Energy Efficiency Improvements in Power Generation and Distribution Sectors of SAARC Countries

SAARC ENERGY CENTRE

Energy Efficiency Improvements in Power Generation and Distribution Sectors of SAARC Countries

Published by

SAARC Energy Centre

697, St. 43, E-11/4 (NFP), Islamabad, Pakistan

Tel: + (92 51) 222 2089. Fax: + (92 51) 222 1937

Email: info@saarcenergy.org

Also available on Website

www.saarcenergy.org

Islamabad, Pakistan, 2021

ACKNOWLEDGEMENTS

This report is based on study carried out by SAARC Energy Centre (SEC), Islamabad. The study was commissioned and supervised by Ahmad Talha (Research Fellow-Technology Transfer). The internal review of the study was conducted by Mr. Ihsanullah (Research Fellow – Energy Efficiency) and Mr. Tula Ram Poudel (Research Fellow – Energy Trade).

SAARC Energy Centre, Islamabad would like to thank Lead Authors of this study; PricewaterhouseCoopers Pvt. Ltd., India for undertaking this study in professional manner. Moreover, SEC acknowledges the valuable contributions made by key stakeholders (government officials, utility companies, academicians, researchers, technology providers) for their inputs and feedback on this study, including provision of data, participation in dissemination video conference, and sharing their knowledge. The efforts made by SEC team specially Ms. Mehnaz Khurshid Gardezi (Communications Specialist), Mr. Muhammad Ali Qureshi (Research Fellow-Power), Mr. Abdul Wahab and Mr. Ammar Hassan from IT for providing valuable support in finalizing and printing this study are highly appreciated.

STUDY COORDINATOR
Mr. Ahmad Talha (Research Fellow – Technology Transfer)

LEAD REVIEWER
Mr. Ihsanullah (Research Fellow – Energy Efficiency)

ATTRIBUTION

Please cite the work as follows: *Energy Efficiency Improvements in Power Generation and Distribution Sectors of SAARC Countries, 2021, SAARC Energy Centre, Islamabad.*

DISCLAIMER

Foreword

South Asia is the fastest growing region in the last decade. This economic development combined with population growth, urbanisation and industrialisation has led to continued expansion in demand for energy. As a result, the energy sector in the SAARC countries has grown rapidly in recent years. To meet the growing energy demand as well as to achieve SDG-7 targets, SAARC Countries require substantial capacity enhancements in their power sectors. Improving energy efficiency in the energy sector can be one of the most economical ways of increasing the available capacity to meet the ever-growing demand.

Energy efficiency improvement is the fastest way to maximise utilization of available resources. The power generation and distribution sectors of SAARC Member States are adversely affected by inefficiency and reliability issues. There exists ample room for SAARC Countries to improve energy efficiency and reap the rewards both in economy, and in form of environmental conservation. Investigating the opportunities of efficiency improvements in SAARC Countries' power sectors and identifying the ways to tap those opportunities are the needs of time. Therefore, in this context, SAARC Energy Centre conducted this study on "*Energy Efficiency Improvements in Power Generation and Distribution Sectors of SAARC Countries"*.

The study not only presents energy efficiency related issues in power sector for all the SAARC Member States but also provides potential feasible solutions to the identified problems. It provides a roadmap on how each country can improve the efficiency of its generation and distribution sectors by highlighting low hanging fruits and their financial implications.

Tailoring the lessons learnt from the international best practices and case studies from other regions, the study presents specific recommendations for each SAARC Member State. A cost benefit analysis of recommended improvements reveals that the payback period for investment in energy efficiency improvements is less than five years for each SAARC Member State. In addition, annual GHG reduction potential ranges from 0.032 million tCO_2 in case of Nepal to 97.4 million tCO_2 in case of India. Various challenges and requirements for implementation of the recommended energy efficiency measures have also been presented in detail for consideration of the stakeholders.

