisting of:

1. 10 x 5KW Zero-Head Run-of-River/Canal Mini hydel generators (USD $2700/KW each)
2. 10 x 250 KW Clean bio gasifier generators with electrical/thermal/biochar outputs (USD 3,000/KW each)
3. 1,000 units of PF correction equipment - target 0.9pf at 2-10 KW load points and lower demand by 5MW or 15% (USD 150 each)
4. 1,000 units of autonomous load controller - target 2-10 KW load points and lower demand by 2.5MW or 7% (USD 300 each)
5. 10 units 250KW x 4 hr containerized Flow Battery for seasonal energy shifting (USD 400/KWh)

Financial Data:

- Required rate of return (Govt. / IFI rates) - 8%

Parameter	Cost
Equipment	$12,085,000.00
Engineering and Development	$150,000.00
Installation & Commissioning	$150,000.00
Total Initial Investments	**$12,385,000.00**

Benefits	YEAR	1	2	3
Diesel Fuel import Saved {5000 KW x 2500 hrs. x 0.28 L/KW x USD 1.75/L}		$6,125,000.00	$6,125,000.00	$6,125,000.00
Carbon Emissions Avoidance {(2.7kg/L x (5000 KW) x 0.28 L/KW x 1/3 x USD 25/ton)		$236,250.00	$236,250.00	$236,250.00
Tourism promotion (long-term reduced pollution) estimate		$50,000.00	$50,000.00	$50,000.00
DG maintenance savings (USD 1.00/hour/50 KW x (5000 KW) x 2500 hours)		$250,000.00	$250,000.00	$250,000.00
Total Benefits		**$6,661,250.00**	**$6,661,250.00**	**$6,661,250.00**

Costs (Excluding Initial Capital Investments)	YEAR	1	2	3
Operations		$50,000.00	$50,000.00	$50,000.00
Maintenance		$40,000.00	$40,000.00	$40,000.00
Project management, customer support		$35,000.00	$35,000.00	$35,000.00
Misc.		$30,000.00	$30,000.00	$30,000.00
Depreciation on capital expenditures (calculation uses 5-year period)		$2,477,000.00	$2,477,000.00	$2,477,000.00
Total Costs		**$2,632,000.00**	**$2,632,000.00**	**$2,632,000.00**

Totals	YEAR	1	2	3
Net Benefits (Costs)		$4,029,250.00	$4,029,250.00	$4,029,250.00
Tax		$1,007,312.50	$1,007,312.50	$1,007,312.50
Value after tax		$3,021,937.50	$3,021,937.50	$3,021,937.50
Depreciation added back		$2,477,000.00	$2,477,000.00	$2,477,000.00
Cash flow	-$12,385,000.00	$5,498,937.50	$5,498,937.50	$5,498,937.50
Cumulative cash flow	-$12,385,000.00	($6,886,062.50)	($1,387,125.00)	$4,111,812.50

Evaluation Metrics		Cautionary Note
Net present value (NPV)	$1,786,295.26	All costs are budgetary for discussions purposes only.
Internal rate of return (IRR)	15.83%	A detailed project report (DPR) needs to be done.
Payback period (in years)	2.25	

3.6.9.3 Relevance of CBA Analysis to SG transition

Nepal has a widening supply-demand gap with low energy access. The country faces daily load shedding of up to 11 hours between January and April when rivers are dry. Adding fossil generation with imported fuel leads to the climate change vulnerability even more as well as financial burden on the country. So is the cost of upgrading its wires infrastructure. A combined solution of localized distributed generation together with DSM is likely the low-cost answer. The current project is worth exploring.

Benefits

The CBA results look promising with a positive NPV and short payback and is worth implementing. A detailed project report (DPR) with formal quotes will be required.

The following are the key benefits:

1. Imported diesel fuel savings in the order of USD $ 6.12 million per annum is extremely beneficial for the economy
2. GHG avoidance estimates amounts to USD $ 236,000 per annum
3. If successful, similar projects can be implemented in other urban clusters
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Local O&M services will also get a boost in operating and maintaining distributed devices
6. All these are low power equipment and hence can be managed even in rural and semi-urban areas

3.6.9.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions (temperature, altitude, humidity, etc.)
2. Some special training/skills may be required for installation, calibration and commissioning of such equipment
3. CDM and DER equipment installations require a coordinated planning for combined effects
4. It is important that the systems and architecture designs of this pilot project be supervised by global experts
5. Training of O&M personnel in new technology equipment (micro-hydel, bio gasifiers)

3.7 Pakistan

3.7.1 Country Overview

Pakistan is bordering the Arabian Sea, between India on the east, Iran and Afghanistan on the west. It is the fifth most populous country on earth with a population exceeding 204 million. Pakistan covers a total area of 0.804 million square kms[39]. Economic growth has flourished in recent years, with Pakistan registering a GDP of USD 1,641 with a 5.79% growth rate for the year 2017-18. Electric power consumption in Pakistan was recorded at 471 kWh/person/year in 2014 which was even lower than the average for SAARC countries.

Population	Electric Power Consumption (kWh per capita)	Economic growth
• Population of 204.92 million spread over a region of 0.804 million square km	• Percapita electric power consumption (kWh per person) in Pakistan was 471 in 2014	• Pakistan economy registered a GDP of USD 1,641 with a 5.79% growth rate in 2017

Figure 46: Socio Economic Overview

3.7.1.1 Power Sector Overview

Pakistan power sector has a mix of thermal, hydro, nuclear and renewable generation and a large network of transmission and distribution infrastructure supplying power to over two hundred million people. Pakistan's installed capacity[40] as of 30th June, 2017 stood at 28,399 MW with thermal generation contributing 65.76% of the total capacity followed by 25.06% from hydro, 4.02% from nuclear and 5.16% from renewable resources.

Table 26: Installed Capacity

S.No	Type of Generation	Installed Capacity (MW) (As on June 2017)
1	Thermal	18,676
2	Hydro	7,116
3	Nuclear	1,142
4	Renewable Energy	1,465
Grand Total		**28,399**

3.7.1.2 Power Sector Structure

Pakistan's power sector was dominated by two vertically integrated entities – Water and Power Development Authority (WAPDA) and the K-Electric. These two entities are involved in power Generation, Transmission, Distribution and retail supply for entire Pakistan. In December 1998, the WAPDA Act was amended to permit the establishment of Pakistan Electric Power Company (PEPCO) and to unbundle WAPDA. The power wing of WAPDA comprising generation, transmission and distribution was restructured into 14 public limited companies. Multiple Independent Power

[39] Country watch report 2018

[40] NEPRA State of industry report 2017

Producers (IPPs) sell power to the distribution entities. An independent regulatory commission was setup which is the National Electric Power Regulatory Authority (NEPRA) in 1997.

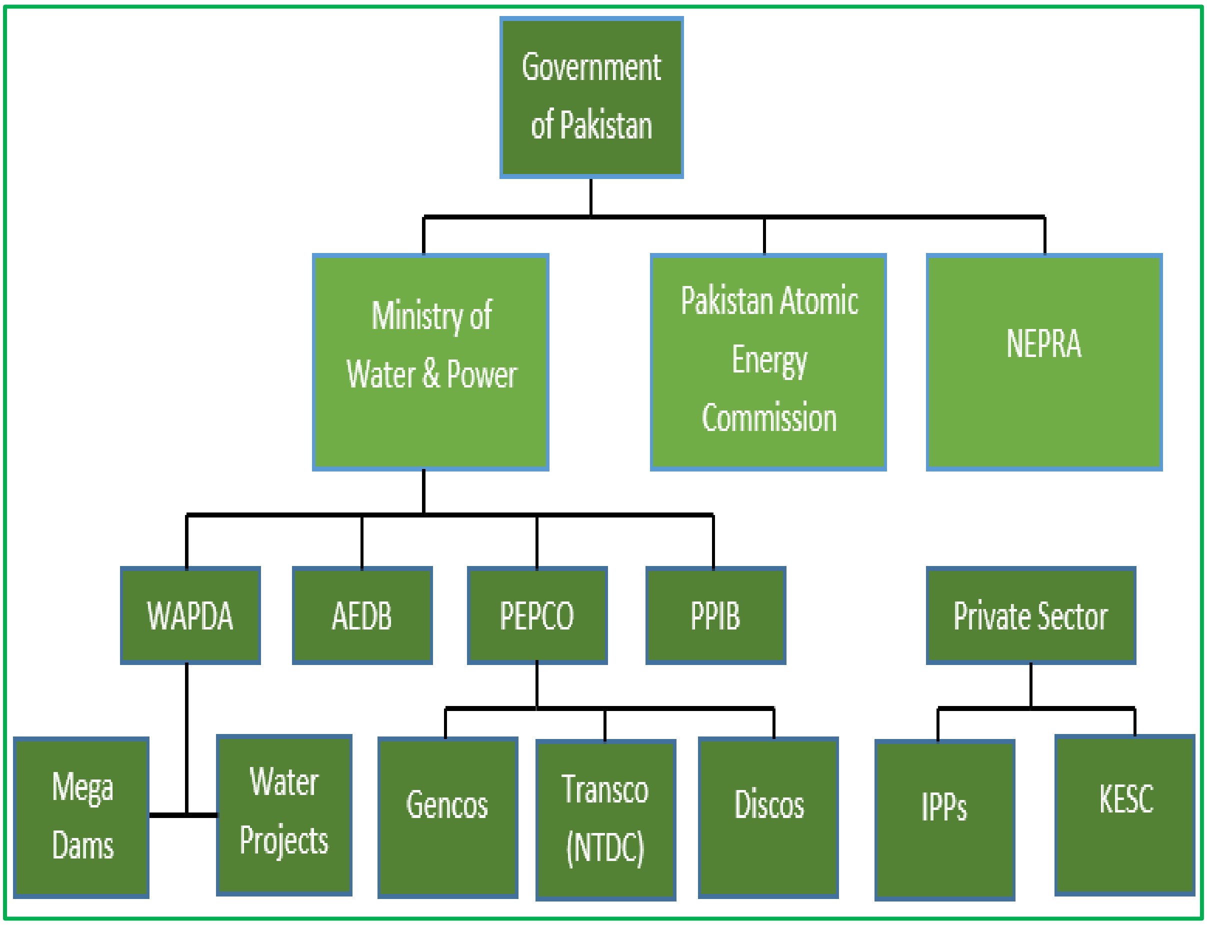


Figure 47: Power Sector Structure in Pakistan

Table 27: Brief Description of Distribution Companies

S. No	Number of Distribution Companies	Areas of operation	Total Area (sq-km) (30 June 2017)	No. of Customers (30 June 2017)	Peak Load (MW) (30 June 2017)
1	Peshawar Electric Supply Company Limited (PEPCO)	Whole Province of Khyber Pakhtunkhwa, except tribal areas	77,474	31,84,576	3,110
2	Tribal Areas Electricity Supply Company Limited (TESCO)	Federally Administrated Tribal Areas (FATA) (comprising of Bajur, Mohmand, Khyber, Ourakzai, Kurrum, North Waziristan, South Waziristan agencies) and Frontier Regions (FRs) (i.e. FR Peshawar, FR Kohat,	27,220	4,41,941	609

		FR Bannu, FR Lakki, FR Tank and FR Dera Ismail Khan			
3	Islamabad Electric Supply Company Limited (IESCO)	Federal Capital Islamabad, Rawalpindi, Attock, Jhelum, Chakwal	23,160	26,72,682	2,314
4	Gujranwala Electric Power Company Limited (GEPCO)	Gujranwala, Sialkot, Mandi Bahauddin, Hafizabad, Narowal, Gujrat	17,207	31,72,969	2,413
5	Lahore Electric Supply Company Limited (LESCO)	Lahore, Sheikhupura, Kasur, Okara, Nankana	19,064	42,77,961	4,765
6	Faisalabad Electric Supply Company Limited (FESCO)	Faisalabad, Sargodha, Khushab, Jhang, Toba Tek Singh, Bhalwal, Mianwali, Bhakkar	36,122	37,40,906	3,053
7	Multan Electric Power Company Limited (MEPCO)	Multan, Rahim Yar Khan, Khanewal, Sahiwal, Pakpattan, Vehari, Muzaffargarh, Dera Ghazi Khan, Leiah, Rajan Pur, Bahawalpur, Lodhran, Bahawalnagar	105,505	57,01,390	3,663
8	Hyderabad Electric Supply Company Limited (HESCO)	All Province of Sindh except Karachi, Sukkur, Ghotki, Khairpur, Kashmore, Kandhkot, Jacobabad, Shikarpur, Larkana, Kambar, Shahdadkot, Dadu and some portions of Jamshoro, Naushehro Feroz, Shaheed Benazirabad and Rahimyar Khan	81,087	10,50,956	1,234
9	Sukkur Electric Supply Company Limited (SEPCO)	Sukkur, Ghotki, Khairpur, Kashmore, Kandhkot, Jacobabad, Shikarpur, Larkana, Kambar, Shahdadkot, Dadu and some portions of Jamshoro, Naushehro Feroz, Shaheed Benazirabad and RYK	56,300	7,36,868	1,359

10	Quetta Electric Supply Company Limited (QESCO)	Whole Province of Balochistan, except Lasbela where KEL is responsible for distribution of power	334,616	5,91,552	1,770
11	K-Electric Limited (K-EL)	Entire Karachi and its suburbs upto Dhabeji and Gharo in Sindh and over Hub, Uthal, Vindhar and Bela in Balochistan	6,500	24,25,998	3,270

3.7.1.3 Key Policies and Regulations

Energy Policy for a developing country like Pakistan is critical to overall development and well-being of the population. There are several policies such as power policy, renewable energy policy, energy conservation and efficiency policy and environment policy[41] that are driving the power sector in the country.

2013 Power Policy

1. Envisage to eliminate the demand supply gap by investing in new power generation capacity
2. Decrease cost of generation from 12 US Cents /kWh to ~10 US Cents /kWh by 2017z

Policy 2006 for Development of Renewable Energy for Power Generation

1. Permitting frameworks for net metering and wheeling
2. Inviting private investment for IPPs and stand-alone grid power projects

Distributed Generation and Net Metering Regulations (NEPRA 2015)

1. Any electric grid customer having a three phase connection can enter into an agreement with a DISCOM to install net meters and small scale RE installations
2. Distribution companies installed net meters different locations successfully

Figure 48: Key Policies

3.7.1.4 Regulatory Framework

Pakistan's regulatory evolution of power market structure is briefly described with the following regulations:

[41] National Electric Power Regulatory Authority (NEPRA)

1990-2005
- National Electricty Regulator (NEPRA) set up in 1997
- WAPDA/PEPCO restructing in 1998 - NTDC (Transmission), 4 thermal power companies, and 9 distribution companies
- K-Electric privatized again in 2005

2005
- NEPRA interim power procurement (procedure and standards) regulations governing power procurement by distribution companies
- NTDC grid code

2015
- NEPRA (Alternative & renewable energy) Distributed Generation and Net Metering regulations

2016
- Wheeling of electric power

2017
- Import of electric power

3.7.2 Generation Sector

3.7.2.1 Overview

Power generation in Pakistan has witnessed a major transformation over the last five years (2013-2018) by moving towards a reliable supply system from large base load power plants using indigenous and imported coal and highly efficient gas-based plants.

Installed Capacity

The power sector in Pakistan is a mix of Thermal, Hydro, and Nuclear and Renewable Energy power plants. The total installed generation capacity of Pakistan as on 30th June, 2017[42] stood at 28,399 MW. The power plants connected with NTDC and K-Electric system generated 120 TWh during the FY 2016-17 as compared to 114 TWh in FY 2015-16.

Table 28: Installed Capacity (MW)

Source		Hydro	Thermal	Nuclear	Renewable Energy	**Total (MW)**
Fiscal Year 30th June, 2017	**Capacity (MW)**	7,116	18,676	1,142	1,465	**28,399**
	% Share	25.06	65.76	4.02	5.16	**100**

[42] NEPRA State of industry report 2017

3.7.2.2 Power Supply Demand and Load Forecast

The planned generation capacity and estimated demand for 2019 and 2020 in the NTDC and K-Electric systems are presented in the table below.

Table 29: Projected Demand and Planned Generation Capability of NTDC and K-Electric system

Fiscal year ended June 30	NTDC			K-Electric		
	Installed capacity (MW)	Planned generation capability (MW)	Estimated Peak Demand (MW)	Installed capacity (MW)	Planned generation capability (MW)	Estimated Peak Demand (MW)
2019	37,633	28,357	26,348	4,430	3,833	3,601
2020	39,821	29,314	27,420	4,520	3,978	3,791

The demand and power supply gap have been increasing till 2017 but is expected to reduce from 2018 due to planned construction of new power capacities. Load forecasts were prepared by the NTDC estimates the PEPCO and K-Electric systems are given in the chart below.

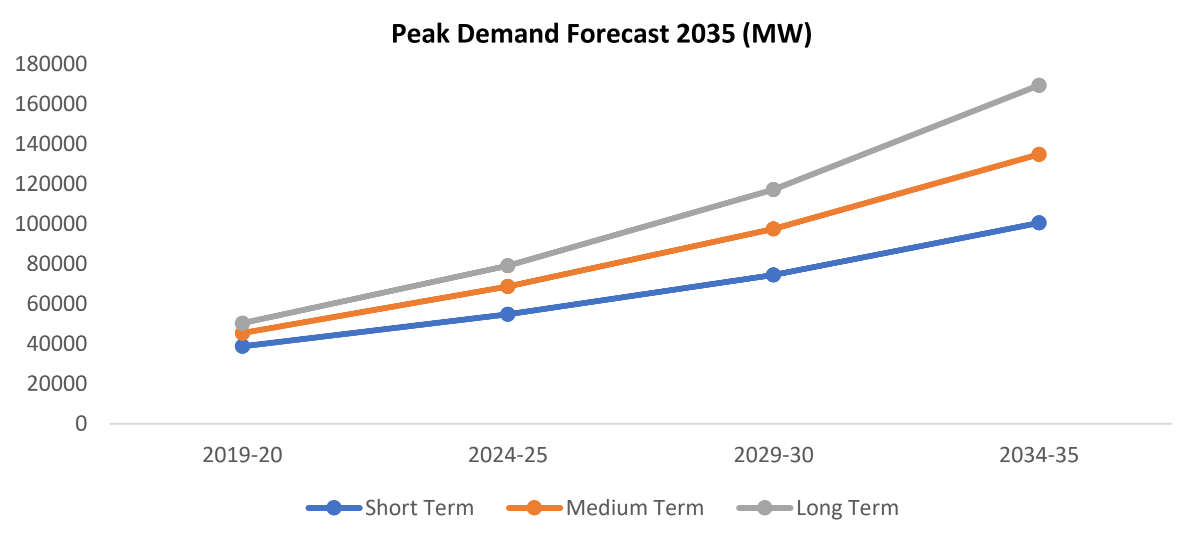


Figure 49: Peak Demand Forecast 2035

3.7.3 Transmission Sector

3.7.3.1 Overview

In Pakistan there are two companies which are presently engaged in the business of electric power transmission. One is National Transmission Dispatch Company Limited (NTDC) and the other is K-Electric Limited. NTDC is the National Grid Company of Pakistan and is exclusively responsible for construction, operation and maintenance of 500 kV and 220 kV grid stations and power transmission lines in the country except in the area served by K-Electric. The other company K-Electric is a vertically integrated company operating in private sector since 2005.

- The transmission line network of NTDC includes 5,197 km transmission lines operating at 500 kV level and 9,814 km long 220 kV lines

- As of 30th June, 2017 NTDC, is maintaining 14 Nos. 500 kV substations with a transformation capacity of 18,624 MVA (33 Nos. 500/220 kV transformers and 35 Nos. 220/132 kV transformers)

3.7.3.2 Future Plan for Transmission Expansion

NTDC aims to ready for the increasing power generation in NTDC has a very important role to play in the coming 4 years to build evacuation capacity from the 12,500 MW of new generation plants under construction. NTDC has ensured efficient evacuation and transmission across the country to its distribution points. During the period 2017-18 to 2021-22, NTDC has planned to commission 3500 km of 500 kV lines with 8 new substations. Due to system augmentation, new grids and transmission lines[43] NTDC's planned system in the FY 2021-22.

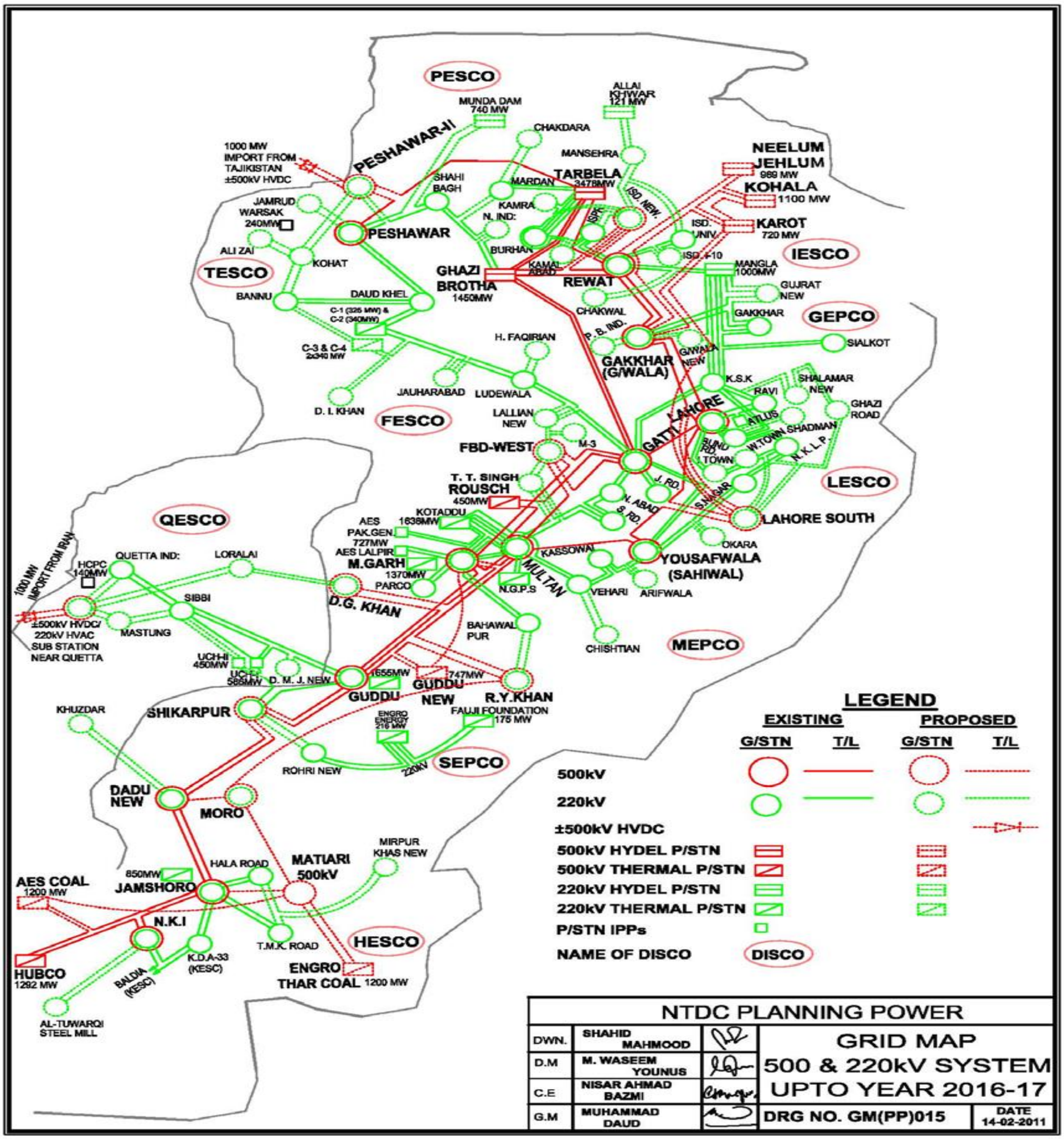


Figure 50: NTDC Planning Network

[43] NTDC expansion plan 2011-2030 final report

3.7.3.3 Transmission Losses

The power transmission losses of Pakistan as on 30th June, 2017 stands at **2.31%,** recording decrease of **0.26%** over the previous year.

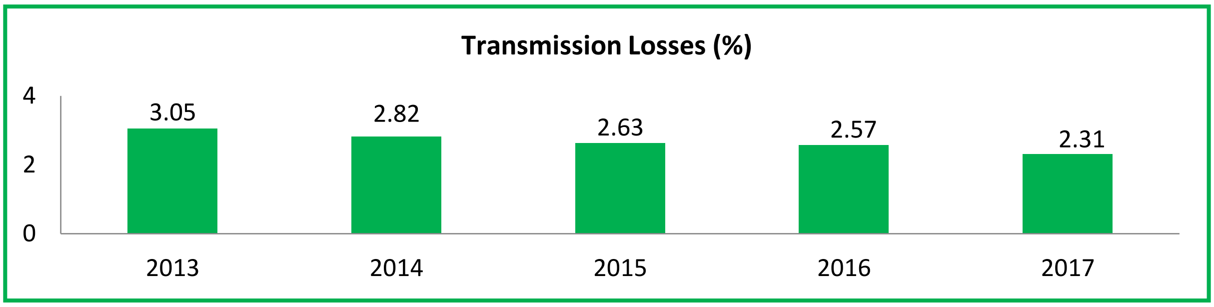


Figure 51: Transmission Losses in percentages

3.7.3.4 New Technologies for Improvement of NTDC System

NTDC wish to be a modern transmission company adopting global best practices, ensuring transmission system reliability and safety and committed to become the best service provider to the power producers, distribution companies and bulk power consumers connected to its network. NTDC aims to achieve this by acquiring new technologies including 765 kV, ± 660 kV DC and import of power from neighboring countries. The following are the proposed system improvement projects:

- ± 660 kV HVDC transmission line along with converter stations at Matiari and Lahore
- 500 kV HVDC transmission line for CASA-1000 project
- 765 kV AC transmission line for power evacuation from Dasu hydro power project
- Up gradation of NTDC Telecom and SCADA systems
- Implementation of integrated solution to improve productivity and control in NTDC by Enterprise Resource Planning (ERP) system
- Procurement of 5 Nos. 220 kV mobile substations

3.7.3.5 Cross Border Interconnections and Trading

The existing Cross-Border Electricity Trade[44] (CBET) between Pakistan and its neighbours namely Iran, India and Afghanistan, provides a foundation for furthering this cooperation at the regional level. Building on the experience of bilateral electricity trade in the region, a multilateral framework for power sector cooperation can be developed. Regional electricity cooperation may include the sharing of cross-border infrastructure, establishing regional power producers, and enhancing competition across regional markets. This would require, among others, investment in new border interconnections and the development of harmonized codes, policies, and regulations facilitating cross border power trade. Presently Pakistan is importing electricity from following counties:

Cross Border Interconnections

- Import of power from Iran
- Import of power from Tajikistan/Kyrgyzstan through Afghanistan (CASA-1000 Project)
- Import of power from India on Medium Voltage and Low Voltage lines

[44] NTDC

Table 30: Cross Border Energy Trading

Name of Transmission Line and Voltage	Power Evacuation Capacity (MW)	Status
A. With Iran		
Existing		
1. Since 2003	70	Completed
2. Since 2002	4	
Planned		
1. Import at Gwadar through 220 kV D/C	100	Contract Signed; Survey work of Gwadar - Pak Iran border 220 kV D/C T/L (75km) is in progress
2. Import through Quetta through ± 500 kV HVDC bipole	1000	MoU signed
B. With India		
Existing		
• 400/220 KV HVDC back-to-back convertor station in Pakistan • 400 KV D/C T/line (approx. 10 km) from convertor station to Pak-India boarder • 400 KV D/C T/line (approx. 26 km) from Balachak to Pak-India border		

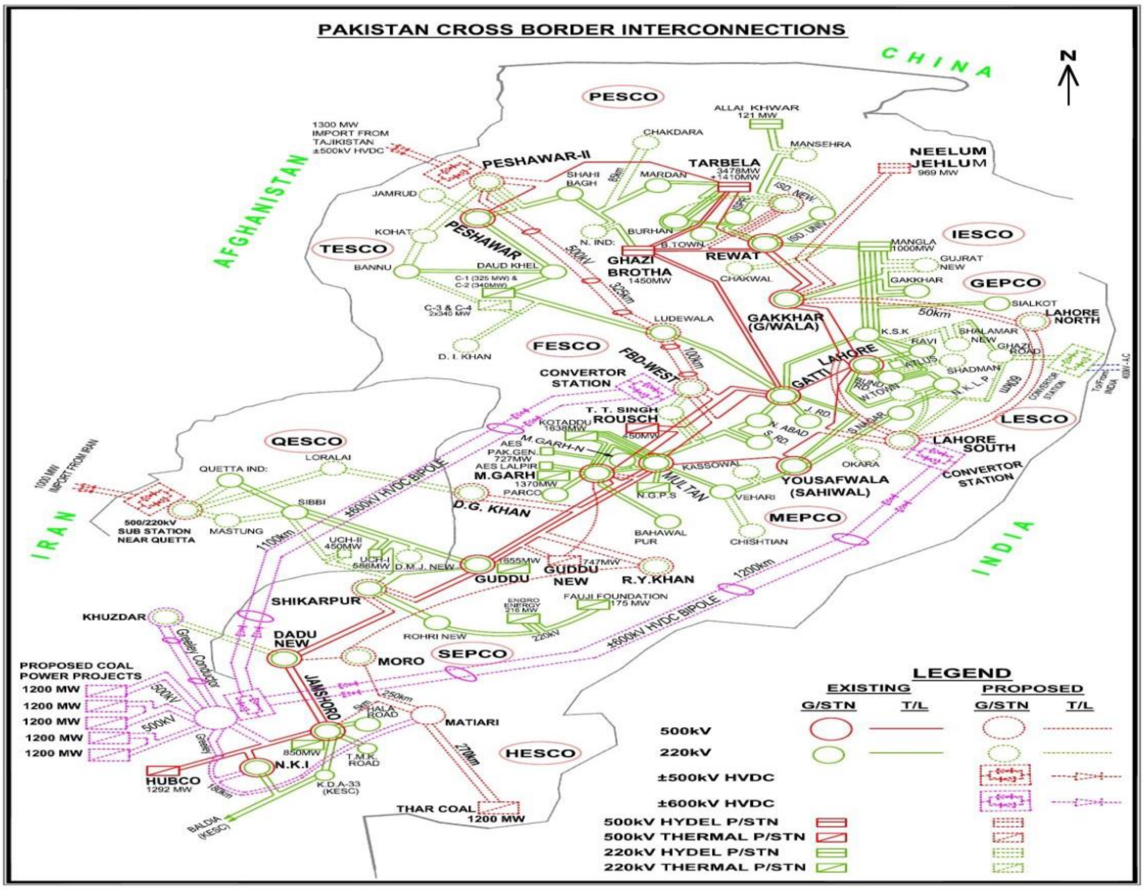


Figure 52: Cross Border Energy Trading

3.7.4 Distribution Sector

3.7.4.1 Overview

Presently there are 10 distribution companies in public sector which are distributing electric power to end consumers in Pakistan except Karachi where K-Electric, a private utility is the license.

Table 31: Electricity Consumers Category-wise

Consumer category	Number of consumers (as on 30th June,2017)	Electricity consumption (kWh)
Domestic	2,39,37,200	1,883.10
Commercial	33,62,034	2,104.49
Industrial	3,56,913	59,713.97
Agriculture	3,26,143	28,013.84
Public Lighting	10,192	29,478.21
Bulk supply	4,484	8,04,156.36
others	833	13,83,052.88
Total	**2,79,97,799**	**15,04,246.49**

Table 32: Substations with Distribution Companies

Substations	132 KV	66 KV	33 KV	Total
Numbers (as on 30th June 2017)	760	111	40	911

3.7.4.2 Distribution Losses

The power Distribution losses of Pakistan as on 30th June, 2017 stands at **17.95%,** recording decrease of **0.19%** over the previous year.

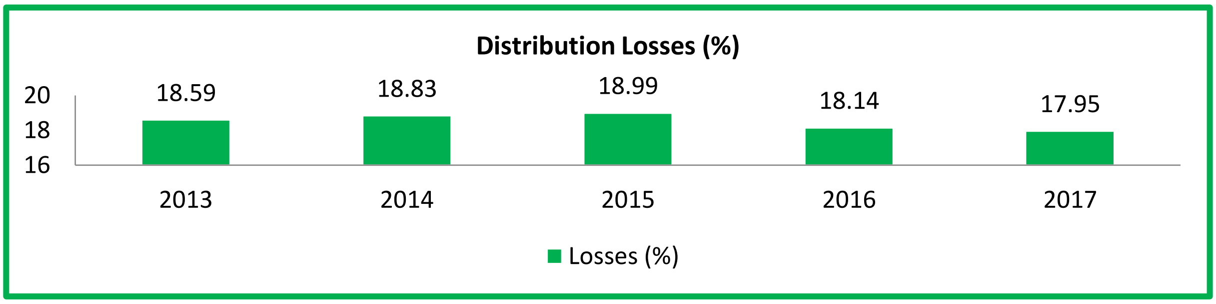


Figure 53: % Distribution Losses

3.7.5 Renewable Energy

3.7.5.1 Government Policies for Renewable Energy

In 2006, Government of Pakistan's released its first policy for development of renewable energy in their energy generation mix. The 2**006 RE Policy**[45] deals with wind, solar and small hydro (<50 MW),

[45] NEPRA

and set out an initial plan for development of renewables within the country. The total installed Renewable Energy (RE) generation capacity of Pakistan as on 30th June, 2017[46] stands at **1,465 MW** with wind generation contributing **54%** of the total capacity followed by **27%** solar, **19%** bagasse.

Subsequently, Government of Pakistan (GoP) announced various policies for promoting RE such as feed-in tariff/upfront tariff, tax incentives, net metering, long term refinancing facility and micro-financing schemes for promoting corporate sector investment in the RE. In view of the evolving market growth, technological developments, recent cost reductions and new financial mechanisms into account, the GoP decided to introduce competition amongst the private sector players for delivering electricity from RE resources at optimal tariff rates.

Table 33: Installed Capacity

Technology	Fiscal year 2017
Wind	785
Solar	400
Bagasse	280
Total	**1,465**

The National Electric Regulatory Authority (NEPRA) announced the Distributed Generation and Net Metering Regulations in September 2015. This allows all electricity customers to utilize net metering for their own photovoltaic and wind power plants from 1 kW up to 1 MW capacity. The Alternative energy Development Board (AE DB) is the nodal agency in Pakistan for promotion of RE. Through net metering connections, it is expected to generate about 6,900 GWh per year in 2024[47] which is about 8% of the total electricity consumption in Pakistan in 2015.

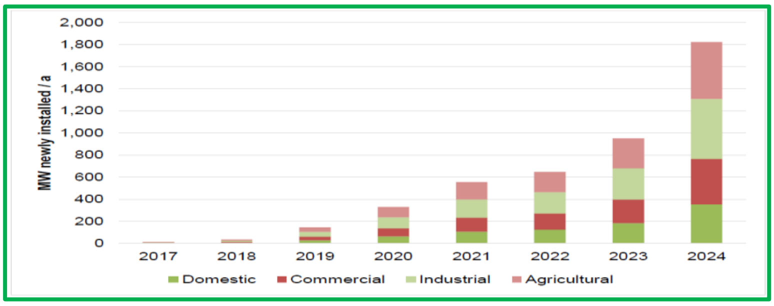


Figure 54: Total Generation of Solar Electricity through Net Metering

3.7.5.2 Integration of Renewable Energy into Pakistan National Grid

With the introduction of large-scale grid-connected solar and wind power projects, the grid's capability to accommodate power from variable renewable energy sources into the power system needs to be augmented. The United States Agency for International Development (USAID) backed NTDC on a study to assess the technical and financial feasibility of integrating power from solar PV and wind. This study evaluated different levels of variable renewable energy in the national grid of Pakistan, their relative impacts on the operational capacities of the system, and overall financial feasibility[48]. The study's main findings are reproduced below:

- 2.2 GW of wind and solar projects can be integrated into the national grid up to 2017
- A few major system reinforcements and additional transmission lines at Lal Suhanra, Jhimpir and Gharo will enable the system to integrate up to 4.06 GW of variable renewable energy up to 2020

[46] NEPRA State of industry report 2017

[47] Road map for the rollout of net metering regulations in Pakistan

[48] Renewables Readiness Assessment Pakistan

- Up until 2022, Pakistan could integrate the planned 9.4 GW of variable renewable energy, subject to the completion of numerous grid reinforcements at 500 kV, 220 kV and 132 kV
- Certain grid code amendments for solar and wind integration are necessary for grid stability
- Even without considering lost GDP caused by load shedding, variable renewable energy integration will reduce costs compared to a system without additional variable renewable energy

3.7.6 Key Drivers for Smart Grid

3.7.6.1 Enhanced Access to Electricity

The electricity access in rural areas in Pakistan is poor. Data pertaining to electrification rate is also unreliable. International Energy Agency (IEA) estimated the electrification rate as 74 % in 2016. In Sindh Province, the equivalent rate is much lower, at 37 %. Till now, efforts to bridge the gap in electricity access have been conducted primarily through grid extension, which has its own limitations in rural areas due to low population density and high dispersion amongst rural settlements. Efforts to provide off-grid solutions have relied upon small hydropower in the Northern provinces, and efforts are being made to provide Solar Home Systems (SHS) in the southern provinces. Smart microgrids and other smart grid technologies for integration of large quantities of RE on the grid could enhance access to electricity for the underserved sections of the society.

3.7.6.2 Reduce Transmission and Distribution Losses

T&D losses in the power systems is reported at 17.409% nationally. Actual number could be higher. Although smart grid is not necessary for T&D loss reduction, but smart grid technologies could help identify locations and main reasons for the losses which could then be reduced through appropriate actions.

3.7.6.3 Reliability and Quality of Supply

The reliability and quality of electricity supply in the country has large scope for improvements. The main factors that directly impact the power sector are electricity generation adequacy, power system infrastructure, utility finances, operational performance, and energy sector regulations.

Authentic data related to reliability of supply could not be found. For instance, the SAIFI of IESCO is 0.029, this means that each consumer, on average, experienced less than one interruption in 2016-17 due to IESCO's own system fault, which is quite questionable and very far from reality. Similarly, the SAIFI of LESCO is 37.44, which means that each consumer, on average experienced thirty-seven interruptions in 2016-17 due to LESCO's own system faults. Similarly, SAIDI in IESCO is 0.79, which means that average duration of each interruption occurred is even less than one minute which is unbelievable. Similarly, the SAIDI of GEPCO is 55.03, which means that average duration of each interruption is fifty-five minutes. The distribution companies can reduce their number of interruptions and can improve their SAIFI through technology interventions and adopting better operation and maintenance practices. The NEPRA has set targets for SAIFI and SAIDI for the year 2016-17 separately for each distribution company which is 5%

Various factors affect the reliability and quality of power supply

- Power system infrastructure
- Generation adequacy
- Regulation
- Financial and operational performance

reduction over mean value of last five years data of SAIFI and 10% reduction over mean value of last five years data of SAIDI[49].

3.7.7 Smart Grid Scenario in Pakistan

3.7.7.1 Introduction

The Pakistan's power system is facing many systematic, operational, management and capacity challenges. Strategic efforts are required from power utilities to not only upgrade the existing grid infrastructure but move forward towards self-healing and resilient grid by integrating the diverse energy resources into the power systems with increased automation and ICT applications for increased visibility and control of power flows. Some of the smart grid initiatives undertaken by utilities in Pakistan are summarized below.

A. Pakistan Vision 2025

Pakistan Vision 2025[50] lays down the foundation to meet the national objective of emerging as one of the top ten economies in the world by 2047. The vision 2025 aims at ensuring uninterrupted power supply for all sections of the population. It identifies the following goals:

- Optimize energy generation mix between oil, gas, hydro, coal, nuclear, solar, wind and biomass with reference to its indigenousness, economic feasibility, scalability, risk assessment and environmental impact
- Maximize distribution efficiency and cut wasteful losses through investment in transmission and distribution infrastructure and effective enforcement of controls

B. SCADA System

NTDC has been using SCADA technology since 1992, which was upgraded very recently with the support from Japanese International Cooperation Agency (JICA) under the Load Dispatch System Upgrade Project (LDSUP or SCADA Phase 2)[51]. Presently, the Asian Development Bank (ADB) is supporting the NTDC in achieving a fully functional SCADA system for operations and monitoring of the complete electric grid and use the SCADA communication system to obtain energy data from all metering points on the system to the CPPA-G (Central Power Purchasing Agency).

C. Smart Metering

The electric utilities in Pakistan losses 89.89 Billion rupees (USD 1.29 billion) annually due to theft of electricity. To reduce these losses Government of Pakistan has introduced smart energy meters with AMR facility at domestic level in some cities with the collaboration of United States Agency for International Development (USAID). In Pakistan, USAID have intended to install more AMR meters in five different power distribution companies. The 26,000 old electricity meters have been replaced by different Power Distribution Companies. Currently 26,000 Smart Meters are being installed at power distribution companies in Pakistan.

[49] NEPRA State of industry report 2017
[50] Pakistan Vision 2025 document
[51] SCADA Phase 3 & Revenue Metering System (RMS)

3.7.7.2 Smart Grid Roadmap for Pakistan

Smart grid roadmap as recommended for the utilities in Pakistan in this section is based on the following key assumptions:

a. Growth of electrical network will accelerate the electrification rate
b. New policies and regulations will be issued by 2020 for expansion and integration of renewable energy sources to grid by 2030
c. Growth of renewable energy resources including rooftop PV will accelerate in the coming years owing to policy mandates as well as cost reduction of PV systems making them economically attractive for larger sections of customers
d. New initiatives/projects and policies will be initiated for AMI, GIS, distribution and substation automation, demand response, integrated billing and customer care systems; and energy accounting system for improved efficiency and customer satisfaction by 2020

The Smart Grid Roadmap recommended in this report are in 3 stages:

a. **Immediate Term (2018-2020):** Proposed some immediate action items that can add clear strategy and plan for power system development and grid modernization in Pakistan in alignment with long term goals set by the Government

b. **Near Term (2020-2025):** Proposed a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction

c. **Medium Term (2025-2030):** Proposed several measures that would transform Discos to a modern utility using planning tools and advanced automation and IT systems and analytics to optimize the assets and operations

The above steps are described in detail in the following sections:

3.7.7.2.1 Pakistan Smart Grid Roadmap 2018 – 2020

Pakistan Smart Grid Roadmap 2020 defines the progressive trajectory of developments from present state (in 2018) to 2020 in following areas: Strategy Management and Regulation (SMR), Organization Structure (OS), Grid operations (GO), Work and Asset Management (WAM).