(Dr Nawaz Ahmad)
Director
SAARC Energy Centre

Table of Contents

List of Abbreviations and Acronyms

ABC	Aerial Bundle Conductor
AC	Alternating Current
ADB	Asian Development Bank
AEA	Accredited Energy Auditor
AHP	Ash Handling Plant
APC	Auxiliary Power Consumption
AT&C	Aggregate Technical and Commercial Losses
BEA	Bhutan Electricity Authority
BEE	Bureau of Energy Efficiency
BERC	Bangladesh Energy Regulatory Commission
BP	British Petroleum
BPC	Bhutan Power Corporation
BPDP	Bangladesh Power Development Board
BREB	Bangladesh Rural Electrification Board
CAPEX	Capital expenditures
CAR	Central Asian republics
CCGT	Combined Cycle Gas Turbines
CCP	Combined Cycle Power Plant
CEA	Central Electricity Authority
CEB	Ceylon Electricity Board
CEP	Condensate Extraction Pump
CERC	Central Electricity Regulatory Commission
CH_4	Methane
CHP	Combined Heat and Power
CI	Compression Ignition
ckt. KM	circuit kilometre
Cm	Centimetre
CO_2	Carbon dioxide
CWP	Cooling water pump
DABS	The Da Afghanistan Breshna Sherkat
DC	Designated Consumers
DC	Direct Current
DCSD	Distribution and Consumer Services Directorate
DESCO	Dhaka Electric Supply Company Limited
DF	Distribution Franchisee
DG Set	Diesel Generator Set
DGPC	Druk Green Power Corporation Limited
DISCOM/DISCO	Distribution Company

DPDC	Dhaka Power Distribution Company
ECM	Energy Conservation Measures
EE	Energy Efficiency
ESCerts	Energy Saving Certificates
ESCO	Energy Service Company
ESP	Electrostatic Precipitators
FD	Forced Draft
FESCO	Faisalabad Electric Supply Company
FY	Fiscal Year
G&T	Generation and Transmission
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GE	General Electric
GENCO	Generation Companies
GEPCO	Gujranwala Electric Power Company
GHG	Greenhouse Gas
GT	Gas Turbine
GW	Gigawatt
HESCO	Hyderabad Electric Supply Company
HFO	Heavy Furnace Oil
HP	High Pressure
HPBFP	High Pressure Boiler Feed Pump
HPP	Hydropower plant
HR	Heat rate
HRSG	Heat Recovery Steam Generator
HT	High Tension
HV	High Voltage
HVAC	Heating, ventilation, and air conditioning
HVDS	High Voltage Distribution Service
Hz	Hertz
IC	Internal Combustion
ID	Induced Draft
IEA	International Energy Agency
IESCO	Islamabad Electric Supply Company
IGCC	Integrated Coal Gasification combined cycle plants
IP	Intermediate Pressure
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
JICA	Japan International Cooperation Agency
K	Kelvin

K-Electric	Karachi Electric Supply Company
kcal	Kilocalorie
kg	Kilogram
km	Kilo Meter
KPI	Key Performance Indicator
kV	Kilo Volt
kWh	Kilowatt-Hour
LECO	Lanka Electricity Company Pvt Ltd
LED	Light emitting Diode
LESCO	Lahore Electric Supply Company
LP	Low Pressure
LPBFP	Low Pressure Boiler Feed Pump
LT	Low Tension
LV	Low Voltage
M&V	Measurement and Verification
MDMS	Meter Data Management System
MEA	Maldives Energy Authority
MEPCO	Multan Electric Power Company
MEW	Ministry of Energy and Water
MIS	Management Information System
mmHg	Millimetre of Mercury
mmWC	Millimetre of Water
MoP	Ministry of Power
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Mega Watt
N_2	Nitrogen
NDC	National Determined Contribution
NEA	Nepal Electricity Authority
NEPRA	National Electric Power Regulatory Authority
NEPS	North East Power System
NESCO	Northern Electricity Supply Company Limited
NGO	Non-Governmental Organization
NSIA	National Statistic and Information Authority
NTDC	National Transmission & Dispatch Company
NTPC	National Thermal Power Corporation
O&M	Operation and Maintenance
O_2	Oxygen
OEM	Original Equipment Manufacturer
PA	Pulverized Air