1. Strategy, Management, and Regulatory (SMR)

Present Maturity Level (In 2018): 0; Target Maturity Level in 2020:1

The utilities in Pakistan could achieve Maturity Level-1 on Strategy, Management and Regulatory domain by undertaking following steps:

- Define smart grid vision, strategy and policy in consultation with Ministry of Water and Power
- Arrange training to key personals to have common understanding about smart grid vision and technologies
- Initiate discussions with regulators on Smart Grid Roadmap of the utilities
- Make departmental structure for smart grid implementation (SCADA/DMS, Substation Automation, AMI) and their role and responsibilities
- Define area load dispatch center, regional load dispatch centre, central load dispatch centre and SCADA hierarchy from across the country

- Identify area for renewable energy development and integration with grid

2. Organization and Structure (OS)

Present Level (In 2018): 0 (Default)

Pakistan has restructured its power sector structure in 1998. It is clearly understood to strengthen electrical network and achieve higher electrification rate. The utilities in the power sector particularly the Discos should restructure their organization structure in order to achieve the objectives of the Smart Grid Vision and Roadmap. Utilities should target to achieve Maturity Level 1 by 2020 by undertaking following steps:

Maturity Level (In 2020): 1

- Organization should articulate (communicate) it's needs to build smart grid competencies in its workforce
- Organization structure and workforce need to align as per Smart Grid Vision and Roadmap
- Conduct workshops/ awareness session on smart grid technologies and needs across multiple functions/line of business to support smart grid activities

3. Grid Operations (GO)

Present Level (In 2018): 0; Target Maturity Level in 2020: 1

Many projects are in progress by Discos for strengthening of electrical network across country. It is recommended that utilities may undertake following measures to achieve Maturity Level 1 on SGMM by 2020:

- Prepare a utility specific Smart Grid Roadmap for (10~15 years) and get it approved by the Board of respective utilities
- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g. AMI with remote connect/disconnect, SCADA/DMS, GIS etc.) may be undertaken
- Strengthening of the transmission grid and installation of Wide Area Monitoring Systems to improve reliability of the EHV network
- Building new substation and medium voltage (MV) and low voltage (LV) lines to meet projected demand growth
- Replacement of existing DTs by new higher capacity DTs wherever required according to load growth
- Installation of Transformer Monitoring Units (TMU) on all power transformers and distribution transformers feeding to key customers and critical assets
- Make plan to implement SCADA/DMS, substation automation and outage management systems in phased manner in urban areas by 2020
- Make strategy and plan to implement pilot projects of AMI at select locations by 2020
- Implementation of Cyber security measures such as:
  - Identity and access management system
  - Implement relevant recommendation of statutory authorities in the country (if any)
  - Compliance with IEC or country specific cyber security standards

4. Work and Asset Management

Present Level (In 2018): 0; Maturity Level (in 2020): 1

It is recommended that utilities should undertake following measures to reach Maturity Level-1 on Work and Asset Management domain by 2020:

- Define business case for GIS maps for asset mapping and consumer indexing and get management approval for the same
- Perform consumer indexing at distribution level and map it to the GIS
- Implementation of ERP system
- Upgrade the communication system architecture to meet near and long-term communication needs
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

3.7.7.2.2 Pakistan Smart Grid Roadmap 2020 – 2025

Pakistan Smart Grid Roadmap 2025 defines the progressive trajectory of developments from present state (in 2020) to 2025 in 7 domains as recommended below:

1. Strategy, Management, and Regulatory (SMR)

Maturity Level (In 2020): 1, Target Maturity Level in 2025:2

For achieving maturity level-2 by 2025, Utilities in Pakistan need to following measures:

- Approval of smart grid projects/investments as per Smart Grid Roadmap
- Establish smart grid governance model and define its hierarchy in line with the Smart Grid Roadmap
- Update policies / regulations if needed to implement measures envisaged in the approved Smart Grid Roadmap
- Support from funding agencies for smart grid projects and make plan / strategy to implement smart grid projects in coming year e.g. SCADA/DMS, AMI, OMS, Distribution and Substation Automation etc. Identify potential areas where projects can be implemented

2. Organization and Structure (OS)

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

For achieving level-2 by 2025, Utilities need to undertake following steps:

- Approval of a Manpower Plan (including Training Plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on the Smart Grid Roadmap, restructure the organization hierarchy and its business process which can align end to end processes for smart grid operations
- Plan workshops and trainings to key personnel to develop smart grid competencies
- Plan for linking of compensation and incentives with achievement of smart grid milestones

3. Grid Operations (GO)

Maturity Level (In 2020): 1; Target Maturity Level (in 2025): 2

For achieving Maturity Level 2 in Grid Operations by 2025, Utilities need to undertake following measures:

- Create a new generation and transmission network, substations, medium voltage and low voltage lines; and upgrade capacity of existing network to meet the demand growth most efficiently
- Replacement of existing / old Distribution Transformers (DTs) with new higher capacity DTs where ever required
- Replacement of old cable / undersize conductors and replace old wire joints on overhead LV lines with proper crimped joints
- Upgrade the existing SCADA/EMS in the transmission system and extend the WAMS to cover entire EHV network
- Establish outage management system (OMS) for efficient outage restoration in urban areas
- Undertake pilot trials on smart microgrids for campuses, industrial parks etc
- Implement AMI in all urban areas
- Undertake pilot trails in energy storage for grid balancing on feeders with higher penetration of renewable energy

4. Work and Asset Management

Maturity Level (In 2020): 1, Target Maturity Level (in 2025): 2

For achieving Maturity Level 2 by 2025, Utilities need to undertake following steps:

- Systems for tracking inventory and event history of assets on GIS maps
- Implementation of enterprise resource planning (ERP) system and its integration with GIS and other IT and automation systems
- Systems in place for load forecasting every year and system upgrade plans to be reviewed and amended appropriately based on actual and expected load growth in each sub-division

5. Technology

Present Level (In 2020): 0; Target Maturity level (in 2025): 1

Utilities in Pakistan could achieve Maturity Level 2 by 2025 by implementing following measures:

- Enterprise IT Architecture: Utilities must develop an enterprise IT Architecture and start its implementation. Need to retire IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated even through a middleware must be replaced with commercially available off the shelf (COTS) applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT Architecture should enable integration of new assets and applications acquired by different LOBs
- All IT applications should adopt change control process e.g. configuration management, patch management, remote updating of applications and integration capability for future integrations

- Implement one integrated billing system in Discos covering all categories of customers
- Conduct audit for cyber security and adopt the recommendations to secure systems from cyber attacks
- Prepare cloud strategy for future expansion

6. Customer

Present Level (In 2020): 0; Target Maturity Level (in 2025): 1

For achieving Maturity Level 1 on Customer domain by 2025, utilities need to undertake following steps:

- Conduct workshops to educate customers about smart grid vision and roadmap
- Conduct study or research work for security and data privacy implication of new technologies and business process / functions to be adopted which can enable customer participation to leverage smart grid functionalities
- Consult with regulators and / or other government related organizations regarding impact of technologies on different categories of customers

7. Societal and Environmental

Maturity Level (In 2020): 0; Target Maturity Level (in 2025): 1

It is recommended to undertake following measures to achieve Maturity Level 1 by 2025:

- Publish the smart grid roadmap with emphasis on:
  - Utility's role in environmental and societal aspects with respect to Smart Grid Vision and Roadmap
  - Utilities should publicly promote the environmental benefits of using smart grid technologies
  - Utility's role in protecting the nation's critical infrastructure
- Approved environmental compliance records may be available for public inspection

3.7.7.2.3 Pakistan Smart Grid Roadmap 2025 – 2030

Pakistan Smart Grid Roadmap 2025-2030 defines the progressive trajectory of developments from present state (in 2018) to 2030 as expanded below:

1. Strategy, Management and Regulatory (SMR)

Maturity Level (In 2025): 2; Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2025, utilities need to undertake following measures:

- Establish smart grid governance model for smart grid development and decision making, define roles, process and tools for the same
- Designate a single smart grid leader in all key line of businesses (LOB) with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap
- Adopt smart grid vision, strategy and business case in organization's vision and strategy

2. Organization and Structure (OS)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, utilities need to take following measures:

- Commitment and consistency of leadership in communication and actions related to smart grid programs and projects
- Redesign organization structure to support smart grid initiatives e.g. matrix organization structure or similar and also execute this structure in view of the new programs and projects for 2030
- Performance awards and compensations are linked to success of smart grid programs and projects
- Conduct educational training programs which are aligned to build smart grid capabilities in the organization
- All changes in organization structure, appointments / transfer / changes being made in consideration and support with smart grid program and projects
- Knowledge Management framework to be put in place to capture the learnings from technology trials and new projects to be institutionalized rather than remain with individuals

3. Grid Operations (GO)

Maturity Level (In 2025): 2, Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, utilities need to undertake following measures:

- Building new generating plants, transmission lines, substation and medium voltage (MV), low voltage (LV) line and upgrade the capacity of existing generation, transmission and distribution system to meet expected demand growth optimally
- Expand distribution network to rural and urban areas to meet targets of electrification rate and increase in peak demand
- Increase transformation capacity at DT level as per organization target of 2030; replacement of exiting DTs with higher capacity DTs where ever required
- Addition of new capacitor banks to regulate power quality where ever required
- Peak load management through demand response (DR) at customer premises
- HT: LT ratio is brought to 1:2 in urban area and 1:4 in rural area
- Implementation of SCADA /DMS, distribution automation and substation automation and AMI across country on selected locations as per organization goals
- Implement outage management system (OMS) and its integration with SCADA /DMS, DAS and GIS in urban areas; prepare plan for extension GIS to MV and LV feeders and customers in semi-urban areas and important rural feeders
- Rollout of EV charging infrastructure and Vehicle to Grid integration solutions in urban areas and highways
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real time load and voltage data on selected urban and rural feeders
- Systems for condition-based maintenance of circuit breakers and power transformers
- Implement voltage and reactive power (Volt-VAR) optimization (VVO) systems on feeders with high penetration of rooftop PV
- Automated operation of capacitor banks (if not part of VVO solution)

- Advanced ground fault detection by installing protective relays (or IEDs) to detect high impedance (very low fault current) faults for faster isolation of downed conductors/section to ensure enhanced safety and improved service reliability
- Implementation of state-of-the-art Security Operation Centre (SOC) to safeguard the power system from cyber and physical attacks

4. Work and Asset Management

Maturity Level (In 2025): 2; Target Maturity Level (in 2030): 3

For achieving maturity level 3 by 2030, utilities need to undertake following measures:

- Asset performance trend analysis and event audit reports are available for all key assets and systems
- Hotline maintenance including bare hand methods are implemented in urban areas
- Integrated view of all key assets on GIS maps which are monitored remotely and are integrated with ERP and mobile workforce management system (MWFM) covering all urban areas
- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals; new communication models include customer to utility, customer to market, and smart equipment to equipment (M2M)
- Network model of distribution grid up to DT level is regularly updated and modelling studies undertaken for assessing various scenarios of network upgrades to balance demand and supply most optimally
- Inventories are tracked remotely using appropriate systems which are integrated with ERP, GIS and MWFM systems
- Analytical tools for predictive maintenance are deployed on trial basis
- AMI integration with OMS – restoration / disconnection messages from smart meters are integrated with OMS for faster restoration and improved customer satisfaction
- AMI- GIS integration to enhance the visualization of network to provide safety, reliability and operational benefits

5. Technology

Maturity Level (In 2025): 1; Target Maturity Level (in 2030): 2

For achieving Maturity Level 2 on technology domain by 2030, utilities need to undertake following measures:

- Alignment of all line of business (LOB) with enterprise IT Architecture across entire organization. If required modify business processes to align it with IT Architecture and systems
- Utilities uses common technology evaluation and selection process for smart grid activities including selection of vendors and external services
- A proper framework must be put in place for change control process for all IT applications and IT infrastructure
- Conduct pilot trails on wide area monitoring and distributed sensor network on MV lines
- Data collection from smart sensors network installed on distribution lines are leveraged by other applications for grid operation and customer service functions
- Prepare cloud strategies

- Cyber security systems in place to secure the digital assets as per statutory norms

6. Customer

Maturity Level (In 2025): 1; Target Maturity Level (in 2030): 2

For achieving Maturity Level 2 by 2030, utilities need to undertake following measures:

- Carry out research studies on enhancing customer experience and benefits through smart grid technologies envisaged in the approved Smart Grid Roadmap. These studies may be conducted for different categories of customers in both urban and rural areas
- Utility’s vision of future smart grid is clearly communicated to customers
- Analyze electricity consumption behavior and pattern of residential customers area-wise and align systems to support their usages pattern and minimize outages; model the reliability of grid equipment
- Assess the impact of new smart grid systems and services on different categories of customers
- Studies are conducted on the implications of data privacy and protection of customers
- Measures for security and privacy of customers are built in the specifications for new systems being procured
- Implementation of a state-of-the-art customer portal
- Prosumer enablement and net-metering plans available to all customers
- Leveraging social media for customer engagement effectively

7. Societal and Environmental

Maturity Level (In 2025): 1; Target Maturity Level (in 2030): 2

Utilities should undertake following steps to reach maturity level 2 by 2030:

- Finalize work plans for addressing the Societal and Environmental issues through smarter technologies
- Undertake proof of concept projects that can demonstrate the environmental benefits of smart grid technologies and applications
- Adopt “Triple Bottom Line” (TBL) framework for key decisions – TBL method covers Societal, Environmental and Financial aspects of every investment plans/projects
- Provide details of granular level energy consumption data to customers – from AMI system through customer portal
- Offer smart grid supported energy efficiency programs to customers
- Societal and Environmental benefits are estimated in the detailed project report for each project
- Diesel Generator sets replacement with batteries (that can be leveraged for load balancing) at customer premises is actively promoted through innovative business models
- Clean energy being moved to the core of Utility’s business model

8. Value Chain Management (VCM)

Present Level (In 2025): 0; Target Maturity Level (in 2030): 1

Utilities should undertake following steps to reach maturity level 1 by 2030:

- Formulation of a strategy for creating and managing a diverse resource portfolio
- Identification of:
  - Assets and programs for load management
  - Distributed generation resources, its locations and its capabilities
- Security requirements to enable interactions with an expanded portfolio of value chain partners

The above maturity levels can be achieved in a phased manner as indicated in the chart below:

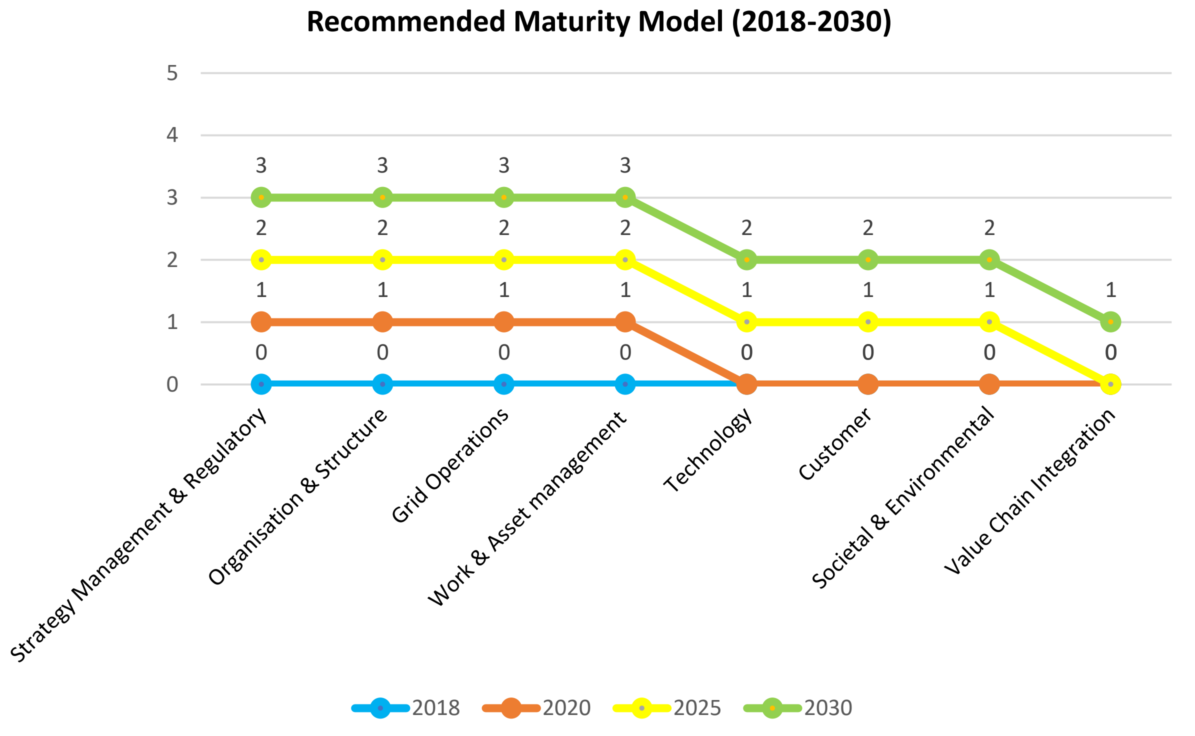


Figure 55: Recommended Maturity Model (2018-2030)

3.7.8 Cost Benefit Analysis

3.7.8.1 Background

Pakistan has a total of 28.4 GW generation (66% coal, 25 % hydro, 4% nuclear and 5% renewable), however due to poor plant availability and transmission system reliability, the maximum generation is around 19 GW against a peak demand of 25 GW. Pakistan's Vision 2025 is to add additional 25 GW. The transmission system contains numerous complexities with inadequate power flow control, reactive power management, and power-angle and voltage instabilities. All these result in numerous planned and unplanned line trips/outages. Annual forced outages rate for 500 kV is 122 interruptions (total 29,600 min) and for 220 kV it is 336 (total 141,600 min). The distribution sector is vast with 28 million consumers with average network losses of 18%. The SAIFI and SAIDI indices are equally challenging in many parts of the network (as high as 160 to 600 SAIFI and 6000 to 20,00 SAIDI). Until T&D unreliability is tracked and solved, the reliable supply will always be challenging.

3.7.8.2 Project Objective and Description

It is proposed to evaluate the efficacy of using PMUs to analyze and reduce SAIFI/SAIDI on a sample

500 kV network and a sample PEPCO Distribution Network through a pilot project as described here. It should be noted that SCADA and associated metering systems in place for its 500 kV and 200 kV system should be adequate to detect and resolve these issues. However, this problem has existed for decades. PMUs are now cost effective and are being proposed to deploy to get to the root cause as to why frequent incidence of line tripping occur. It could be due to inter-area oscillations and “swings” between large generation and weak / long transmission lines. Hence this alternative attempt.

A small pilot centralized hub to capture PMU measurements (on both T&D) with analytics, consisting of:

1. 10 sets 3-phase fast PMU for 500kV (USD 25,000 per set)
2. 30 sets of 3-phase slower PMUs for PEPCO Distribution network (USD 15,000 per set)
3. GPS Clock and Telecom Network (USD 150,000 Lumpsum)
4. Central station for the national center and accessories (USD 100,000 Lumpsum) for selects regional centers including Dx systems which may have communication bandwidth issues to the national center
5. PMU Analytics, stations, accessories (USD 100,000 Lumpsum)

Financial Data

- Required rate of return (Govt. / IFI rates) – 8%
- Tax rate – 25%

Initial Investments

Parameter	Cost
Equipment	USD 1,050,000.00
Engineering and Development	USD 100,000.00
Installation & Commissioning	USD 150,000.00
Total Initial Investments	**USD 1,300,000.00**

Benefits	YEAR	1	2	3
Benefit of 500 KV SAIFI improvement (10% x 122 x 500 MW x $15wheeling/MWh x 1 hr)		$91,500.00	$91,500.00	$91,500.00
Benefit of 500 KV SAIDI improvement (10% x 29643min x 500 MW x $25/MWh)		$617,562.50	$617,562.50	$617,562.50
Benefit of Dx SAIFI improvement (10% x 160 x 50 MW x $8wheeling/MWh x 1 hr)		$6,400.00	$6,400.00	$6,400.00
Benefit of Dx SAIDI improvement (10% x 14643min x 50 MW x $20/MWh)		$24,405.00	$24,405.00	$24,405.00
Note: Only 10% improvement in SAIFI/SAIDI is assumed from this pilot				
Total Benefits		**$739,867.50**	**$739,867.50**	**$739,867.50**
Costs (Excluding Initial Capital Investments)	**YEAR**			
Operations		$35,000.00	$35,000.00	$35,000.00
Maintenance		$20,000.00	$20,000.00	$20,000.00
Project management, customer support		$35,000.00	$35,000.00	$35,000.00
Misc.		$5,000.00	$5,000.00	$5,000.00
Depreciation on capital expenditures (calculation uses 5-year period)		$260,000.00	$260,000.00	$260,000.00
Total Costs		**$355,000.00**	**$355,000.00**	**$355,000.00**
Totals	**YEAR**	**1**	**2**	**3**
Net Benefits (Costs)		$384,867.50	$384,867.50	$384,867.50
Tax		$96,216.88	$96,216.88	$96,216.88
Value after tax		$288,650.63	$288,650.63	$288,650.63
Depreciation added back		$260,000.00	$260,000.00	$260,000.00
Cash flow	-$1,300,000.00	$548,650.63	$548,650.63	$548,650.63
Cumulative cash flow	-$1,300,000.00	($751,349.38)	($202,698.7)	$345,951.88

3.5.8.4 Evolution Metrics

Evaluation Metrics	Cautionary Note:
Net present value (NPV) - $113,925.87	All costs are budgetary for discussions purposes only.
Internal rate of return - (IRR)12.79%	A detailed project report (DPR) needs to be done.
Payback period (in years) - 2.37	

3.7.8.3 Relevance of CBA Analysis to Smart Grid Transition

Pakistan's transmission system contains numerous complexities with inadequate power flow control, reactive power management, and power-angle and voltage instabilities. All this results in numerous planned and unplanned trips/outages. The proposed project to improve the 500KV reliability by 10% and a sample PEPCO distribution segment by 10%, is worthwhile exploring.

Benefits:

The CBA results look promising with a positive NPV and short payback and is worth implementing.

A detailed project report (DPR) with formal quotes will be required.

The following are the key benefits:

1. Benefits in just 10% SAIDI/SAIFI improvements in 500 KV amounts to USD $ 709,000 per annum
2. Benefits in just 10% SAIDI/SAIFI improvements in Dx amounts to USD $ 31,000 per annum
3. If successful, similar projects can be implemented in other parts of 500 KV, 220 KV and Distribution systems
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Utility O&M services will also get a boost in operating and maintaining these devices

3.7.8.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions (temperature, humidity, dust, etc.)
2. Special training/skills will be required for installation, calibration and commissioning of these specialized equipment. 3. PMU equipment installations require coordinated planning for combined effects. 4. It is important that the systems and architecture designs of this pilot project be supervised by global experts who are knowledgeable in this. 5. Training of O&M personnel in new technology equipment (PMU, Data Acquisition, data analytics, software, etc.)

3.8 Sri Lanka

3.8.1 Sri Lanka Country Overview

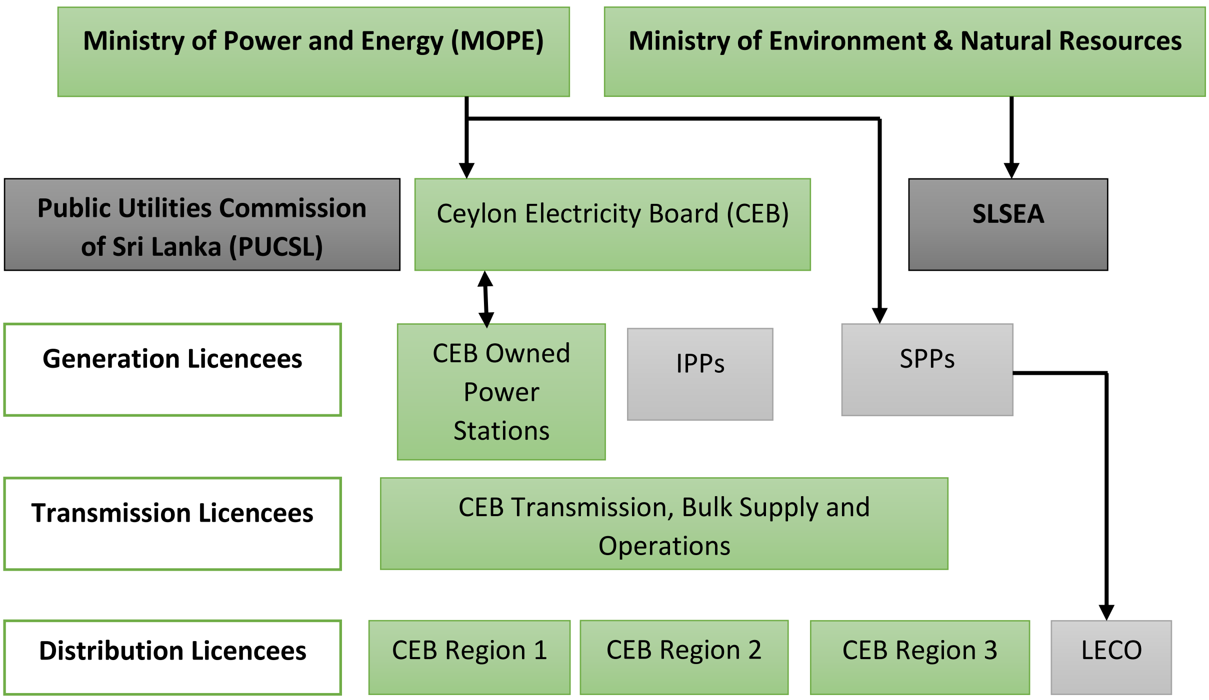
Sri Lanka is a middle-income country of 21.4 million people with per capita GDP of USD 4,065 in 2017. Sri Lanka's national electrification ratio has grown from 99.3% in 2016 to 99.7% in October 2017[52], and has already reached 100% electricity accessibility.

3.8.1.1 Power Sector

Sri Lanka's national electrification ratio has grown from 99.3% in 2016 to 99.7% in October 2017 and has already reached 100% electricity accessibility. Demand for electricity is growing at a rate of about 6% per year. Maximum reported peak demand was 2,523 MW on 17th May, 2017 and average daily demand was approximately 40 GWh.[53] Electricity demand consists of 34% of domestic consumers, 29% from industries and 21% from general purpose consumers, with the balance 16% coming from others. Electricity distribution network consist of 28,479 low voltage electricity distribution substations, 32,863 km of 33 kV and 11 kV medium voltage (MV) lines; and 139,213 km of low voltage distribution lines including underground cables.[54]

In the power sector, the Ceylon Electricity Board (CEB), under the Ministry of Power and Renewable Energy (MoPE), is the owner and operator of the national electricity grid. It owns all large hydropower stations and 50% of the thermal power generation capacity in Sri Lanka. The remainder of the thermal-based power generation is owned by private players. On the distribution side, the CEB caters to 85% of the consumers connected to the national grid and the Lanka Electricity Company (LECO), under the MoPE, supplies electricity to consumers, mainly in urban and suburban areas constituting about 15% of total customers in the country.

Figure 56: Sri Lanka's Power Sector Overview



[52] Economic Statistics of Sri Lanka 2017
[53] http://powermin.gov.lk/english/wp-content/uploads/2017/10/MoPRE-2017.2018-03-English.pdf
[54] MoPE Performance 2017 and Program 2018 report

3.8.1.2 Energy Resource Potential

Sri Lanka has a limited reserve of oil, most of which are still unexplored. The estimated oil reserve is 150 million barrels. Present requirements are met through imports.

Table 34: Resource wise Potential

Coal (Million Tonnes)	Oil (Million Barrels)	Natural Gas (Trillion Cubic Feet)	Biomass (Million Tonnes)	Hydropower (GW)
0	150	0	12	2

Sri Lanka has no proven reserves of natural gas and coal. The total estimated potential for small hydro is 873 MW, wind power is 5650 MW, mainly in the north-western and central regions, solar power potential is 6000 MW and bio-mass is 2370 MW.[55]

3.8.1.3 Key Challenges faced by the Sri Lankan Power Sector

The Sri Lankan power sector faces multiple challenges, highlighted below, which need to be proactively tackled if the country wishes to be successful in achieving higher levels of renewable energy.

Investment for Infrastructure Development	•Sri Lanka does not have the domestic capability to fund ambitious projects from commercial banks
Inadequacy of Ancillary System	•High penetration of RE is likely to induce intra-day variability in power supply and this variability needs to be addressed with a strong ancillary systems
Non-availability of Incentives for RE capacity development	•Developing coal based capacity becomes more efficient because of large unit size, high plant load factor and base load operation
High Cost of RE sources	•With technological innovation, there is expected to be a drop in the price of RE-generated power such as solar and wind, which could make RE a commercially viable option
Lack of local R&D to promote local capacity development	•Creating an industry which is dependent on importing RE expertise and resources can be expensive and risky to maintain
Slow development of Rooftop Solar	•Slow development of roof-top solar due to lack of proper education among consumers and limited options for low cost finance from commercial banks

[55] Generation Performance in Sri Lanka 2016

3.8.2 Generation

Sri Lanka's current electricity generation portfolio comprises of both grids connected and off-grid systems. Thermal plants contribute 2,115 MW, Major Hydro stations 1364 MW and 546 MW of renewables. The total generation capacity of Sri Lanka is 4043 MW in 2018.[56] This is excluding the contribution from Mini Hydro, Biomass and Small-Scale Solar. The capacity growth in the year of 2016 was 6% with a peak demand of 2453 MW. The most important measure in the energy balance of Sri Lanka is the total consumption of 11.72 billion kWh of energy per year. Per capita, this is an average of 547 kWh[57].

Table 35: Annual Cumulative Generation

Generation Source	Capacity (MW)
Major Hydro	1,364
Thermal	
Coal	900
CEB	604
IPP	611
Renewable	564
Total	**4,043**

3.8.2.1 Grid connected generation plants

The CEB currently owns all the large-scale hydro power plants, the coal-based power project and a significant amount of the oil-fired capacity in the country. Apart from generation, it purchases electricity from private Independent Power Producers (IPPs) with whom it has entered into contracts. While all large IPPs are oil fired, mechanisms set up to purchase electricity from renewable based power plants have enabled many Small Power Producers (SPPs) to generate and sell renewable power to the national grid. With the increase in electricity demand, contributions from private power plants have increased significantly in recent years. At present, over 50 percent of electricity generated in Sri Lanka is from thermal power plants.

3.8.2.2 Off-Grid Electricity Generation

Off-grid generation is available in some locations, due techno-economic un-viability of extension of the national grid. Standby power supplies are also available in most industrial and commercial facilities, although their operation is limited to short durations.

The two main areas of off-grid generation are:

- Diesel generators utilized as a standby option to run only for short durations during grid failures
- RE systems, such as small hydro, wind and solar photovoltaic systems for households which are operated off-grid due to unavailability of the grid and other technical reasons

However, with increasing demand, Sri Lanka has had to increase its dependence on costly imported fossil fuels (49 percent of the total energy mix). The increased dependence on fossil fuels has also led to an increase in Sri Lanka's GHG emissions, which while amongst the lowest in the world (ranked 194th out of a total 251 countries) as well as in South Asia (0.8 mtCO2e/capita in 2015).

[56] Generation Report March-18 by PUCSL
[57] https://www.worlddata.info/asia/sri-lanka/energy-consumption.php

3.8.2.3 Electricity Load Forecast

Since the domestic sector is the biggest consumer of electricity (34%), the power system experiences very high evening peak. Although some policy initiatives have been taken recently to mitigate this, including the new tariff structure, the annual load factor shows the ratio between peak demand and average demand is continuously growing. Therefore, immediate steps to be taken to study the system load profile and finding appropriate options to flatten the system load curve.

3.8.2.4 Generation Expansion Plan for Sri Lanka

Renewable energy, thermal plants running on imported coal, oil and gas; and nuclear plants are the options to being considered in meeting the future electricity demand. A large number of factors including cost of development, operation and maintenance costs and environmental effects have to be evaluated in order to consider the suitability of these options. In the context where global consensus is in place to combat climate change, Sri Lanka is ambitious and progressing towards low carbon pathways through renewable energy development. Increasing the contribution of indigenous renewable energy sources is envisaged in the electricity sector and it will reduce the greenhouse gas emission as well as enhance the energy security aspects.

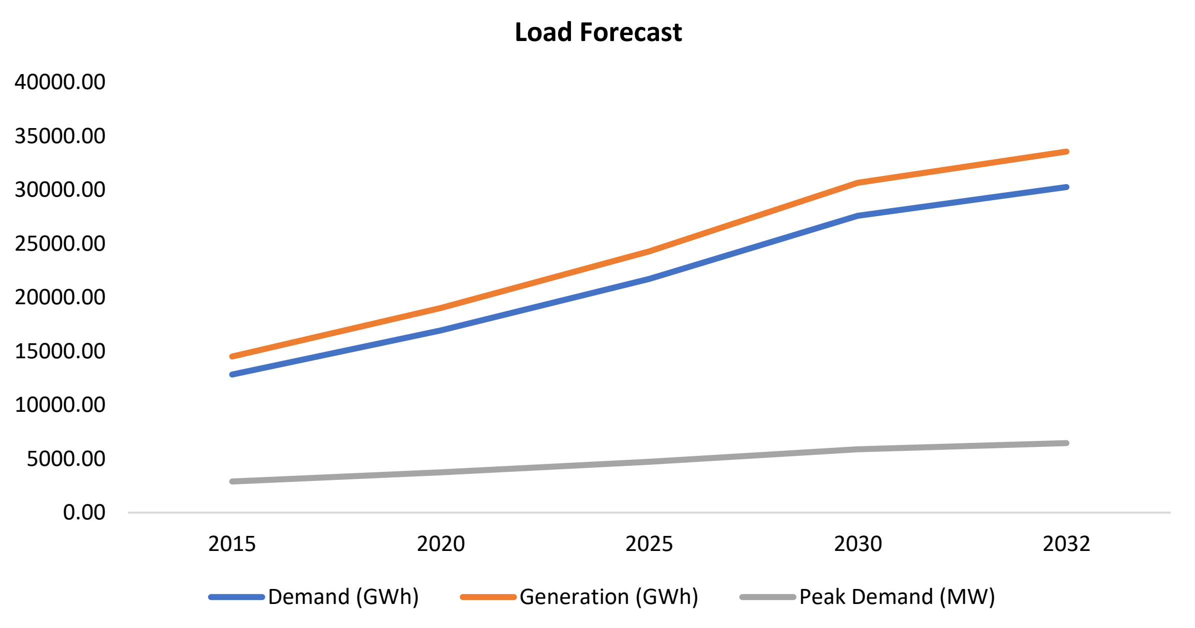


Figure 57: Electricity Load Forecast

Table 36: Generation Expansion Plan

Year	Renewable Addition	Thermal Addition	Thermal Retirements
2018	27 MW Moragolia Plant	2×250 MW Trincomalee Plant	4×5 MW Northern Power Plant
2019		2×300 MW Coal Plant	5×17 MW Kelanitissa Gas Turbines
2021		1×300 MW Coal Plant	

2022	49 MW Gin Ganga	1×300 MW Coal Plant	

3.8.3 Transmission

The electricity transmission network in Sri Lanka is solely owned by the Ceylon Electricity Board (CEB) and is operated at 220 kV and 132 kV to transport electricity from the point of generation to distribution bulk supply points. Sri Lanka is likely to expand the current network of 220 kV lines toward the northern, eastern and southern parts of the country and build 400 kV lines on the eastern and southern legs as a 10-year rolling plan to accommodate any new requirements. Electricity distribution and sales in Sri Lanka come under the purview of two state owned organizations:

- Ceylon Electricity Board (CEB)
- Lanka Electricity Company (Pvt.) Ltd. (LECO)

Table 37: Transmission Scenario

Total Installed Capacity (CEB Hydro Power)	**1,377 MW**
Total Installed Capacity (CEB Thermal Power)	1,466.7 MW
Total Installed Capacity (CEB Wind Power)	3 MW
Number of Hydro Power Stations (CEB)	17
Number of Thermal Power Stations (CEB)	7
Number of 220kV Grid Substations	8
Number of 132 kV Grid Substations	55

Distribution network operated by LECO use 11 kV and Low Voltage (LV) system whereas CEB distribution system has both 33 kV, 11 kV and LV lines. Both CEB and LECO supply at 400 /230 Volt to small scale consumers. The national transmission network comprises of 601 km of 220 kV lines and 2310 km of 132 kV lines and 63 substations. CEB Transmission Division plans, develops, operates and maintains the whole of the transmission assets in the country.

3.8.3.1 Transmission Losses

The integration of a number of smart grid technologies can contribute to significant efficiency improvements. By improving the efficiency of the electric system, positive impacts can be made on the environmental friendliness of the grid. The transmission losses were around 14.33% in the year 2009 from where it was reduced to around 9.98% in the year 2013 after which it again rose to 11.44% in the year 2014.

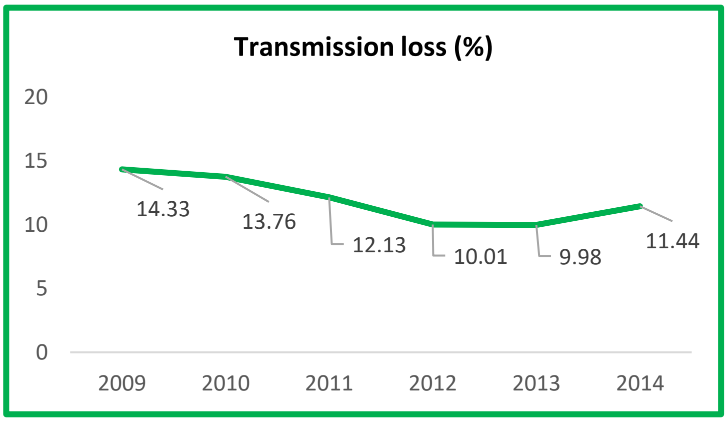


Figure 58: Transmission Loss (%)

The power transmission system has large scope for improvements through system upgrade and new technologies for system operation and monitoring.

3.8.4 Distribution

The CEB distributes electricity to about 85% of total customers in the country while the rest is taken care by Lanka Electricity Company Ltd (LECO), a subsidiary of the CEB. The electrification level in the country is calculated as 99.4 % as at end of June 2017. Distribution System of CEB consists of four divisions. The main objectives of the formation of four divisions are to achieve benchmark competition to improve efficiency and quality of supply to the customers. The distribution consists of 33kV and 11kV Medium Voltage (MV) lines and 400V Low Voltage (LV) lines.

Table 38: Total number of Consumers

Consumer Category	No. of Consumers
Domestic	58,13,077
Religious	39,744
General Purpose	7,26,271
Industrial	62,437
Government	2,212
Hotel	565
Bulk + Street Lighting	2,768
Total	**66,47,074**

Table 39: Division wise Distribution lines and cables

Description	Units	DD1	DD2	DD3	DD4	Total
33 kV Distribution Lines	km	9,968	8,810	7,970	4,477	31,225
11 kV Distribution Lines	km	781	622	40	328	1,771
11 kV Underground Cables	km	647	121	5	22	795
No. of 33/11 kV Primary Substations	no	45	40	12	39	136
LV Distribution Lines	km	35,953	35,958	28,880	24,699	1,25,490
LV Underground Cables	km	602	70	6	6	6984
No. of LV Distribution Substations	No	9,191	7,648	5,415	4,630	26,884

3.8.5 Renewable Energy

Cost of electricity from thermal power plants is much higher than renewable energy in Sri Lanka. Hence the Government has identified the development of RE as a priority in the energy policy to diversify the electricity sector from high cost thermal power generation. Several incentives and assistance were provided for the RE development (mini-hydro, bio-mass, wind and solar). Further National Energy Policy 2006 has identified fuel diversity and energy security in electricity generation as a strategic objective and development of RE projects was identified as a part of this strategy.

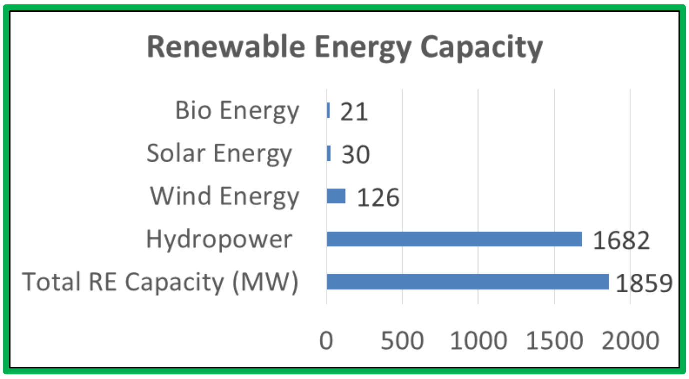


Figure 59: Renewable Energy Capacity

3.8.5.1 Present Status of Non-Conventional Renewable Energy Sector (as of 2017-07-31)

The off-grid rural electrification program aims to electrify households using off-grid solar and mini-grid solutions. The Sri Lanka Sustainable Energy Authority (SLSEA) has identified the northern and western regions of the country to build wind and solar power plants. Sri Lanka has also had an active rooftop solar program. In addition, CEB has set a target to increase electricity produced by renewables to 17% of the total generation by the end of 2019. A mandatory energy efficiency and labelling program is being implemented with the goal of covering the most commonly used appliances.

Table 40: Present Status of Non-Conventional Renewable Energy Sector (as of 2017-07-31)

Description	Project Type	No. of Projects	Capacity (MW)
Commissioned Projects	Mini Hydro	181	353.744
	Wind Power	15	128.85
	Biomass – Agricultural & Industrial Waste Power	4	13.08
	Biomass – Dendro Power	5	11.02
	Solar	8	51.36
	Total – Commissioned	**213**	**557.65**

3.8.6 Key Drivers for Smart Grids in Sri Lanka

Since the early 21st century, advancement in electronic communication technology is being leveraged to address the limitations and improve the efficiency and reliability of the electricity grids. Key drivers for smart grid in Sri Lanka are briefed below.

Flexibility Requirement	Sources of Flexibility	Minimizing Flexibility
• Flexibility Reserve • Ramp Charecteristics	• Dispatchable Generation • Storage • Demand Side Activities • Interconnections	• Geographical Spread

3.8.6.1 Renewable Energy Development and Integration with the Grid

Sri Lanka has already reached a grid connectivity of 98.7% and 100% electricity accessibility which is commendable by South Asian standards. However, the cost of electricity is primarily driven by fuel price fluctuations for thermal plants and water availability for hydroelectric plants. Cost of electricity from RE sources like solar and wind are stable for 25+ years. Hence increasing the share of RE in the energy mix is top priority in the country. In order to integrate higher levels of variable RE on the grid, better systems for monitoring and control of both demand and supply are required which are offered by smart grid technologies.

To accommodate intermittency of wind and solar PV generation, the power system needs to be operationally flexible and stable. Therefore, to determine the stability and operational constraints and to determine the required countermeasures, a detail system operation analysis and a power system stability analysis were carried out in a recent study[58]. The scope of the study covers the areas of renewable energy resource estimation, future renewable energy projection with optimized long-term generation expansion planning, transmission infrastructure availability and development, system stability and operation, economics of integration.

By 2050, Sri Lanka's electricity generation demand is likely to increase fivefold to ~70,000 GWh from ~14,000 GWh in 2016.[59] Even though Sri Lanka has abundant potential for harnessing wind and solar energy, a proper mix is required to meet the evening peak demand, when solar energy will not be available.

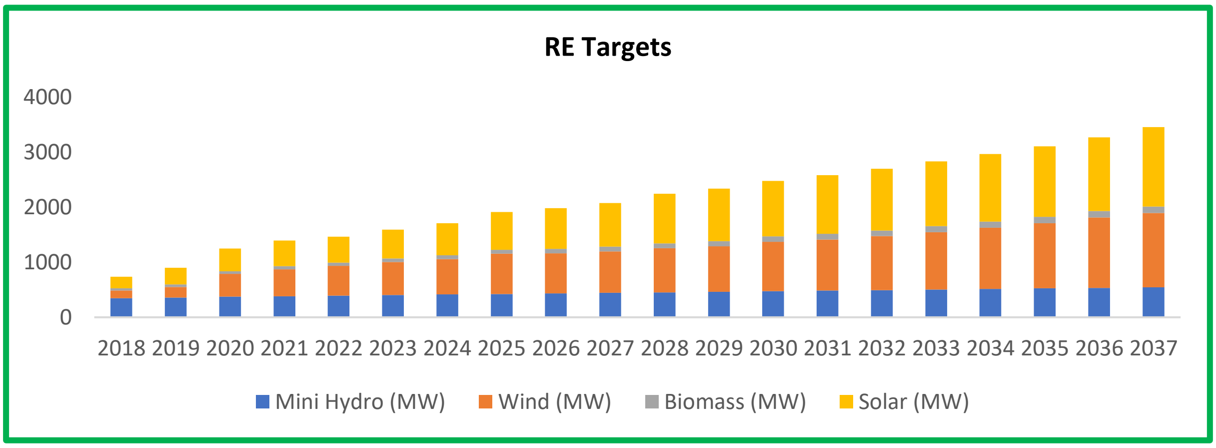


Figure 60: Renewable Energy Integration Study

[58] Integration Renewable based generation into Sri Lankan Grid 2018-20

[59] The CEB has estimated demand for Sri Lanka to 2034 based on an econometric model. Demand for 2035-50 has been estimated by extrapolating the demand at a rate equal to the CAGR for the period 2020-34 ~4.8 percent.

The way forward of the Integration of Renewable based generation into Sri Lankan Grid 2018-2028[60] are:

- Diversified and prioritized resource locations for VRE
- Establishing wind and solar forecasting systems to the national dispatch center
- Providing Variable Renewable Energy (VRE) curtailment rights to system operator
- Base load power plants with increased flexibility
- Utilizing demand side management and demand response to provide flexibility
- Continuous upgrades to RE integration studies
- Proper and timely implementation of VRE and other major power plants

3.8.6.2 Renewable Energy Targets

Sri Lanka Sustainable Energy Authority (SLSEA), the nodal government entity for development of RE in Sri Lanka has set following targets:

- 20% grid electricity generation using New Renewable Energy sources by 2020 as an alternative to imported fossil fuel
- 10% reduction in total energy consumption by 2020 through implementation of energy conservation measures[61]

3.8.6.3 Electric Mobility

Total vehicles on the roads in the country are about 7.1 million which has been growing at the rate of 8-12% of late. Entire fuel for transportation sector is imported and prone to price volatility in the international oil market. Sri Lanka has taken the preliminary steps towards adoption of electric vehicles (EV). Presently there are over 4300 EVs in operation.

Since the EV usage in Sri Lanka is on a positive trend, the EV load and its charging behavior could pose significant effect on the grid during the peak load period as the EV fleet increases. Smarter technologies are required for large rollout of EVs and vehicle grid integration (VGI).