PADO	Plant Analysis, Diagnosis and Optimization
PAT	Perform Achieve & Trade
PEPCO	Pakistan Electric Power Company
PESCO	Peshawar Electric Supply Company
PF	Power Factor
PGD	Power Generation and Distribution
PHPL	Power Holding Private Limited
PLF	Plant Load Factor
PPM	Plant Performance Management
PPP	Private Power Producers
PSH	Pumped-storage hydropower
PSI	Pound-force per square inch
PwC	PricewaterhouseCoopers
QESCO	Quetta Electric Supply Company
R&D	Research and Development
R&M	Renovation & Modernization
S. No.	Serial Number
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAARC	South Asian Association for Regional Cooperation
SCADA	Supervisory control and data acquisition
SCPC	Super Critical Power Plant
SDA	State Designated Authority
SEB	State Electricity Boards
SEC	SAARC Energy Centre
SEC	Specific Energy Consumption
SEPCO	Sukkur Electric Power Company
SEPS	South East Power System
SLSEA	The Sri Lanka Sustainable Energy Authority
SMS	SAARC Member State
SOP	Standard Operational Practices
SPP	Small Power Plant
SREDA	Sustainable and Renewable Energy Development Authority
ST	Steam Turbine
STELCO	State Electric Company Limited, Maldives
STFF	Syndicated Term Finance Facility
T&D	Transmission & Distribution Losses
Tcf	Trillion Cubic feet
TESCO	Tribal Electric Supply Company
TL	Technical Loss

TPH	Tonne per Hour
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
USA	United States of America
USAID	United States Agency for International Development
USC	Ultra-Super Critical
USCPC	Ultra-Supercritical Pulverized Coal
USD	U.S. Dollar
VFD	Variable Frequency Drive
WAPDA	Water and Power Development Authority
WZPDC	West Zone Power Distribution Company

List of Tables

List of Figures

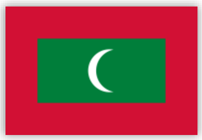
1. Introduction

1.1. Background

The South Asian Association for Regional Cooperation (SAARC) Member Nations, comprise of some of the fastest growing economies in the world, with a cumulative GDP growth of 4.8% (The World Bank, 2020). The geographical size of SAARC Nations is just 3% of the world's area however they comprise 21% of the world's population and 4.21% of world economy (World Economic Outlook Database, 2020). With increasing economic activities in the region, the per capita electricity consumption of these countries is increasing at rapid rate.

SAARC Countries (Table 1) are adversely affected by energy inefficiency and reliability issues in their power generation and distribution sectors. The electrification rates vary among the SAARC nations - Afghanistan 30%, Bangladesh 64%, Bhutan 100% and Maldives 93% (SAARC Energy Centre, 2017) - thus highlighting these nations have highly contrasting economic and power sector profiles. Further, Bhutan and Nepal meet much of their electricity demands by hydro power; the remaining 6 nations are highly dependent on fossil fuel imports for their electricity generation.

Table 1 SAARC Member States

SAARC Countries			
			
Afghanistan	**Bangladesh**	**Bhutan**	**India**
			
Maldives	**Nepal**	**Pakistan**	**Sri Lanka**

Energy efficiency improvement is the fastest mitigation method to meet the growing energy demands. SAARC Member States (SMS) have tremendous potential of energy efficiency improvements in their electricity generation and distribution sectors. Energy efficiency improvements in power generation and distribution infrastructure of these countries will bring about rewards in economic development and environment conservation.

1.2. Introduction to SEC

The SAARC Energy Centre (SEC) was established in 2006 as a technical arm to the SAARC, with a purpose of converting energy challenges to opportunities for development. Since inception, the SEC has successfully partnered/collaborated with officials, experts, academia, environmentalist and NGOs to leverage their knowledge and expertise and bring latest international skills to capitalize on synergies in the energy sector.

The SEC has prioritized its programmes based on the region's energy needs and demands. In the context, lately, SEC is focused on reducing region's dependency on imported fossil fuels. SEC has conducted several programmes and studies in areas such as energy conservation, financing for implementation of renewable energy projects in the SMS, SAARC energy outlook, requirement of infrastructure and importance of enabling environment for road electric transport, cross-border electricity trade etc.

SAARC Energy Centre has defined its primary objective as a regional institution of excellence for the initiation, coordination and facilitation of SAARC programmes in energy. The goals of SEC are presented in Table 2.

Table 2 Goals of SAARC Energy Centre

S. No	Goals of SAARC Energy Centre
1.	To strengthen South Asia's capacity to collectively address global and regional energy issues.
2.	To facilitate energy trade within the SAARC region, through the establishment of a regional electricity grid and natural gas pipelines.
3.	To promote more efficient use of energy within the SAARC region.
4.	To enhance cooperation in the use of new and renewable energy sources in the region, thereby contributing towards more sustainable development in the SAARC member countries.
5.	To serve as a focal point for providing reliable energy data for the individual member countries and the South Asian region.
6.	To enhance SAARC expertise in energy development and management.
7.	To promote private sector investment and participation in energy activities in the region.
8.	To undertake programmes to achieve the goals mentioned above.