3.8.6.4 Demand Side Management

The peak electricity demand in Sri Lanka has been growing steadily. It is envisaged that an average of 1,000 GWh of electricity can be saved within next 5 years through following DSM programs:

- Replacing inefficient street lamps with efficient LED street lamps by the Ministry of Provincial Councils and Local Government - Bidding process has been commenced
- Energy labelling for electric appliances - Energy labelling of Fans & LED bulbs has been completed, and energy labelling of Refrigerators is in progress
- Development of a Smart Grid
- Distribution of LED Lamps to the households targeting to reduce 300 MW from the Peak Demand
- 10 million LED Bulbs to be distributed among the consumers of less than 90 units per month replacing inefficient incandescent bulbs

Energy savings (GWh) and demand savings (MW) are estimated at 1,104 GWh by 2020 and differ 417 MW capacity in generation expansion. Similarly, the Smart Home initiative focusing on solar PV roof

[60] Integration of Renewable based Generation into Sri Lankan Grid 2018-2028 by CEB, 5th June, 2018

[61] Integration of Renewable based Generation into Sri Lankan Grid 2018-28

top systems can avoid 139.2 GWh by 2020 and differ a 100 MW capacity in day time grid generation.[62] While incentives and penalties could promote energy savings and peak load shifting to certain extent, direct interventions with little or no room for human response factors, ranging from automated demand response technologies to large scale plant improvement investments can offer reliable and predictable demand reductions and energy savings.

The electricity system load profile of Sri Lanka has a high evening peak, and recently, some steps have been taken to mitigate this, including the new tariff structure, but annual load factor, which shows the ratio between peak demand and average demand, continue to show a clear increasing trend. Therefore, studying the system load profile and finding further options to flatten the system load curve is a timely requirement. DSM Unit has been established in order to address these issues.

A Green Village was inaugurated on 19th June 2015. DSM unit of R&D Branch and North Western Province of CEB jointly inaugurated a scheme of LED distribution among the domestic customers of the Green Village in Kurunegala on 2nd November 2015 at YMBA Kurunagala. The scheme facilitates customers in the Green Village to procure LED on a loan recoverable in 12 monthly instalments with zero interest rate. Many interested customers participated in the inauguration and procured LED Lamps.

3.8.6.5 Reliability and Quality of Supply

Reliability and quality of supply in Sri Lanka has huge scope for improvement. During 2015–2016, Sri Lanka suffered three country-wide blackouts within the span of 7 months[63]. All these blackouts were attributed to poor operation of the protection system, lack of operational flexibility and bottlenecks in the transmission system. Strengthening the transmission system, improving the 33/11 kilovolt (kV) medium voltage network, and upgrading the protection system are needed to ensure reliable operation of the power system. These interventions will also help increase absorption of intermittent wind and solar power which in turn will contribute to achieving government targets for clean energy development. Similarly, these will improve the quality of power supply in rural areas, where currently the quality is low. Recently Asian Development Bank has provided grant to undertake detailed studies for power system reliability improvement which is presently in progress. The reports are expected to be available in March 2019.

Presently, in Sri Lanka, there are no ancillary services in the power system except black start plants. As the grid is small, any kind of frequency imbalance is dealt with by available hydro plants and oil-fired plants. But, as the grid grows bigger, coupled with rapid penetration of RE, ancillary services for primary response and secondary response are vital to the grid stability. By 2050, with 100% RE target, Sri Lanka will need to have a significant amount of energy storage facility in place. Also, to avoid emissions, by 2050, gas turbines will no longer be a plausible option to meet peaking power demands and pump and battery storage will be the two most suitable means for meeting peak demand.

[62] CEB Annual Report 2015
[63] https://economynext.com/ADB_aid_for_Sri_Lanka_power_system_reliability_study-3-9584-.html

3.8.7 Smart Grid Scenario

3.8.7.1 Introduction

In recent years Sri Lanka has significantly improved its electricity access and achieved a national electrification rate of 98.7% in 2018 compared to 29% in 1990. However, the sector struggles to (a) meet growing demand for electricity at a low cost and acceptable reliability rates, and (b) attain long term sustainability. Diversification of the generation mix, especially from renewable energy sources, improved network efficiency, and supply and demand side management are the only way to correct this situation. The transmission network also needs expansion and modernization, particularly in the former conflict-affected areas in Northern and Eastern provinces. Another challenge is to improve system reliability and cut technical losses. Medium voltage (MV) network of 33 kV and 11 kV also need augmentation to supply reliable power in rural areas, where many of the poor households remain unconnected or have poor quality of supplies. Finally, the government intends to pursue financial, managerial, and institutional reforms, in line with the Sri Lanka Electricity Act, 2009.

Sri Lanka started experimenting with select smart grid technologies recently as listed below.

- General Electric in collaboration with CEB deployed the centrally integrated control and load forecasting system in the National System Control Center (NSCC) in Colombo. The system will cover 100% of the nation's transmission power flow by managing peak loads of 2,500 MW
- JLanka Technologies, a dominant player in the residential solar PV market in the country, introduced their smart meter device, ePro1000 which helps every home and office to monitor and manage the electricity consumption and other electricity parameters

3.8.7.2 Smart Grid Roadmap for Sri Lanka

The Smart Grid Roadmap recommended in this section are for CEB and LECO. The key assumptions behind the proposed roadmap are:

a. New Policies and regulations will be recommended by 2020 for expansion and integration of renewable energy sources to achieve the vision of 100% RE by 2050
b. Growth of renewable energy resources including rooftop PV will accelerate in the coming years owing to policy mandates as well as cost reduction of PV systems making them economically attractive for larger sections of customers
c. New initiatives/projects and Policies will be initiated for AMI, GIS, integrated billing system etc to reduce T&D losses and improved asset performance in the coming years

The Smart Grid Roadmap recommended in this report are in 3 phases:

a. Immediate Term (2018-2020): Proposed some immediate action items that can bring immediate results

b. Near Term (2020-2025): Proposed a set of smart grid initiatives that will yield benefits to all stakeholders and lead to significant improvement in the power supply position and customer satisfaction

c. Medium Term (2025-2030): Proposed several measures that would transform CEB and LECO to modern utilities using planning tools and advanced automation and IT systems and analytics to optimize the assets and operations

The above steps are described in detail in the following sections:

3.8.7.2.1 Sri Lanka Smart Grid Roadmap 2018 – 2020

Sri Lanka Smart Grid Roadmap 2020 proposes certain immediate steps for CEB and LEEO may adopt for initiating their smart grid journey to move ahead from the present state (in 2018) to 2020 in following areas: Strategy Management and Regulation (SMR), Organization Structure (OS), Grid Operations (GO) and Work and Asset Management (WAM).

1. Strategy, Management, and Regulatory (SMR)

Present Maturity Level (In 2018): 0; Target Maturity Level by 2020: 1

Both CEB and LECO should formulate their Smart Grid vison and Roadmap. Planning needs to be done to achieve targets for 2020, 2025 and 2030. CEB and LECO may target to achieve maturity level-1 by 2020 by undertaking following steps:

- Define Smart Grid Vision and Roadmap, strategy and policies in consultation with Ministry of Power and Renewable Energy
- Arrange training to key personnel to have common understanding about smart grid vision and technologies
- Initiate discussions with regulators and other key stakeholders on the Smart Grid Roadmap
- Make departmental structure for priority smart grid technologies (SCADA/DMA, Substation Automation, AMI, OMS etc) and define their role and responsibilities
- Identify areas for renewable energy growth and integration with grid
- Identify potential area for smart grid pilot projects
- Approval of funds for the pilot projects

2. Organization and Structure (OS)

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level (In 2020): 1

CEB and LECO should undertake following steps:

- Organizations should articulate and communicate the need to build smart grid competencies in their workforce
- Organization structure and workforce needs to be aligned as per Smart Grid Vision and Roadmap
- Leadership should demonstrate a commitment to change the organization in support of achieving smart grid objectives and targets by assigning resources and budgets
- Conduct workshops and awareness sessions on smart grid technologies and needs across multiple functions/line of business to support smart grid activities

3. Grid Operations (GO)

Present Level (In 2018): 0; Target Maturity Level to achieve in 2020: 1

Few projects are in progress in CEB and LECO for strengthening of electrical network. We recommend the following steps to reach maturity level 1 in grid operations domain:

- Prepare the utility specific Smart Grid Roadmap for (10~15 years) and get it approved by the Board of Directors
- Define Smart Grid as an important item in business plan, budget and annual revenue requirement (ARR) plan and define future work plan for the same

- Identify business case for new equipment and systems related to smart grid for at least one business function (e.g. AMI, with remote connect/disconnect, SCADA/DMS, GIS etc.) may be undertaken
- Define strategy and plan for proof of concept projects and/or component testing for grid monitoring and control underway related to smart grid technologies
- Establish framework to calculate outages and reliability indices at distribution level
- Implementation of peak load management through demand response (DR) at distribution level
- Make plan to implement SCADA/DMS, substation automation and IT systems in phased manner in urban areas by 2020
- Make strategy and plan to implement pilot projects of AMI at select locations
- Implementation of cyber security measures such as:
    - Identity and Access Management System
    - Implement relevant recommendation of statutory authorities in the country (If any)
    - Compliance with IEC or country specific cyber security standards

4. Work and Asset Management (WAM)

Present Maturity Level (In 2018): 0 (Default); Target Maturity Level (in 2020): 1

Looking into present progress of work, it is expected that CEB and LECO could target for Maturity Level-1 by 2020 by undertaking following steps:

- Define business case for GIS for asset mapping and consumer indexing at transmission and distribution levels (only distribution for LECO) and get approval for the same
- Perform consumer indexing at distribution level and map it on GIS
- Implementation of ERP system
- Plan for load forecasting every year and upgrade the network for increased load growth in each region

3.8.7.2.2 Sri Lanka Smart Grid Roadmap 2020 – 2025

Sri Lanka Smart Grid Roadmap 2025 defines the progressive trajectory of developments from the state in 2020 to 2025 in 7 domains as recommended in the following sections:

1. Strategy, Management, and Regulatory (SMR)

Maturity Level (In 2020): 1, Target Maturity Level (by 2025): 2

For achieving maturity level-2 by 2025, CEB and LECO need to undertake following measures:

- Approval and acceptance of smart grid roadmap from higher management and ministry across all multiple functions and line of business. Include the same in the business plan of CEB and LECO
- Approval for smart grid projects and investments as envisaged in the Smart Grid Roadmap
- Establish smart grid governance framework and define its hierarchy in alignment with Smart Grid Roadmap
- Update policies and regulations if needed to implement measures envisaged in the approved Smart Grid Roadmap

- Support from funding agencies for smart grid projects and make plan / strategy to implement smart grid projects such as SCADA/DMS, AMI, OMS etc. Identify potential areas where new projects can be implemented

2. Organization and Structure (OS)

Maturity Level (In 2020): 1, Target Maturity Level (by 2025): 2

For achieving level-2 by 2025, CEB and LECO need to take following steps:

- Approval of a Manpower Plan (including Training Plan) in alignment with the approved Smart Grid Roadmap to build adequately skilled workforce in all LOBs to support the implementation of the smart grid initiatives prescribed in the approved Smart Grid Roadmap
- Based on approved Smart Grid Roadmap, restructure the organization hierarchy and its business process which can align end process for smart grid operations
- Create cross functional teams among all LOBs for implementation of smart grid initiatives as per approved Smart Grid Roadmap
- Plan for linking of compensation and incentive plans with achievement of smart grid milestones

3. Grid Operations (GO)

Maturity Level (In 2020): 1, Target Maturity Level (by 2025): 2

For achieving Maturity Level 2 by 2025, CEB and LECO need to take following measures:

- Create a new generation resources and transmission network, substations, medium voltage and low voltage lines as well as upgrading the transmission and distribution capacity to meet the demand growth in the most efficient manner
- Bifurcation and trifurcation of 11kV lines wherever required to improve HT:LT ratio
- Replacement of old wire/undersize conductors/cables and replace old wire joints on overhead LV lines with proper crimped joints
- Establish demand response (DR) for peak load management at customer level in select regions
- Establish SCADA/DMS in urban areas in phased manner by 2025
- Establish outage management system (OMS) for efficient outage restoration
- Undertake pilot trials on Smart Microgrids for campuses, industrial parks etc
- Undertake pilot trails in Energy Storage for grid balancing on feeders with higher penetration of renewable energy
- Pilot trials on Vehicle Grid Integration (VGI) on EV charging stations

4. Work and Asset Management

Maturity Level (In 2020): 1, Target Maturity Level (by 2025): 2

For achieving Maturity Level 2 by 2025, CEB and LECO may take following steps:

- Systems for tracking inventory and event history of assets on GIS maps
- Develop and implement a communication systems architecture to meet near term and long-term communication need adopting a multi-tier, multi-service telecommunication infrastructure architecture consisting of a core network and an edge network

- Development network model for the distribution grid up to DT level so that modelling studies can be undertaken for assessing various scenarios of network upgrades to balance demand and supply most optimally
- Prepare plan for mobile workforce management (MWFM) systems

5. Technology

Maturity Level (In 2020): 0 (Default), Target Maturity Level (by 2025): 1

CEB and LECO can target Maturity Level 1 by 2025 by undertaking following measures:

- Enterprise IT Architecture: CEB and LECO must develop an enterprise IT Architecture and start its implementation. Need to retire IT applications that are not in use; and integrate those being used through a middleware. The proprietary applications which cannot be integrated even through a middleware must be replaced with commercially available off the shelf (COTS) applications. Services of an international IT Consultant may be availed for achieving this objective. The approved enterprise IT Architecture should enable integration of new assets and applications acquired by different LOBs
- All IT applications should adopt change control process e.g. configuration management, patch management, remote updating of applications and integration capability for future integrations
- Implement single integrated billing systems in CEB and LECO covering every type of customers
- Conduct audit for cyber security and adopt the relevant recommendations to secure systems from cyber attacks
- Prepare cloud strategy for future expansion

6. Customer

Maturity Level (In 2020): 0; Target Maturity Level (by 2025): 1

It is recommended to undertake following steps to achieve Maturity Level 1 by 2025:

- Conduct research studies for customer experience, satisfaction and benefits through smart grid technologies as per approved smart grid roadmap. These studies will identify customer benefits and satisfaction. Utilities may conduct these studies with input from different categories of customers in urban and rural areas
- Conduct workshops to educate customers about Smart Grid Vision and Roadmap of the utilities
- Consult with regulators and / or other government related organization regarding impact of technologies on different categories of customers

7. Societal and Environmental

Maturity Level (In 2020): 0; Target Maturity Level (in 2025): 1

It is recommended to undertake following measures to achieve Maturity Level 1 by 2025:

- Publish the smart grid roadmap with emphasis on:
    - Utility's role in environmental and societal aspects with respect to Smart Grid Vision and Roadmap
    - CEB and LECO should publicly promote the environmental benefits of using smart grid technologies

   - Utility's role in protecting the nation's critical infrastructure
- Approved environmental compliance records may be available for public inspection

3.8.7.2.3 Sri Lanka Smart Grid Roadmap 2025 – 2030

1. Strategy, Management and Regulatory (SMR)

Maturity Level (In 2025): 2, Target Maturity Level (by 2030): 3

For achieving maturity level 3 by 2025, CEB and LECO need to undertake following measures:

- Establish Smart Grid Governance Model for smart grid development and decision making. Define roles, process and tools for the same
- Designate a Single Smart Grid Leader in all key line of businesses with clearly defined authority to implement the measures envisaged in the approved Smart Grid Roadmap
- Adopt smart grid vision, strategy and business case in organization's vision and strategy

2. Organization and Structure (OS)

Maturity Level (In 2025): 2, Target Maturity Level (by 2030): 3

For achieving Maturity Level 3 by 2030, CEB and LECO need to take following measures:

- Redesign organization structure to support smart grid initiatives e.g. matrix organization structure or similar and also execute this structure in view of the new programs and projects for 2040
- All changes in organization structure, appointments / transfer / changes being made in consideration and support with smart grid program and projects
- Knowledge Management framework to be put in place to capture the learnings from technology trials and new projects planned as per approved Smart Grid Roadmap. This knowledge must be institutionalized

3. Grid Operations (GO)

Maturity Level (In 2025): 2, Target Maturity Level (by 2030): 3

For achieving Maturity Level 3 by 2030, CEB and LECO need to undertake following measures:

- Building new generating plants, transmission lines, substations and medium voltage (MV), low voltage (LV) lines and upgrade the capacity of existing generation, transmission and distribution systems to meet projected demand
- Increase transformation capacity at DT level to meet the demand target for 2030
- Plan for rollout of EV charging infrastructure and Vehicle to Grid Integration in all urban areas
- Deployment of advanced analytic solutions to ensure important grid operational data is available in near real-time to key decision makers in all lines of business (LOBs), dashboard with relevant information are made available in each LOBs
- Implementation of Fault Location, Isolation and Service Restoration (FLISR) systems with real time load and voltage data on selected urban and rural feeders
- Establishment of dedicated Smart Meter Operation Centre (SMOC) that will monitor and control smart meter operations and provide centralized information repository of smart meter data accessible to other users and applications supporting customer service and grid operations

- Advanced ground fault detection by installing protective relays (or IEDs) to detect high impedance (very low fault current) faults for faster isolation of downed conductors/ section promoting enhanced safety and improved service reliability
- Implementation of state of art Security Operation Centre (SOC) to safeguard the system from cyber and physical attacks

4. Work and Asset Management

Maturity Level (In 2025): 2, Target Maturity Level (by 2030): 3

For achieving maturity level 3 by 2030, CEB and LECO need to undertake following measures:

- Asset performance trend analysis and event audit reports are available for all major assets and systems
- Integrated view of all major/ key assets on GIS maps with remote monitoring facility and their further integration with ERP system, outage management system (OMS) and mobile workforce management system (MWFM) covering all major urban areas
- For reliable performance of all automation and IT systems, their communication systems are upgraded at frequent intervals
- Network model of transmission and distribution grids up to DT level is regularly updated and modelling studies undertaken for accessing various scenarios of network upgrades to balance demand and supply most optimally
- Analytical tools for predictive maintenance are deployed on trial basis

5. Technology

Maturity Level (In 2025): 1, Target Maturity Level (by 2030): 2

For achieving maturity level 2 by 2030, CEB and LECO need to undertake the following measures:

- Alignment of line of business with enterprise IT Architecture across entire organization. If required modify business process to align it with IT Architecture and systems
- Framework in process for change control of all IT applications and infrastructure
- Conduct pilot trials on wide area monitoring and distributed sensor networks
- Cloud services are in place and all new applications are hosted on secured public cloud; existing applications are migrated to the cloud as the old hardware becomes redundant

6. Customer

Maturity Level (In 2025): 1, Target Maturity Level (by 2030): 2

For achieving maturity level 2 by 2030, CEB and LECO need to undertake following measures:

- Carry out research studies on enhancing customer experience and benefits through smart grid technologies envisaged in the approved Smart Grid Roadmap. These studies may be conducted for different categories of customers in both urban and rural areas
- Utility's vision of future smart grid is clearly communicated to customers
- Analyze electricity consumption behavior and pattern of residential customers area-wise and align systems to support their usages pattern and minimize outages; model the reliability of grid equipment
- Assess the impact of new smart grid systems and services on different categories of customers
- Studies are conducted on the implications of data privacy and protection of customers

- Measures for security and privacy of customers are built in the specifications for new systems being procured
- Implementation of a state-of-the-art customer portal
- Prosumer enablement and net-metering plans available to all customers
- Leveraging social media for customer engagement effectively

7. Societal and Environmental (SE)

Maturity Level (In 2025): 1, Target Maturity Level (by 2030): 2

CEB and LECO should undertake following steps to reach Maturity Level 2 by 2030:

- Finalize work plans for addressing the societal and environmental issues through smarter technologies
- Undertake proof of concept projects that can demonstrate the environmental benefits of smart grid technologies and applications
- Societal and environmental benefits are estimated in the DPR for each project
- Offer smart grid supported energy efficiency programs for customers
- Provide details of granular level energy consumption details to customers – from AMI systems through customer portal
- Adopt "Triple Bottom Line" (TBL) framework for key decisions – TBL method covers Societal, Environmental and Financial aspects of every investment plans/projects
- Diesel Generator replacement with battery (that can be leveraged for load balancing) at customer premises is actively promoted through innovative business models
- Clean energy being moved to the core of the business model of CEB and LECO

8. Value Chain Management (VCM)

Maturity Level (In 2025): 0; Target Maturity Level (in 2030): 1

CEB and LECO should undertake following steps to reach maturity level 1 by 2030 on Value Chain Management:

- Formulation of a strategy for creating and managing a diverse resource portfolio
- Identification of:
  - Assets and programs for load management
  - Distributed generation resources, its locations and its capabilities
  - Security requirements to enable interactions with an expanded portfolio of value chain partners
  - Evaluate and identify the security requirement to enable interaction with expanded portfolio of value chain partners

The recommended Smart Grid Roadmap for CEB and LECO are indicated in a phased manner below:

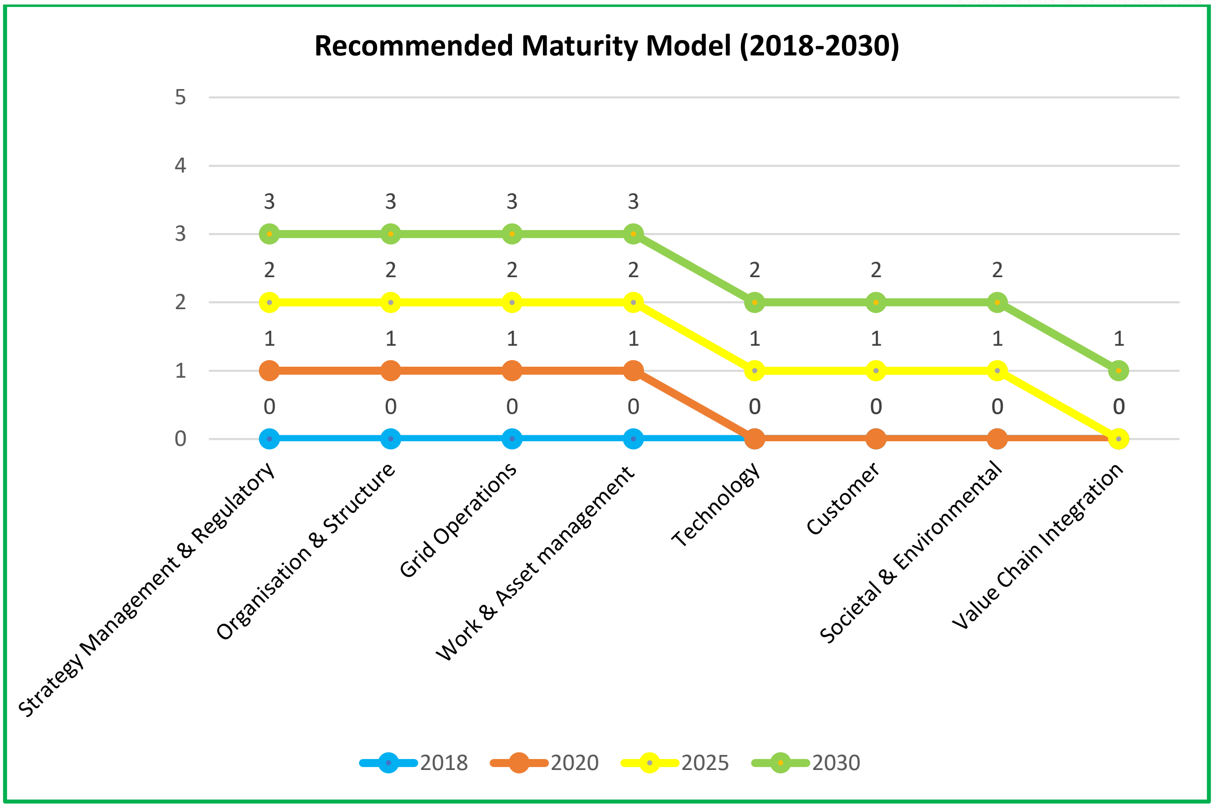


Figure 61: Recommended Smart Grid Maturity Levels (2018-2030)

3.8.8 Cost Benefit Analysis

3.8.8.1 Background

Sri Lanka is the only country in South Asia that has 100% electricity accessibility with a stable supply. With increasing demand, Sri Lanka has had to increase its dependence on costly imported fossil fuels (49 % mix) from a predominant hydro power earlier. Current generation capacity stands at 4054 MW. Any variability in the monsoon pattern hits the hydro sector hard. The peak electricity demand has grown at 3.2 % from 2008-2015, while demand increased from 1992 MW to 2283 MW. The domestic sector is the biggest consumer (40 %) followed by industrial (33 %) and commercial (27 %). By 2017, about 550 MW of RE projects were integrated (Mini-hydel 353 MW; Wind 129 MW and Solar PV 51 MW), to diversify from high cost thermal power generation. Integration of RE is one of the priority areas as it expected to grow rapidly in the coming years, to wean the country off fossil generation.