1.3. Overview of Power Generation and Distribution Sector

1.3.1. Power Generation

The power generation of a country is primarily dependant on the available resources and the type of generation infrastructure present. The power sector of SAARC Countries varies significantly in terms of installed capacity and power generation mix by fuel type. The total combined power generation capacity of the SAARC Member States was about 399.6 GW in FY 2018, with 86% (Central Electricity Authority, 2008-2020) of total generation capacity installed in India, 7% (Pakistan Bureau of Statistics, 2019) in Pakistan, 5% in Bangladesh and rest 2% in other SAARC countries (See Figure 1).

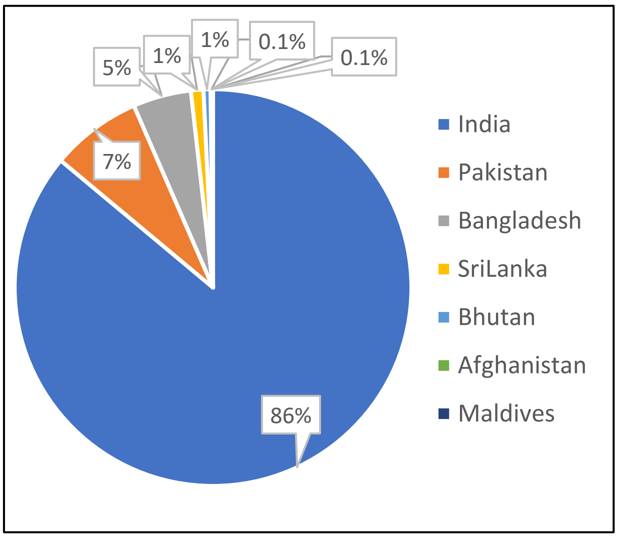


Figure 1 Installed power generation capacity of SAARC Member States

Afghanistan

Afghanistan is highly dependent on imports to meet its electricity demands. It imports electricity from neighbouring Central Asian countries: Uzbekistan, Tajikistan and Kyrgyzstan. Afghanistan's net installed capacity is primarily based on hydropower and thermal power plants (39%). The net installed capacity in the country is about 520 MW (NSIA, 2019), of which 252 MW is hydropower and 268 MW is from other thermal sources such as furnace oil, diesel, gas and distributed generators as shown in Figure 2.

The total domestic electric power generation as of FY 2019 was about 1,285 GWh (NSIA, 2019) and about 4,931 GWh was imported from neighbouring central Asian countries for meeting the electricity demand of the country (Figure 3). Hydropower generation accounted for 86% of the total domestic generation in the country followed by fuel oil (11%) and diesel (3%).

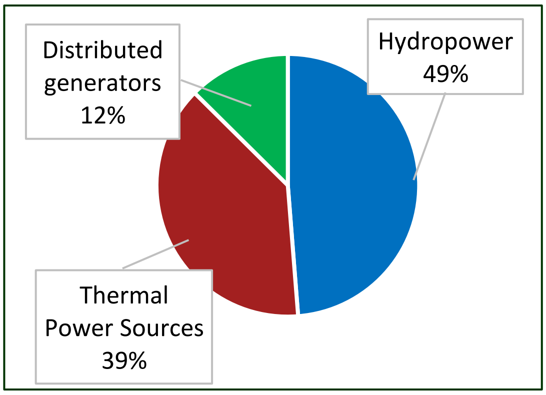


Figure 2 Installed capacity of Afghanistan

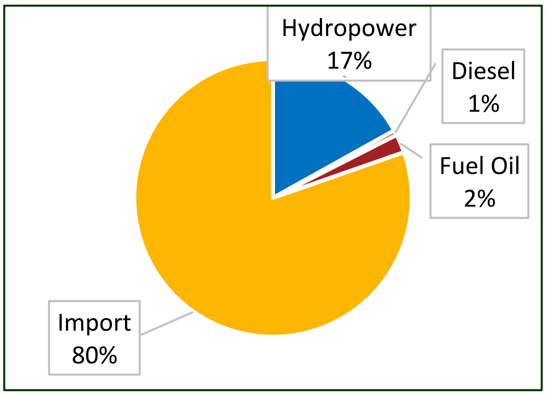


Figure 3 Generation mix for Afghanistan

Bangladesh

Bangladesh is well endowed with natural gas reserves, with nearly 5.7 trillion cubic feet of natural gas proven reserves at end of the year 2018 (British Petroleum, 2019). The natural gas based thermal plants thereby form the main source of electricity generation in Bangladesh accounting for nearly 57.4% of total installed capacity (Bangladesh Power Development Board, 2019) (Figure 4). The furnace oil based thermal power plants is next with about 25.2% of the installed capacity.

Bangladesh's total domestic power generation of electricity for FY 2018-19 was about 70,533 GWh (Bangladesh Power Development Board, 2019). The natural gas-based power generation accounts for two-third of total power generation in the country.

Bangladesh's electricity imports for the same period i.e., FY 2018-19 was about 1,160 MW, which 6% of the total power installed capacity (Bangladesh Power Development Board, 2019).

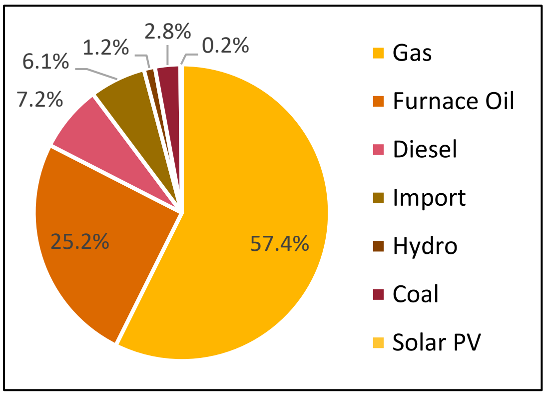


Figure 4 Installed capacity of Bangladesh

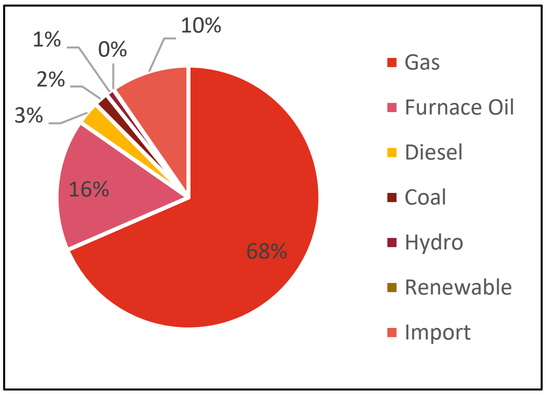


Figure 5 Generation mix of Bangladesh

The power generation mix by fuel type for Bangladesh is presented in Figure 5.

Bhutan

Hydropower plants are the main source of on-grid power generation in Bhutan. Bhutan has an installed capacity of 2,326 MW of hydropower plant that account for about 99% of the total installed capacity (Bhutan Electricity Authority, 2019) (Figure 6).

The domestic power consumption for FY 2018 was 2,280 GWh (Bhutan Power Corporation Limited, 2019). A major share of Bhutan's electricity generation is exported to neighbouring country (India), the exports in FY 2018 stood at 6,172 GWh (Bhutan Power Corporation Limited, 2019) (Figure 7).

India

India is the third largest producer and consumer of electricity in the world. The total installed capacity of power generation in the country as on April 2020 was 371,054 MW. The thermal power plants (coal, oil and natural gas) contribute the major share in net generation capacity, nearly 62%. The coal-based power plants account for about 85% of the total thermal power production. Renewable energy and large hydro combined accounts for about 36% of total power generation installed capacity (Central Electricity Authority, 2020).

The electricity generation of India in the financial year 2019-20 was about 1,389,121 GWh (Ministry of Power, 2020). The electricity generation compound annual growth rate in last decade was 5.49%. In FY 2018-19, the generation by thermal utilities was ~80% of the total power generation, followed by hydropower 10%, nuclear 3% and other renewable sources 7% (National Statistical Office, 2020) (see Figure 8).

The installed capacity of power generation by fuel type for India is presented in Figure 9.