Based on the above recommendations till 2030 in each of the eight domains of smart grid, ISGF has identified various activities that need to be undertaken by the utilities in different phases for example, "Evaluate a MV Feeder that has a high RE generation (> 50%) with potential for reverse flow during low load periods" and also identified one project for development in future based on various parameters as mentioned below. These parameters have also taken into account the envisaged or future targets of the governments in terms of electricity supply, renewable energy development, cross border power trading, operational performance of the utilities etc.

With the increase in renewable generation and roof top PV penetration, integration of these variable resources into low voltage grid poses serious concern on grid reliability and increases the operational difficulties for the utilities. Therefore, load control mitigation measures need to be in place with the increase in roof top PV penetration in the urban areas. The detailed cost benefit analysis for such a project has been done considering its priority and the huge amount of benefits it accrues compared to the investment it needs.

National priority + Business requirement of the utilities + Investment & duration of project development + Higher return on investment

3.8.8.2 Project Objective and Description

Evaluate a MV feeder that has a high RE generation (> 50%) with potential for reverse flow during low load periods. Integrate high penetration of RE (say 50MW) on a MV Feeder:

- 3 sets of 3x 150 KVA Single phase, MV Line Regulators (USD 17,000 each)
- 2 units of above-ground containerized 4 x 60 KW flywheels for inertia and PQ mitigation (USD 3,000 KW each)
- 2 units of 250KW x 4 hr. BESS (USD 240/KWh)
- Set of 3 x 20 single phase line sensors (USD USD1800 each)
- Telecom, Hubs, Controllers (USD 75,000 lump sum)

Financial Data:

- Required rate of return (Govt. / IFI rates) - 8%
- Tax rate - 25%

Initial Investments:

Parameter	Cost
Equipment	USD 2,256,000.00
Engineering and Development	USD 150,000.00
Installation & Commissioning	USD 150,000.00
Total Initial Investments	**USD 2,556,000.00**

Benefits	YEAR	1	2	3
Annual PQ Improvement Impact (2multiple x 0.10cents x 10 MW x 1000 hr.)		USD2,000,000.00	USD2,000,000.00	USD2,000,000.00
RE dispatch ability /Decrease in curtailment (10% of 50MW x 0.03cents x 2000		USD300,000.00	USD300,000.00	USD300,000.00
Total Benefits		**USD2,300,000.00**	**USD2,300,000.00**	**USD2,300,000.00**

Costs (Excluding Initial Capital Investments)	YEAR	1	2	3
Operations		USD50,000.00	USD50,000.00	USD 50,000.00
Maintenance		USD40,000.00	USD40,000.00	USD 40,000.00
Project management, customer support		USD35,000.00	USD35,000.00	USD 35,000.00
Misc.		USD10,000.00	USD10,000.00	USD 10,000.00
Depreciation on capital expenditures (calculation uses 5-year period)		USD511,200.00	USD511,200.00	USD511,200.00
Total Costs		**USD646,200.00**	**USD646,200.00**	**USD646,200.00**

Totals	YEAR	1	2	3
Net Benefits (Costs)		USD1,653,800.00	USD1,653,800.00	USD1,653,800.00
Tax		USD413,450.00	USD413,450.00	USD413,450.00
Value after tax		USD1,240,350.00	USD1,240,350.00	USD1,240,350.00
Depreciation added back		USD511,200.00	USD511,200.00	USD511,200.00
Cash flow	-USD2,556,000.00	USD1,751,550.00	USD1,751,550.00	USD1,751,550.00
Cumulative cash flow	-USD2,556,000.00	(USD804,450.00)	USD947,100.00	USD2,698,650.00

Evaluation Metrics	Cautionary Note
Net present value (NPV): USD1,957,914.23	All costs are budgetary for discussions purposes only
Internal rate of return (IRR): 46.92%	A detailed project report (DPR) needs to be done
Payback period (in years): 1.46	

3.8.8.3 Relevance of CBA Analysis to Smart Grid Transition

With increasing demand, Sri Lanka has had to increase its dependence on costly imported fossil fuels which is no longer sustainable. To alleviate this situation, Sri Lanka must set high targets for solar and wind resources. Integration of RE is one of the priority areas as it expected to grow rapidly in the coming years, to wean the country off fossil generation. The addition of such large solar PV on MV and LT levels will likely cause power quality issues. Multiple active/reactive power and load control mitigation measures will be needed to manage this well at higher targeted penetration levels.

Benefits:

The CBA results look promising with a positive NPV and short payback and is worth implementing.

A detailed project report (DPR) with formal quotes will be required.

The following are the key benefits:

1. Power quality improvement impact due to high penetration VRE amounts to USD $ 2,000,000 per annum
2. Improvement in VRE curtailments by 10% amounts to USD $ 300,000 annually
3. If successful, similar projects can be implemented in other semi-urban and remote clusters
4. Local contracting and other EPC sectors will get a boost as a result of such multi-year projects
5. Utility O&M services will also get a boost in operating and maintaining distributed devices
6. All these are distribution voltage power equipment and hence can be managed by the Utility

3.8.8.4 Potential Barriers to Success

1. Need to ascertain these new technology devices can be operated in the environmental conditions (temperature, humidity, etc.)
2. Some special training/skills may be required for installation, calibration and commissioning of such equipment
3. BESS, Flywheels, Sensors and telecom and associated equipment installations require coordinated planning for good outcomes
4. It is important that the systems and architecture designs of this pilot project be supervised by global experts

4 Way Forward

4.1 Overview

Smart Grid transformation is a capital intensive and a very complex (often politically challenging) reform-based process that needs to be enabled to realize the full potential of investments later on. Once enabled, the building-blocks of subsequent investments and/or reforms, tends to fall into the policy/regulatory framework in a forward-looking, market oriented, "business-as-usual" guiding structure.

Almost all utilities (even in the developed countries) began on a SGMM level of "near-zero" or "near-one" level, despite their stable histories of technology, policy and regulatory advancement. This resetting is needed, as Smart Grid transformations are about changing the paradigm of the electricity market from a centralized generation and a one-way flow power system, into a more decentralized, multi-way power flow system duly leveraging the various technologies available today.

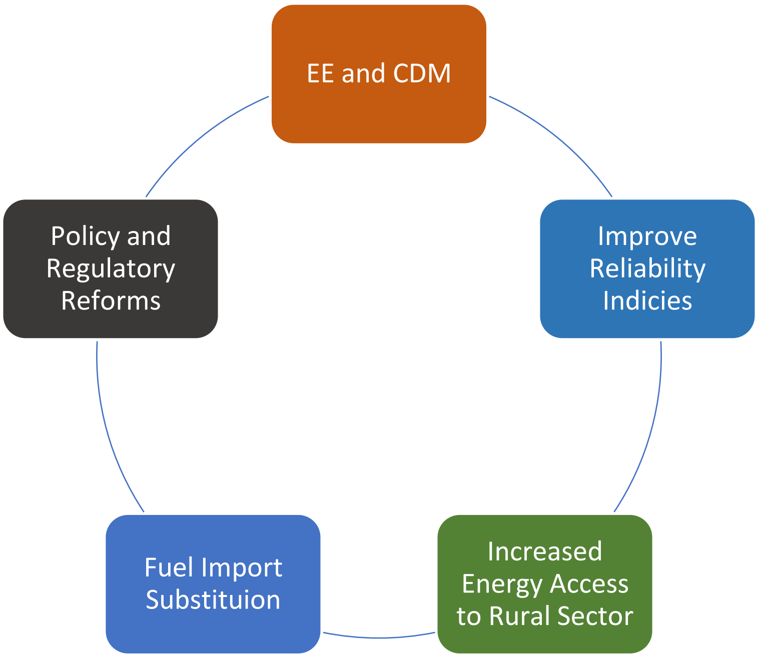
The "way forward" strategies for the SAARC countries will need to be prudently staged, while keeping the main objectives of the smart grid roadmap in focus - i.e. Distribution Automation; Network Reliability; Renewables Integration; Geo-spatial Information Systems; Distributed Generation; Fuel Security and Retail Customer Choice etc. Although, cost of most of the systems have fallen substantially from a decade ago, yet, the overall investments to undertake all of the above in a short time is huge and likely not feasible from the organizational capacity standpoint as well. Hence the staged approach.

4.1.1 Common Minimum Strategies

A sound footing in enabling Smart Grid transformation, is to "shore up the foundation" to secure the benefits of the "low hanging fruits" first. These often tend to lie in the efficiency, effectiveness and reliability areas. Improvements in these areas yield a much higher multiple for economic growth and public welfare, while usually costing less than new additional generation. A common set of minimum strategies apply to each of the SAARC countries. These are:

1. Lowering energy consumption and demand growth though non-wire alternatives (NWA) of demand side management (conservation and demand response) and power-factor improvement (VAR). This is the lowest cost strategy. In many countries these have been achieved for almost half the cost of adding new generation and also allows for the wires to feed more consumer loads
2. Improve the reliability indices (SAIDI, SAIFI, CAIDI) of power supply at the various "Delivery Points" which often exists at the medium voltage levels. For this, distributed generation (renewable and/or otherwise) would help as opposed to the "wires capacity uplift" and central generation
3. Energy Access for the rural sector is best delivered through solar/wind/biomass/biogas in isolated microgrids (for now) capable of expansion and eventual tie to the grid later
4. Fuel Import substitution efforts (i.e. displace imported diesel, gas or coal) for generation is highly based on availability of domestic surplus of other fuels (which itself could be scarce or used for other sectors)
5. Regulatory and Organizational reforms are needed to ensure that effectiveness and "market-like" price signals (albeit sector subsidized) are sent to all consumers. Any subsidies must not occur at the bottom-line profitability to the utilities. Price signals have yielded the best results in demand supply management

The following pictorial charts depicts the above.



4.1.2 Country Specific Short-Term Power System Improvement Strategies

Linking new investments to the minimum strategies (above), yields better results for the medium-term for all stakeholders (Govt., utilities, regulators, customers and industry). However, each country has a unique set of historical policy challenges and hence no "one-size fits all" transformation model works.

Country specific initiatives/thrusts are outlined below (discussed in the previous Chapter). It is recommended that these be implemented in the short term (3-5 years) to gain a strong base to launch the Smart Grid transformation outlined later in this Chapter. Without the benefit of an improved/robust power systems infrastructure, all other aspects of Smart Grid transformation investments are unlikely to yield positive results.

4.2 Afghanistan

Afghanistan has only one utility the DABS which is fully owned by the Government. Afghanistan's key challenges are (i) Lack of generation capacity, (ii) Increasing constraints in transmission and distribution systems, (iii) Weak financial management and sustainability of sector entities caused by lack of cost-reflective tariff frameworks, and (iv) Inadequate sector regulation. Imported electricity constitute nearly 80% of the total power consumption, and the import bill of energy has increased 14 times from $16 million in 2007 to nearly $224 million to 2015. Less than 9% of the rural population has access to electricity, while more than 75% of Afghans live in rural areas and 67% of the gross domestic product comes from rural areas. Afghanistan has an estimated potential for 23 GW Hydro, 67 GW wind, and 222 GW solar. Installed capacity of solar PV is 13MW mainly stand-alone systems and used for rural house lighting purposes.

From the above factors, the following would be the strategic steps to move forward:

Fuel security and Generation Expansion:

1. A five-year focused emphasis should be placed on achieving (a) New water treaty with neighboring countries for its hydro power development (to yield 10% target or 2.3 GW); (b) Exploit indigenous coal reserves for domestic thermal generation (to yield 5% target of 1.0 GW)

   A three-year focused emphasis to promote Off-Grid networks using renewables with a full thrust for the development of its wind/solar potential (to target 20GW capacity) particularly for its economic development (which is rural based)
2. Interconnecting the regional grids to one common grid and centralized scheduling and dispatch in next 2-3 years
3. Define area load dispatch centres, and SCADA hierarchy for the country. Make plans to implement SCADA/DMS, substation automation and IT system in phased manner in urban areas by 2020

Roadmap is recommended in 3 stages i.e. immediate terms (2018-2020), near term (2020-2025), medium term (2025-2030).

- In immediate term to define strategy, plans for power system gird modernization aligning with long terms goals of Government. These are essential goals which will be footsteps toward smart grid. This would also involve a SGMM compass survey and preparation of a detailed Smart Grid Roadmap with input from all stakeholders
- Going forward to near term goals, proposed initiatives will bring benefits to all stakeholders as well as improve power supply position and customer satisfaction
- Medium term goals would transform DABS to modern utility with advanced automation and IT systems. Beyond 2030, DABS could target for higher levels of maturity with respect to all 8 domains of SGMM

4.3 Bangladesh

Bangladesh economy has undergone a major transformation since 2004 and has seen an annual GDP growth of 6.5%. Over 90% of the population has access to electricity with the distribution system having a low network loss in the range of 10%. It is Asia's 7th largest producer of natural gas (which the government now wants to conserve). Its 20,000 MW of generation (mostly old gas plants) is targeted to double by 2030. Solar PV penetration is low at 285 MW. Although Bangladesh has the most successful rural energy access in Asia, about 70% of rural lighting comes from kerosene. The major problem in the grid today is (1) Overloading of equipment due to constant load growth; (2) No DSM (DR/Conservation) systems in place; (3) Poor reactive power support and hence power quality problems; (4) Old distribution network. Left unchecked, it will harm the economic growth and investments.

From the factors above, the following would be strategic steps to move forward:

1. Alleviate poor power quality and Volt-Var support in the distribution segment

A three-year focused emphasis should be placed on achieving (a) power-factor improvement to 0.95+ at large and medium load points (industrial/commercial/residential segments) limiting feeder over-loading issues; (b) Lower line losses from 10% to a more manageable 6% range (a 40% improvement) including power thefts.

2. Upgrade old (select/stressed) Transmission and Distribution networks to integrate Distributed Generation

A five-year focused emphasis should be placed on achieving (a) capacity improvements to its transmission and distribution segments where the load growth is high; (b) Off-set economic losses due to load-shedding; and (c) integrate DERs in the system optimally.

3. Set up regional centers to offer Conservation and Demand Management Programs

A five-year focused emphasis should be placed on achieving (a) lowering energy consumption by 25% through efficient equipment; (b) lower peak demand by 10%; and (c) make this subscription-based with incentives for customers to avail benefit and values.

4.4 Bhutan

Bhutan is well endowed with hydroelectric power (5307 MW wheeled to India) and hence enjoys some of the lowest tariffs in Asia. Bhutan has a peak load of 362 MW. However, its distribution system (due to its forested and mountainous terrain) is prone to faults and lengthy restorations. Currently, the maximum period of power supply restoration is one day in urban and two days in rural areas. Monitoring/calculating reliability indices are also inaccurate but improving. Statistics for the year 2017 were: (1) SAIDI - 10.47 hours/customer/year; (2) SAIFI - 29.42 times/customer/year; (3) CAIDI - 0.57 hours /incident. Per the Bhutan Electricity Authority (BEA), the outage-minutes of 369,005 listed under 'Beyond the Control of Bhutan Power Corporation (BPC)', (which is 54% of total 678,595), is a matter of serious concern. A new data format was issued by BEA in 2017 and it is expected that more accurate data will be captured in 2018. At any rate, even with a large variance, there is huge scope for significant improvement in Bhutan's reliability indices.

From the factors above, the following would be strategic steps to move forward:

1. Automate fault detection systems in key distribution feeders (through line-sensors) to identify fault location for speedier dispatch of maintenance crew and fast restoration

A three-year focused emphasis should be placed on achieving (a) lowering SAIDI, SAIFI and CAIDI by at least 50% through effective deployment of line-sensors and analytical tools.; (b) to better determine effective preventive maintenance in select areas with forestry services activities for brush clearing.

2. Improve system index and Asset Management

A five-year focused emphasis should be placed on achieving capacity improvements to its identification, asset management and maintenance efforts to lower its outage-minutes index by 75% in the "beyond control of BPC" category through (a) centralized visibility systems; (b) integrated communications systems and (c) a data analytics tool.

Roadmap is recommended in 3 stages i.e. immediate terms (2018-2020), near term (2020-2025), medium term (2025-2030). In immediate terms Bhutan need to define strategy, plans for power system modernization aligning with long terms goals of Government. Near-Term goals, proposes initiatives to benefit improved power supply positions. Medium term goals would transform BPC to a modern utility with advanced automation and IT systems. After 2030, Bhutan could target to achieve higher levels of maturity in all 8 domains of SGMM based on the Governments priorities and business case for BPC.

4.5 India

India has an installed generation capacity of 346 GW (65% thermal; 13% hydro; 20% Renewable; 2% Nuclear). The average PLF over the past 5 years has declined from 70% to 60%. The peak demand met is 172.4 GW. A ten-year energy blueprint published in 2016 predicts 57% of India's total electricity capacity will come from non-fossil fuel sources by 2027. The Paris climate accord target is 40% by 2030. Most of this RE addition will be solar PV (100 GW PV by 2022 of which 40 GW will be Rooftop PV connected on MV and LV grid). Currently, four states are generating over 50% of load from solar PV/Wind and RE curtailments take place regularly (particularly wind). The addition of such large solar PV on MV and LV grid will likely cause power quality issues. Multiple active/reactive power and load control mitigation measures will be needed to manage this well at higher targeted penetration levels.

From the factors above, the following would be strategic steps to move forward:

1. Alleviate poor power quality and availability at Delivery Points in MV and LV network

Despite a robust transmission and surplus generation situation, India suffers extensive load shedding at the consumer level. A three-year focused emphasis should be placed on achieving (a) power-factor improvement to 0.95+ at large/medium load points (industrial/commercial/residential); and (b) Lowering AT&C losses to a more manageable 10-15% range including mitigating power theft.

2. Upgrade critical distribution networks to manage large distributed generation (Solar PV) with distributed energy storage systems

A five-year focused emphasis should be placed on achieving (a) distributed energy storage capacity improvements to select distribution segments where large PV are connected (40GW Rooftop PV Policy) and/or the load growth is high; (b) Off-set economic losses due to load-shedding; and (c) integrate DERs in efficiently.

3. Evaluate near-autonomous load-following of variable-generation (Solar/Wind) on a select distribution station (MV+LV) where renewables share is higher than 50%

Given a very high goal of renewables (170 GW by 2022 including 40 GW RTPV), and the fact that RE curtailing is occurring frequently in four southern states, a five-year focused emphasis should be placed on achieving autonomous variable generation following capability by loads though (a) Peak shaving; (b) load displacement; and (c) energy storage/deferrals through investments in thermal and electrical energy storage devices.

4. Set up conservation and demand management programs in each district of every State

India stands to shave 70 GW of peak generation capacity, if DSM were to be implemented in earnest. Currently only LED lighting has been implemented (with good results). Far more needs to be done by way of energy efficiency retrofits for air-conditioning, agricultural pump sets and other smaller electrical drives. A five-year focused emphasis should be placed on achieving (a) lowering energy consumption by 25% through efficient equipment; (b) lower peak demand by 10%; and (c) make this subscription-based with incentives for customers to see benefit and values.

As indicated in the India section, out of 72 distribution utilities majority of them do not have smart grid roadmaps and all of them have different pieces of automation and IT systems. It is recommended that distribution utilities in India should undertake following steps:

1. SGMM Compass Survey and Preparation of utility specific Smart Grid Roadmaps

2. Integration of New Smart Grid Systems with R-APDRP Systems: Utilities must prepare the IT architecture for integration of new smart grid solutions (AMI, OMS, SCADA/DMS, DA/SA etc) with the R-APDRP systems (Billing & Customer Care, GIS Maps, Energy Accounting Module etc)
3. One Billing System in a DISCOM: Most DISCOMs in India are using more than one billing system: RAPDRP Billing System, Non-RAPDRP Billing System, HT Billing System etc. Billing System is the heart of a distribution Utility's operations and there is a burning need to bring all billing activities under ONE integrated billing system. It is the first step towards efficient energy accounting and loss reduction.
4. **Microgrids:** Microgrids are considered a key component of the 21st century grids for a variety of reasons. The primary focus on microgrids (grid connected smart microgrids) is to ensure reliability of supply for critical loads (with in the microgrid) in the event of a grid failure or extreme weather (or terror/natural disaster) events. The Smart Grid Roadmap of 2013 envisages 31000 microgrids but hardly any progress here.
5. Business Process Re-Engineering (BPR): With more and more automated systems being implemented, there is an urgent need for business process reengineering (BPR) and changes in organizational structure in DISCOMs.

4.6 Maldives

Maldives has population of 341,256 dispersed over 1,192 tropical islands (26 geographical atolls) spreading over an area of 300 sq. km. of which 187 are inhabited, 1,123 are self-contained tourist resorts and 128 are used for industrial/commercial activities. Maldives have a total installed capacity of 363 MW of which 214 MW is diesel generation and only 6MW is renewables (total 186 stations). Each island is effectively a mini grid with a diesel-based generation system. No interconnection exists between the islands. Its capital Male' accounts for 63 % of the total electricity generation of all the inhabited islands. The electricity tariff for diesel-based generation is in the range of USD 0.14–0.50. Total fuel import (2016) was 537,060 metric tons and annual carbon emission totals 473,784 tones.

From the factors above, the following would be strategic steps to move forward:

a. Fuel Import Security and Efficient Renewable Generation Mix

A five-year focused emphasis should be placed on achieving lower diesel import cost through (a) fuel efficient variable speed diesel generators; together with (b) energy storage systems; and (c) solar PV mix

b. Promote Off-Grid Hybrid networks using renewables

A three-year focused emphasis to promote Off-Grid hybrid microgrid networks using renewables with a full thrust for the development of its wind/solar potential for its non-industrial and resort sectors (agriculture, fishing, village clusters, etc.).

c. Set up centers to offer Conservation and Demand Management Programs in each Island

A five-year focused emphasis should be placed on achieving (a) lowering energy consumption by 25% through efficient equipment; (b) lower peak demand by 10%; and (c) make this subscription-based with incentives for customers to see benefit and values.

4.7 Nepal

Nepal is among the countries that are most vulnerable to climate change. Its power sector is interwoven with overlap between the roles of various institutions which are impeding the development of the sector. Inadequate investments have led to a very slow pace of hydropower development, resulting in a widening demand-supply gap, low customer satisfaction and low energy access. Installed power generation capacity has grown slowly from 706 MW in FY2011 to 856 MW in FY2016, (3.9% p.a.) but peak demand for electricity during the same period grew faster, from 946 MW to 1385 MW, (7.9% p.a.), thus widening the supply–demand gap. Peak demand in Nepal in FY2016 was 1,385 MW, with 534 MW of load shedding, resulting in daily load shedding of up to 11 hours during the winter months of January –April. Of the 42 GW of feasible hydropower, only a small share of 1.7 % is tapped.

From the factors above, the following would be strategic steps to move forward particularly to mitigate the January – April shortfall months:

1. Fuel Import Security and Efficient Renewable Generation Mix

A five-year focused emphasis should be placed on achieving lower annual diesel cost through (a) increasing Zero-head Run of the river/canal based micro-hydel generation (target 50 MW); together with (b) solar PV mix

2. Promote Off-Grid Hybrid Networks using Renewables

A three-year focused emphasis to promote Off-Grid hybrid microgrids using clean bio-gasifier generators with electrical/thermal/biochar outputs (Target 10 MW) with a full thrust for the development of its potential for industrial and agriculture clusters.

3. Promote Localized Load Control for Load Shedding/Sharing

A three-year focused emphasis to target 2-10 kW load points for (a) load shedding/sharing and lowering demand by 2.5 MW in each area together with (b) containerized Flow Battery for seasonal energy shifting (target 10 MWh).

4. Set up centers to offer Conservation and Demand Management Programs in each area

A five-year focused emphasis should be placed on achieving (a) lowering energy consumption by 25% through efficient equipment; (b) lower peak demand by 10%; and (c) make this subscription-based with incentives for customers to see benefit and values.

4.8 Pakistan

Pakistan has a total of 28.4 GW generation capacity (66% coal, 25 % hydro, 4% nuclear and 5% renewable), however due to poor plant availability the maximum generation is around 19 GW against a peak demand of 25 GW. Pakistan's Vision 2025 is to add an additional 25 GW. The transmission system contains numerous complexities with inadequate power flow control, reactive power management, power angle and voltage instabilities. All this results in numerous planned and unplanned line trips/outages. Annual forced outages of the 500 kV lines was 122 interruptions (total 29,600 min) and for 220 kV it was 336 (total 141,600 min). The distribution sector is vast with 28 million consumers with average network losses of 18%. The SAIFI and SAIDI indices are equally challenging in many parts of the network (as high as 160-600 SAIFI and 6000-20,00 SAIDI). Until the transmission and distribution system unreliability is tracked and solved, the electricity supply will always be challenging.

From the factors above, the following would be strategic steps to move forward:

1. Explore and Resolve the root cause for its Transmission system's instability and unplanned outages

A three-year focused emphasis should be placed on achieving (a) lowering SAIDI, SAIFI and CAIDI by at least 75% on its transmission (500 kV and 220 kV) systems. While one would expect the installed transmission/generation SCADA systems would have detected these, it appears not to be the case. The root cause could essentially lie in stability swings and inter-area "swings" particularly with long and/or weak transmission lines together with strong generation points. Hence, it is prudent to invest in PMUs to analyze why the cause exists.

2. Explore and Resolve the root cause for its Distribution system's poor reliability and unplanned outages

A five-year focused emphasis should be placed on achieving improvements to its distribution system reliability indices and to lower it by 75% through (a) centralized SCADA/DMS; (b) lower cost distribution PMUs to identify swings in heavy loaded long feeders particularly those with renewables; (c) integrated communications systems and (d) a data analytical tool.

3. Explore Load-Balancing Systems particularly on an Area Basis, if larger share renewables are to be integrated

A five-year focused emphasis should be placed on achieving improvements to area load-balancing efforts and to improve its overall system index and reliability indices through (a) centralized load dispatch and inter-area load-balancing centers; (b) regulatory reform for penalties related to over/under frequency at inter-tie boundaries; (c) integrated bulk TSO and DSO dispatch supervisory systems and (d) a data analytical tool.

4.9 Sri Lanka

Sri Lanka is the only country in South Asia that has 100% electricity accessibility with a stable supply. With increasing demand, Sri Lanka has had to increase its dependence on costly imported fossil fuels (49 % mix) from a predominant hydro power earlier. Current generation stands at 4000 MW. Any variability in the monsoon pattern hits the hydro sector hard. The peak electricity demand has grown at 3.2 % during 2008-2015, while demand increased from 1992 MW to 2283 MW. The domestic sector is the biggest consumer (40 %) followed by industrial (33 %) and commercial (27 %). By 2017, about 550 MW of RE projects were integrated (Mini-hydel 353 MW; Wind 129 MW and Solar PV 51 MW), to diversify from high cost thermal power generation. Integration of RE is one of the priority areas as it expected to grow rapidly in the coming years, to wean the country off fossil generation.

From the factors above, the following would be strategic steps to move forward:

1. Fuel Security and Generation Expansion

A five-year focused emphasis should be placed on achieving securing (a) Wind energy imports from southern India which is in surplus (target 300 MW) through sub-sea cables; (b) Exploit its own wind resources in the coastal areas (additional 200 MW)

2. A three-year focused emphasis to promote Off-Grid networks using renewables with a full thrust for the development of its wind/solar potential (to target 100 MW capacity) particularly for its rural and northern economic development
3. **Set up regional centers to offer Conservation and Demand Management Programs**

A five-year focused emphasis should be placed on achieving (a) Lowering energy consumption by 25% through efficient equipment; (b) Lower peak demand by 10%; and (c) Make this subscription-based with incentives for customers to see benefit and values.

4.10 Medium-Term Smart Grid Transformation Strategies

The following outlines a series of medium-term (5-10 years) strategies that if commenced/enabled would offer a stable platform start for the long-term Smart Grid transformation. These typically include institutional reforms and creation of market structures. These are grouped together, as each country needs to adopt these elements as a part of their individual national policy and planning processes. The following are the key steps:

1. Regulatory Reform

Regulatory reforms are difficult, as it requires Regulatory Authorities to distance itself from governments of all levels (and their policy-making role) into a stand-alone statutory body (as a law tribunal) empowered to adjudicate the customer interests in electricity (and their freedom behind the meter) in a monopoly environment of electricity producers, transmitters and distributors. Given the state of maturity of new technologies already making commercial grade entry, the future of Regulatory jurisdictions to enable a Smart Grid transformation would include:

a. Enshrine Prosumer rights and their self-interests to locally generate, store, consume and locally transact electricity with or without the support of the utility wires
b. Enable value streams from distributed energy resources (DERs), storage technologies (ESS) and demand reduction devices (DRs) to be captured across the utility spectrum as it relates to power system planning and operations. These areas could be in a wide variety of the electricity segment such as delaying wires infrastructure capex, peak shaving, virtual power plants, renewal energy supply, VAR support, etc
c. Separate "carriage and content" in the electricity monopoly. While this has mixed successes in the developed countries, it is still one of the best options for developing economies in order to stave off government/political interventions (where "content" subsidies such as free or subsidized power decreed by the government is often borne by the "carrier" or wires business segment of the utility
d. Enable a market-based tariff structure for all of the above, to allow for the best economical choices as leveraged by Smart Meters in reducing electricity theft and promoting time-of-use (TOU)

2. Distribution Utilities Reform

This area of reform is equally difficult (as regulatory reform) for historical reasons i.e. (a) utilities never needed to be competitive and focus on their customers; (b) are risk averse due to their stable cost-of-service revenue model; (c) the focus is in electricity sales and asset growth, not conservation and demand reduction; and (d) little experience in managing DERs and VPPs in their operations. Given the state of maturity of new technologies already making commercial grade entry, the future of

Distribution Utility business (i.e. Planning, Asset Management and Operations) will require radical changes from its past to enable a Smart Grid transformation, to include:

a. Reshape the distribution system architecture from the traditional one-way power flow to a multiway (or peer-to-peer) networks with increased share of distributed generation (traditional boundaries between generation, transmission and distribution is fast disappearing)
b. Seek alternative strategies in storage technologies as an option towards traditional capacity augmentation in transmission and distribution assets.
c. Focus on Power Quality (in addition to reliability), as present-day digital loads require quality power at constant frequency and voltage on a real time basis

3. Wholesale and Retail Market Operations Reform

Wholesale and retail market and their operations will also need to be revamped to enable Smart Grid transformations. These include:

a. Enable reasonably accurate predictive forecasting of variable resources (such as Wind and Solar) into the generation procurement market mix
b. Move away from long-term (25 year+) inflexible contracts in power purchases, to admit new and shorter lead-time generation assets (e.g. Wind/Solar, biogas and other). The procurement "stack" would need to be short-term focused (say less than 10 years max)
c. With demand now moving to being price-responsive (prosumer, local generation, rooftop PV, storage etc.), the need now is move away from "volumetric" to "transactive" Tariffs
d. Wholesale "Merit Order Dispatch" will need to be graduated towards "Energy Efficient and Environmentally Responsible Dispatch" which would include DERs, VPPs and DRs
e. Large fleets of Electric Vehicles that can be aggregated as virtual power plants which could support short term supply-demand balancing efforts

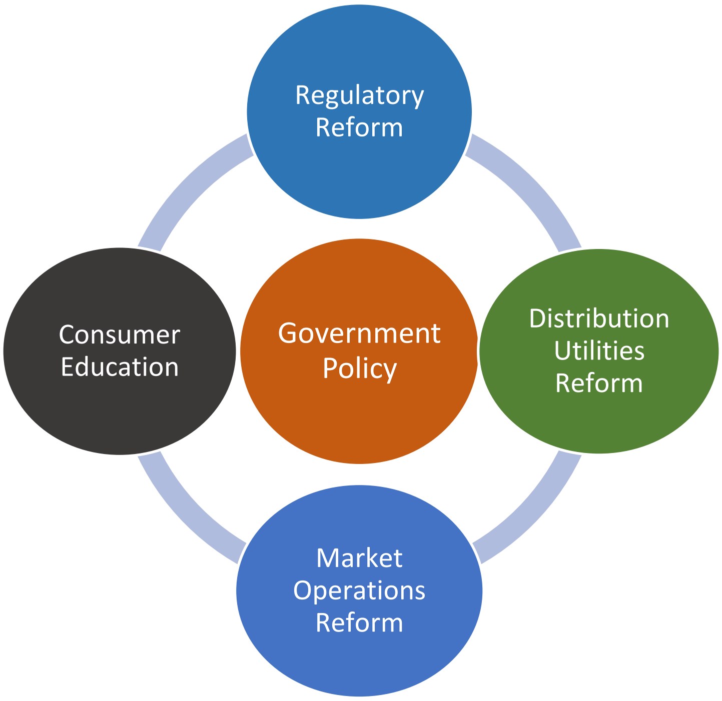
4. Overall Policy Reform

All of the above institutional and market reforms will require tremendous support (and government's test of willpower), to make these structural changes happen and be sustained in the longer term. The following are indicated:

a. Since most of the utilities are owned by the government (Central /State/Municipal), the rate-base is second only to tax-base in its vast outlay, it will be difficult for most governments to divest its control from the electricity sector
b. The market operations, utilities and regulation exist in different layers of governments' influence today, and hence the policy reform has to be in tandem and accommodate inherent "inertia"
c. The move to market-like rates and prosumer-ism, will need exertive consumer education and acceptance (particularly from NGOs and pro-poor organizations)
d. Any and all government subsidies, must now must be funded by the government's own budgets (and recoverable by the utilities). This will place a large dent in government budget allocations

Typically, most governments see the "electoral-cycle" as their true window towards any new policy enablement. Hence, this will not be easy.

The following pictorial charts depicts the above commentary on institutional and market reforms:



4.11 Long-Term Implications to Smart Grid Transformation Strategies

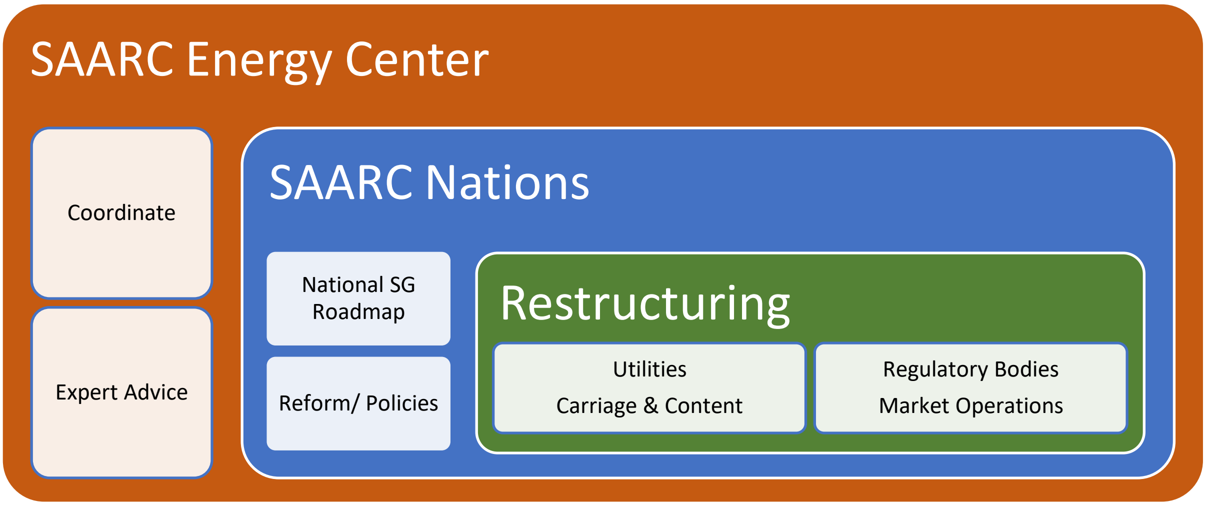
While these transformational shifts are taking place, the focus should be to grow and operate the electricity system to meet demand, leverage economic opportunities (urban and rural), while planning and operating the electricity system efficiently and reliably leveraging smart technologies. Since investments today will shape the infrastructure/economy in 2050, SAARC nations have the enviable opportunity to build this new smart infrastructure without (hopefully) revisiting the mistakes of other countries. The proposed transition to a cleaner power system will insulate the SAARC countries from price spikes of fossil fuels and will be cheaper in the long run.

In the long term a much larger interconnected "SAARC Grid" with diverse mix of energy resources could address the region's needs more effectively and efficiently (and allow for a much higher penetration of renewables) rather than each country fighting their battles separately. In the planning process it is imperative to include all stakeholders and sufficient care should be taken to protect the interests of low-to-medium income groups and other vulnerable sections of the society.

The long-term pursuit would be to boost productivity and quality of life of future generations by helping ensure reliable supply of low-cost clean electricity at affordable cost.

4.12 Continuing Role of the SAARC Energy Center in Enabling SG Transformation

All of the above recommended transformative changes will require a continuous centralized planning, preparation, monitoring, coordinating, education, support and training roles from the SAARC Energy Centre, as these countries embark on their individual country transformations. It is recommended, that the SAARC Energy Centre seek additional budgets for the next 5 years to create a "SG Support Team" of Experts Advisors who can help in guiding the individual countries in their roadmaps and being available periodically to visit and answer queries or partake in discussions.



4.13 In Closing

It is commendable that a very pertinent and timely initiative has been undertaken by the SAARC Energy Centre to prepare this Smart Grid Roadmap Study for SAARC countries. This Report has been considering the diversity amongst the SAARC nations (national priorities, size, economy, geography, electricity development and market structure). The Smart Grid Roadmap and its recommendations is based on (a) analysis of data gathered from secondary sources; (b) Smart Grid Maturity Model (albeit not formally administered/evaluated), to suggest an operational framework; (c) evaluation and prioritization of the immediate power system needs and upliftment; and (d) interesting pilot projects for each country.

With this Report, the "heavy lifting" now begins. We wish each of the nations and the SAARC Energy Centre, all success in this collective endeavor.

5 Appendix-A

The AS-IS study of the Utility in the 8 domains has to be captured through COMPASS Survey as below.

Strategy, Management and Regulatory (SMR)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	
SMR 1.1	Utility has developed a smart grid vision that addresses operational improvement within a single function or line of business
SMR 1.2	Limited experimentation of smart grid concepts with strong organizational support
SMR 1.3	Limited informal discussions with regulators about smart grid vision have been held
2.Enabling	
SMR 2.1	An initial smart grid strategy and business plan have been formally approved by executive management
SMR 2.2	A common smart grid vision has been accepted across multiple functions and/or line of business of organization
SMR 2.3	Organization's operational investments has partial and explicit alignment driven from smart grid to the smart grid strategy and business plan
SMR 2.4	Extensive (>70%) budgets have been established specifically for funding the implementation of the smart grid
SMR 2.5	Organization is collaborating with regulators and other stakeholders about smart grid vision and strategy
SMR 2.6	Significant support and funding are provided for conducting smart grid proof-of-concept projects (e.g., AMI, DG)
3.Integrating	
SMR 3.1	Smart grid vision, strategy, and business case have been partially incorporated into your organization’s vision and strategy
SMR 3.2	Established a standalone smart grid governance model for smart grid management and decision-making roles, processes, and tools
SMR 3.3	Organization has a single smart grid leader with explicit authority across functions and lines of business to ensure proper implementation of smart grid strategy
SMR 3.4	Required authorizations for smart grid investments been secured indirectly from stakeholders (e.g., regulators, stockholders, tax payers)
4.Optimising	

SMR 4.1	Smart grid vision and strategy has limited and indirect impact on strategy and direction at the highest level (e.g., enterprise or corporate level)
SMR 4.2	Smart grid is not a core competency throughout the organization
SMR 4.3	Smart grid strategy communicated and revised collaboratively with external stakeholders, excluding some sensitive aspects
5.Pioneering	Organization to a little extent capitalize on smart grid as a foundation for the introduction of new services and product offerings
SMR 5.1	Smart grid business activities provide sufficient financial resources to enable continued investment in smart grid sustainment and expansion
SMR 5.2	Smart grid business activities provide partially financial resources to enable continued investment in smart grid sustainment and expansion
SMR 5.3	Organization has not implemented new business models as a result of smart grid capabilities

Organizational Structure (OS)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	
OS 1.1	Organization has partially articulated (communicated) the need to build smart grid competencies in its workforce
OS 1.2	Leadership demonstrated a commitment to change the organization in support of achieving smart grid by assigning resources and budget
OS 1.3	Awareness efforts within the workforce has been initiated across multiple functions/line of business to support your smart grid activities
2.Enabling	
OS 2.1	Smart grid vision has begun to drive change and affect related priorities (e.g., addressing the need for an adequately skilled workforce) across multiple functions/line of business
OS 2.2	Operations around a few end-to-end processes are aligned to leverage smart grid capabilities
OS 2.3	Smart grid implementation and deployment teams partially include participants from all impacted functions and lines of business
OS 2.4	Education and training activities to develop smart grid competencies are in the process of development
OS 2.5	Performance and/or compensation plans is not linked to the achievement of smart grid strategy milestones

3.Integrating	
OS 3.1	Smart grid vision and strategy is indirectly driving organizational change (e.g., roles, interactions, compensation, hiring criteria)
OS 3.2	Organization's measurement system incorporates smart grid measures across two or more functions and/or lines of business
OS 3.3	Performance evaluation and/or compensation linked to smart grid success (i.e., tangible benefits resulting from smart grid deployment or application)
OS 3.4	Leadership provides a consistent smart grid vision and strategy in both actions and communications to a great extent
OS 3.5	Evaluation of a matrix/overlay structure to support smart grid activities is complete and changes are documented in a plan for implementation
OS 3.6	Education and training programs are not aligned to exploit smart grid capabilities
4.Optimising	
OS 4.1	Management systems and organizational structures are capable of taking widespread advantage of the increased visibility and control capabilities provided through smart grid to a limited extent
OS 4.2	Organization have end-to-end grid observability to a limited extent that can be leveraged by both internal and external stakeholders?
5.Pioneering	
OS 5.1	Organizational structure enables a little collaboration with other grid stakeholders to optimize overall grid operation and health
OS 5.2	Organization and its structure are readily adapting to support new ventures, products and services as they emerge as a result of smart grid to a limited extent.
OS 5.3	Limited Channels are established to harvest ideas, develop them, and reward those that help to shape future advances in process, workforce competencies, and technology

Grid Operations (GO)

LEVEL	AS-IS SCENARIO(A/B/C/D/E)
1.Initiating	
GO 1.1	A business case for new equipment and systems related to smart grid for at least one business function (e.g., AMI, remote disconnect, PMUs, etc.) is being executed
GO 1.2	Organization is evaluating new sensors, switches, and communications technologies for grid monitoring and control to some extent for smart grid

GO 1.3	Organization has proof-of-concept projects and/or component testing for grid monitoring and control underway to some extent, not directly for smart grid
GO 1.4	Organization is evaluating outage and distribution management systems linked to substation automation (beyond SCADA)
	to some extent, not directly for smart grid
GO 1.5	safety and security (physical and cyber) requirements considered in some grid operation initiatives
2.Enabling	
GO 2.1	Automation of distribution substations and implementation of links to some form of remote distribution automation (e.g., smart switching in the field) are in progress
GO 2.2	Implementation of advanced outage restoration schemes that automatically resolve (self-heal) or reduce the magnitude of unplanned outages is under progress
GO 2.3	Aside from SCADA, piloting of remote asset monitoring of key grid assets to support manual decision making is in documented plan including committed schedule and budget
GO 2.4	Investment in expanded data communications networks in support of grid operations is partially complete
3.Integrating	
GO 3.1	Smart grid information made available across a few systems and organizational functions
GO 3.2	Implementation of new control analytics improved across several line-of-business decision-making
GO 3.3	Grid operations planning transitioned moderately from estimation to fact-based using grid data made available from smart grid deployment
GO 3.4	Organization has documented plan including committed schedule and budget for smart meters to become important grid management sensors within your network
GO 3.5	Grid data being used to support physical and cyber security through situational awareness and diagnostic activities deployed for one or more critical functions
GO 3.6	Automated decision-making within protection schemes -Analytics-based decision-support informs human operators
4.Optimising	
GO 4.1	Operational data from smart grid deployments is being used to a little extent to optimize processes across the organization

GO 4.2	Grid operational management based on near real-time data (dynamic grid management) to a little extent
GO 4.3	Operational forecasts are moderately based upon data gathered through smart grid capabilities
GO 4.4	Grid operations information has been made available across functions and lines of business with end-to-end observability to a little extent
GO 4.5	At least one wide area analytics-based decision type is being automatically executed for
	automated decision-making within protection schemes based on wide area monitoring (beyond operational boundaries)
5.Pioneering	
GO 5.1	No self-healing operation is employed for operational grid
GO 5.2	System-wide analytics-based and automated decision-making is in place to a little extent (applying proven analytics-based control)

Work and Asset Management (WAM)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	
WAM 1.1	A functional-level business case for work and asset management enhancements via smart grid is approved and being executed
WAM 1.2	Potential uses of remote asset monitoring is in documented plan including committed schedule and budget
WAM 1.3	Organization is evaluating asset and workforce management equipment and systems not aligned to the smart grid vision
2.Enabling	
WAM 2.1	An approach to track, inventory, and maintain event histories of assets using smart grid capabilities is in documented plan including committed schedule and budget
WAM 2.3	Development of an organization-wide mobile workforce strategy is in progress
3.Integrating	
WAM 3.1	1/25% percentage of individual components in cyber and physical systems has performance, trend analysis, and event audit data available
WAM 3.2	No condition-based maintenance that uses real-time data from asset monitoring to drive maintenance and replacement decisions have been implemented for any key component

WAM 3.3	Integration of remote asset monitoring with asset management is in documented plan including committed schedule and budget
WAM 3.4	Integration of remote asset monitoring capabilities with mobile workforce systems to automate work order creation has not been done
WAM 3.5	an integrated view of GIS and asset monitoring based upon location, status, and interconnectivity is under development
WAM 3.6	1-25% of asset inventory is tracked using some level of automation from source to utilization (e.g., from supplier to installed location)
WAM 3.7	Modelling asset investments for key components based upon smart grid data is not undertaken
4.Optimising	
WAM 4.1	51-75% of asset classes have a complete view (including location, interrelationships) based upon status (including security state), connectivity and proximity
WAM 4.2	51-75% of asset models are based upon real (both current and historical) performance and monitoring data
WAM 4.3	Performance and use of assets (from procurement through retirement) in consideration of the entire asset fleet and across asset categories are optimized for 51-75% of asset classes
WAM 4.4	Organization has condition-based and predictive maintenance on 1-25% of key components
5.Pioneering	
WAM 5.1	Organization is optimizing the use of assets between and across supply-chain participants
WAM 5.2	Very few assets (<10%) are leveraged to maximize utilization, including just-in-time asset retirement, based on smart grid data and systems

TECHNOLOGY (TECH)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	
TECH 1.1	Enterprise IT architecture is under development
TECH 1.2	Organization is planning to evaluate existing or proposed enterprise IT architecture for the quality attributes that would support smart grid applications

TECH 1.3	A formal change control process (e.g., configuration management, patch updates) for applications and IT infrastructure has been deployed for numerous classes and/or elements
TECH 1.4	Organization has partially identified where technology can improve the performance of functional departments (e.g., reduce cost, improve workflow, simplify, automate, reduce risk, improve flexibility/adaptability)
TECH 1.5	Informal process is used to evaluate and select technologies in alignment with smart grid vision and/or strategy
2.Enabling	
TECH 2.1	Organization aligns tactical IT investments within a function and/or line of business to enterprise IT architecture
TECH 2.2	Changes to your enterprise IT architecture are in progress to enable smart grid being deployed
TECH 2.3	standards that support your smart grid strategy within enterprise IT architecture are being evaluated or developed
TECH 2.4	organization uses an informal common technology evaluation and selection process for all smart grid activities, including vendor and external source selection
TECH 2.5	A data communications strategy for grid is under development
TECH 2.6	Documented plan including committed schedule and budget for pilots exists for business unit applications based on connectivity to intelligent electronic devices (IED) (e.g., remote processors)
TECH 2.7	26-50% of smart grid initiatives have information security considerations built in from the outset
3.Integrating	
TECH 3.1	Alignment of smart grid-impacted business processes with enterprise IT architecture across LOBs is under development
TECH 3.2	26-50% of systems adhere to enterprise IT architectural framework for smart grid
TECH 3.3	Smart grid-specific technology to improve cross-LOB performance (e.g., peak demand management, fault detection, integrated VVO) have been implemented only as pilots or demonstration projects
TECH 3.4	Distributed intelligence and analytical capabilities that are enabled through smart grid technologies are under development
TECH 3.5	An advanced sensor plan (e.g., for situational awareness, for near real-time control, using phasor measurement units or other sophisticated sensors) is under development

TECH 3.6	a detailed data communications strategy and corresponding tactics are under development
4.Optimising	
TECH 4.1	End-to-end data flow from customer to generation (where permitted by security, privacy, and other requirements) is under development
TECH 4.2	26-50% of business processes are optimized by leveraging your enterprise IT architecture
TECH 4.3	1 – 25% of applicable systems have sufficient wide-area situational awareness to enable real-time monitoring/control/mitigation in response to complex events (e.g., natural disasters, severe weather, extreme demand fluctuations, etc.)
TECH 4.4	Predictive modeling and/or near real-time simulation to optimize support processes (e.g., for maintenance, power management, call centre, decision support) is under development
TECH 4.5	Organization's performance is being somewhat improved by using sophisticated systems that are informed by smart grid data (e.g., business intelligence or knowledge management systems)
5.Pioneering	
TECH 5.1	Autonomic computing using machine learning has not been implemented
TECH 5.2	Information systems do not automatically identify, mitigate, and recover from cyber incidents

CUSTOMER (CUST)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	
CUST 1.1	Organization is conducting research indirectly (not as part of smart grid initiatives, but providing smart grid insights) on how to use smart grid technologies to enhance customers' experience, benefits, and participation.
CUST 1.2	Organization is investigating indirectly (not as part of smart grid initiatives, but providing smart grid insights) the security and privacy implications of the new technologies and business functions that enable customer participation in the smart grid
CUST 1.3	Organization is communicating and explaining its vision of the future grid to customers (e.g., by explaining smart grid benefits and describing potential use case scenarios) informally with no structured communications
CUST 1.4	Organization is consulting with public Utility commissions and/or other government organizations regarding the impact on customers of smart grid

	strategies and anticipated implementation schedule on a limited basis (collaboration is infrequent and not part of normal business processes).
2.Enabling	
CUST 2.1	Organization has a documented plan including committed schedule and budget for a pilot Advanced Metering Infrastructure (AMI) and /or Automated Meter Reading (AMR) to residential customers
CUST 2.2	Organization has a documented plan including committed schedule and budget for collecting residential customer usage data more frequently than monthly for use in operational analytics and planning
CUST 2.3	Organization is not modelling reliability of grid equipment
CUST 2.4	Organization has a documented plan including committed schedule and budget for a pilot remote disconnect/connect technology for residential customers
CUST 2.5	Organization has a documented plan including committed schedule and budget for assessing the impact on customers of new services and delivery processes such as Home Area Networks (HAN), smart meter installs, dynamic pricing, and/or turning power on/off remotely
CUST 2.6	1-25% of smart grid-related pilots and Requests for Proposals (RFPs) specify security and privacy requirements for customer protection
3. Integration	
CUST 3.1	Organization is evaluating residential customer segmentation that can enable more tailored customer programs
CUST 3.2	There is no residential customer meter with two-way communication capabilities (e.g., an advanced metering infrastructure)
CUST 3.3	Organization has not enabled remote connect/disconnect capability for any residential customer
CUST 3.4	Organization has not enabled demand response or remote load control for any residential customer
CUST 3.5	There is no substation equipped with automated outage detection
CUST 3.6	No residential customer has on-demand access to daily (or more frequent) usage data?
CUST 3.7	A common customer experience (e.g., look and feel, consistency of message, available information) have been implemented across multiple residential customer interface channels (e.g., web, voice response, hand-held
CUST 3.8	Organization provides customer education on how to use smart grid services to curtail peak usage actively, indirectly through media or other broadcast channels
4.Optimising	

CUST 4.1	Organization Provides limited support to customers to help them analyze and compare their actual usage against all available pricing programs
CUST 4.2	1-25% of circuits are equipped with automatic outage detection and proactive notification
CUST 4.3	No customer has on-demand access to near real-time (up to the minute) usage data
CUST 4.4	No customer participates in demand response or remote load control programs
CUST 4.5	No residential customer is provided with the capability for automated response to pricing signals for major energy consumption devices in their premise
CUST 4.5	No residential customer is provided with the capability for automated response to pricing signals for major energy consumption devices in their premise
CUST 4.6	76-100% customers are in-home net billing programs available (e.g., credit/payment for solar panels, wind, electric vehicle battery to grid)
CUST 4.7	Organization has integrated a common experience across all residential customer interfaces for all services provided (e.g., leveraging common data sources) across all channels
5.Pioneering	
CUST 5.1	No customer can manage their end-to-end energy supply and usage levels (energy source and mix)
CUST 5.2	No customer (including residential) has automatic outage detection at the premise or device level
CUST 5.2	No customer (including residential) has automatic outage detection at the premise or device level
CUST 5.3	1-25% of customers are supported by plug-and-play customer-based generation (including necessary support infrastructure such as net billing, control, etc.)
CUST 5.4	Organization can provide Self-generated evidence (e.g., design reviews, code reviews) evidence of assurance of the security and privacy of customer data stored, transmitted or processed on the grid
CUST 5.5	Organization does not play a leadership role in industry-wide information sharing and standards development efforts for smart grid

Value Chain Integration (VCI)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	

VCI 1.1	Evaluation and identification of the assets and programs needed to facilitate load management is underway
VCI 1.2	Evaluation and identification of distributed generation sources and the capabilities needed to support them is underway
VCI 1.3	Organization has a documented plan including committed schedule and budget for identification of energy storage options and the capabilities needed to support them
VCI 1.4	Organization is in process of creating a strategy for developing, enabling, and managing a diverse resource portfolio (e.g., integration of new resources such as DR, DG)
VCI 1.5	Evaluation and identification of security requirements to enable interaction with an expanded portfolio of value chain partners is underway
2.Enabling	
VCI 2.1	Organization has a documented plan including committed schedule and budget for providing support for home energy management systems (e.g., via customer portals or in-home displays)
VCI 2.2	Organization has a documented plan including committed schedule and budget for redefining the value chain based upon smart grid capabilities (including DG, micro-generation, energy storage, and other new customers and suppliers)
VCI 2.3	Organization has a documented plan including committed schedule and budget for conducting pilots to support a diverse resource portfolio (e.g., distributed generation, demand-side management, demand response, storage)
VCI 2.4	Organization has a documented plan including committed schedule and budget for piloting secure interaction with an expanded portfolio of value chain partners
3.Integrating	
VCI 3.1	An integrated resource plan is partly in place (supporting at least one resource) that includes new targeted resources and technologies (e.g., Volt/Volt-Ampere Reactive (VAR) management systems, demand response, distributed generation)
VCI 3.2	Organization is developing enablement of customer (including commercial, industrial, and residential) premise energy management solutions with market and usage information
VCI 3.3	Additional resources (e.g., EVs, storage, DR) have been identified but not enabled or deployed to provide substitutes for market products to support reliability or other objectives

VCI 3.4	Organization is developing security management and monitoring processes to protect the interactions with your expanded portfolio of value chain partners
4.Optimising	
VCI 4.1	Energy resources (including resources such as Volt/VAR, DR, DG) are not dispatchable and tradeable
VCI 4.2	Organization has not implemented portfolio optimization models that encompass available resources and real-time markets (e.g., to enable response to dynamic market/supply conditions)
VCI 4.3	Secure two-way communication via Home Area Networks (HAN) for residential customers is under development
VCI 4.4	visibility and control of large-demand appliances (e.g., air conditioners, water heaters) for residential customers is under development
5.Pioneering	
VCI 5.1	Automation of the optimization of energy assets across the full value chain is under development
VCI 5.2	Organization is developing resources adequately dispatchable and controllable so as to take advantage of granular market options (e.g., locational marginal pricing)
VCI 5.3	Organization is developing automated control and resource optimization schemes to consider and support regional and/or national grid optimization

Societal and Environmental (SE)

Level	AS-IS Scenario (A/B/C/D/E)
1.Initiating	
SE 1.1	Organization's role in societal and environmental issues is acknowledged in smart grid strategy or vision
SE 1.2	Organization has publicly promoted the environmental benefits of your smart grid vision or strategy informally without any structured communication
SE 1.3	Compliance record with environmental regulations is not made available for public inspection
SE 1.4	Organization's role in protecting the nation's critical infrastructure is acknowledged in smart grid strategy or vision
2.Enabling	
SE 2.1	Smart grid strategies and work plans do not address societal and environmental issues (cost increases, global warming, pollution, hazardous materials, spill control, "not in my backyard," and other public concerns)

SE 2.2	Organization has established energy efficiency programs for all customers
SE 2.3	A "triple bottom line" view when making decisions (considering Societal, environmental, and financial performance measures) is under consideration
SE 2.4	Implementation of environmental proof-of-concept projects (e.g., solar or wind generation) to demonstrate smart grid benefits to the public and the environment is under progress
SE 2.5	Organization is making increasingly granular and more frequent consumption information available to customers (including residential)
3.Integrating	
SE 3.1	Only informal performance measurement is considered for societal and environmental programs within smart grid strategy
SE 3.2	segmented and tailored information that includes environmental and societal benefits and costs is under development in order to make them available to customers
SE 3.3	organization has a documented plan for programs to encourage off-peak usage by customers
4.Optimising	
SE 4.1	Organization does not collaborate with outside stakeholders to address societal and environmental issues
SE 4.2	organization does not maintain a public environmental and societal scorecard
SE 4.3	Smart grid programs (e.g., demand response programs, dynamic pricing signals, and managed control of devices) to shave peak demand are under development
SE 4.4	Organization cannot actively manage end-user usage and devices and therefore consumption, where appropriate, through network for customers (including commercial, industrial, and residential)
SE 4.5	There are no explicit critical infrastructure assurance goals
5.Pioneering	
SE 5.1	organization's triple-bottom-line goals have limited alignment with local, regional, and national objectives
SE 5.2	No customer is enabled to control their energy-based environmental footprint through automatic optimization of their end-to-end energy supply and usage level (energy source and mix) based on customer-selected preferences?

SE 5.3	organization is not a leader in developing and promoting industry-wide resilience best practices and/or technologies for protection of the national critical infrastructure but members of our organization participate in relevant industry and/or government forums

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Abbreviations

ABBREVIATION	Full Form
AD	Accelerated Depreciation
ADB	Asian Development Bank
ADR	Auto Demand Response
AEDB	Alternative Energy Development Board
AIIMS	All India Institute for Medical Sciences
ALCS	Afghanistan Living Conditions Survey
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
APDCL	Assam Power Distribution Company Ltd.
APSCL	Ashuganj Power Station
AT&C	Aggregate Technical and Commercial
BEA	Bhutan Electricity Authority
BERC	Bangladesh Energy Regulatory Commission
BESS	Battery Energy Storage System
BMS	Building Management System
BPC	Bhutan Power Corporation Limited
BPDB	Bangladesh Power Development Board
B2G	Building to Grid
CAGR	Compound Annual Growth Rate
CAREC	Central Asia Regional Economic Co-Operation
CAS	Central Asian States
CASA	Central Asia - South Asia
CBET	Cross-Border Electricity Trade20
CEA	Central Electricity Authority
CEB	Ceylon Electricity Board
CED	Cathode Electrode Deposition
CEI	Chief Electrical Inspector

CES	Customized Energy Solutions
CIS	Customer Information System
CMA	Colombo Metropolitan Area
CMU	Carnegie Mellon University
CPEC	China-Pakistan Economic Corridor
CPF	Carbon Partnership Facility
CSEB	Chhattisgarh State Electricity Board
CT	Current Transformer
CTU	Central Transmission Utility
DA	Distribution Automation
DABS	Da Afghanistan Breshna Sherkat
DDUGJY	Deendayal Upadhyaya Gram Jyoti Yojana
DER	Distributed Energy Resources
DESCO	Dhaka Electricity Supply Company Limited
DGPC	Druk Green Power Corporation Limited
DISCOM	Distribution Company
DLMS/COSEM	Device Language Message Specification / Companion Specification for Energy Metering
DMS	Distribution Management System
DoED	Department of Electricity Development
DPDC	Dhaka Power Distribution Company
DR	Demand Response
DRE	Distributed Renewable Energy
DRES	Distributed Renewable Energy Sources
DSM	Demand Side Management
DT	Distribution Transformers
EA	Electricity Act
EC	Energy Conservation
EDP	Economic Development Policy
EMS	Energy Management System

ERP	Enterprise Resource Planning
ESP	Electrical Service Providers
ESS	Energy Storage Systems
ETFC	Electricity Tariff Fixation Committee
EV	Electric Vehicles
EVSE	Electric Vehicle Supply Equipment
FiTs	Feed in Tariffs
FLISR	Fault Location, Isolation and Service Restoration
FSAS	Frequency Support Ancillary Services
GBI	Generation Based Incentives For WIND
GIS	Geographical Information System
GIUNC	Global Intelligent Utility Network Coalition
GO	Grid Operation
GOP	Government of Pakistan
GTF	Global Tracking Framework
GW	Gigawatts
HAN	Home Area Network
HPSEB	Himachal Pradesh State Electricity Board Ltd
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IEC	International Electro technical Commission
IESCO	Islamabad Electric Supply Company
IOT	Internet of Things
IPDS	Integrated Power Development Scheme
IPPs	Independent Power Producers
ISGF	India Smart Grid Forum
ISGTF	India Smart Grid Task Force
IVR	Interactive Voice Response
JNNSM	Jawaharlal Nehru National Solar Mission

JVVNL	Jaipur Vidyut Vitran Nigam Limited
KSEBL	Kerala State Electricity Board
KW	Kilowatts
LDC	Load Dispatch Centre
LECO	Lanka Electricity Company
LED	Light Emitting Diode
LOB	Line of Business
MDA	Meter Data Acquisition
MDMS	Meter Data Management System
MEA	Maldives Energy Authority
MEW	Ministry of Energy and Water
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MOEC	Ministry of Economy
MOF	Ministry of Finance
MoP	Ministry of Power
MOU	Memorandum of Understanding
MRRD	Ministry of Rural Rehabilitation and Development`
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MV	Medium Voltage
MW	Mega Watt
MWFM	Mobile Workforce Management
NAPCC	National Action Plan on Climate Change
NBSG	National Board for Smart Grids
NCSG	National Council for Smart Grids
NEA	Nepal Electricity Authority
NEF	National Electricity Fund
NEO	National Energy Office

NEPRA	National Electric Regulatory Authority
NIP	National Infrastructure Plan
NLDC	National Load Dispatch Centre
NOFM	National Optical Fiber Network
NSGM	National Smart Grid Mission
NTGMP	National Transmission Grid Master Plan
NZEB	Net-Zero Energy Building
OMS	Outage Management System
OS	Organization Structure
OTEC	Ocean Thermal Energy Conversion
PEVs	Plug-in Electric Vehicles
PGCB	Power Grid Company of Bangladesh
PHEV	Plug-in Hybrid Electric Vehicle
POSOCO	Power System Operation Corporation Ltd
PPA	Power Purchase Agreements
PPP	Public Private Partnership
PV2G	Photovoltaic (Solar) to Grid
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RBHSL	Royal Bhutan Helicopter Services Limited
RE	Renewable Energy
REMC	Renewable Energy Monitoring Centre
RERED	Rural Electrification and Renewable Energy Development
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RMU	Remote Monitoring Unit
RPCs	Regional Power Committees
RTU	Remote Terminal Unit
SA	Substation Automation
SAARC	South Asian Association for Regional Cooperation

SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SEI	Software Engineering Institute
SERC	State Electricity Regulatory Commission
SGMM	Smart Grid Maturity Model
SLDC	State Load Dispatch Centres
SLSEA	Sri Lanka Sustainable Energy Authority
SMOC	Smart Meter Operation Centre
SMPS	Switch-Mode Power Supply
SMR	Strategy, Management, And Regulatory
SREDA	Sustainable Renewable Energy Development Authority
STATCOM	Static VAR Compensator
STELCO	State Electric Company Limited
STU	State Transmission Utilities
SWERA	Solar and Wind Energy Resource Assessment
T&D	Transmission and Distribution
TAPI	Turkmenistan Into Afghanistan, Pakistan, And India
TBL	Triple Bottom Line
TMU	Transformer Monitoring Units
TSECL	Tripura State Electricity Corporation Limited
TSSPDCL	Southern Power Distribution Company of Telangana
TUTAP	Turkmenistan–Uzbekistan–Tajikistan–Afghanistan–Pakistan
UGVCL	Uttar Gujarat Vij Company Limited
UHBVN	Uttar Haryana Bijli Vitran Nigam
USAID	United States Agency for International Development

VCM	Value Chain Management
VGF	Viability Gap Funding for Solar
V2G	Vehicle to Grid
VPP	Virtual Power Plant
WAM	Work and Asset Management
WAMS	Wide Area Monitoring Systems
WAN	Wide Area Network
WBSEDCL	West Bengal State Electricity Distribution Company Limited