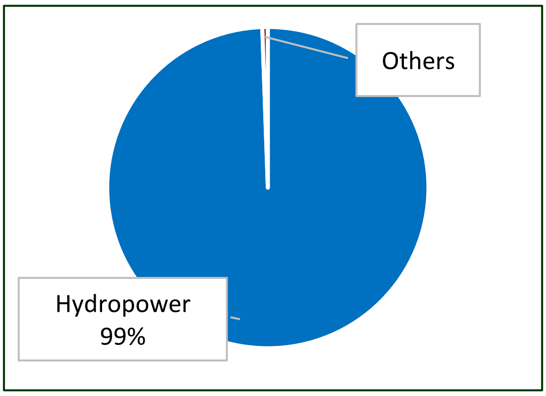


Figure 6 Installed capacity of Bhutan

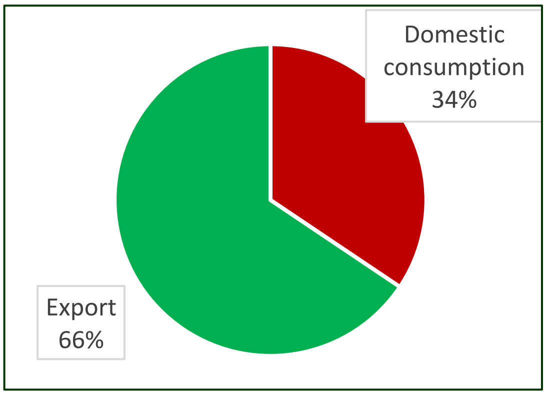


Figure 7 Electricity consumption in Bhutan

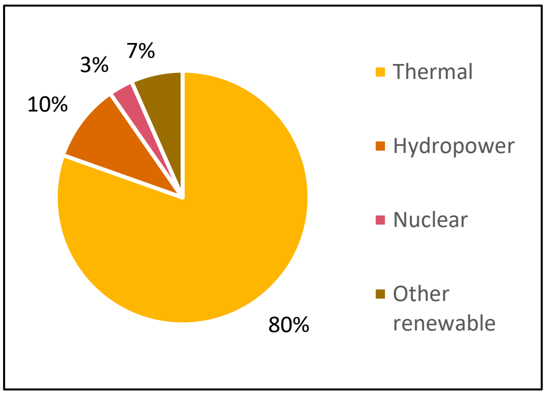


Figure 8 Generation mix of India

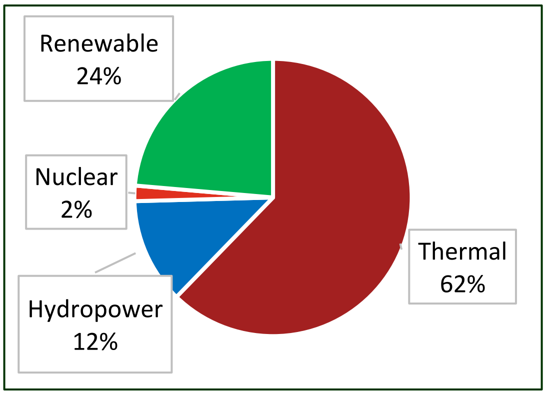


Figure 9 Total installed capacity of India

Maldivies

Maldives being a collection of small islands, is heavily reliant on imported oil and diesel-based generators to meet its electricity demands. The state-owned electric company, State Electricity Company of Maldives (STELCO) is responsible for generation and distribution of electricity throughout in Maldives. Maldives, being an island state has majority of its islands having their own captive power generation systems. The overall installed generation capacity of Maldives is about 251 MW, of this STELCO has the major share in generation (Ministry of Environment, 2018).

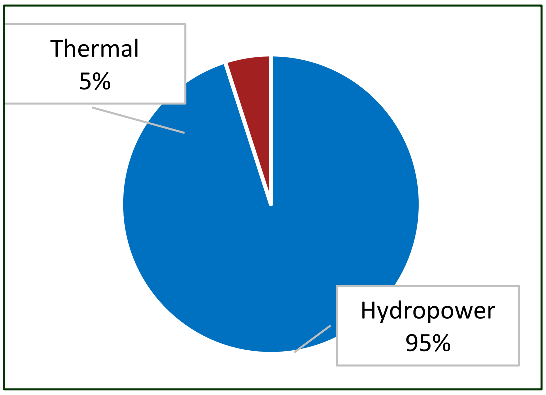


Figure 10 Installed capacity of Nepal

Nepal

Nepal is predominantly dependant on hydropower for its electric power generation. Hydropower provides almost entire country's electricity on the grid. The hydropower capacity in Nepal is about 1,020 MW as shown in Figure 10 (SAARC Energy Centre, 2018). The majority of the installed hydro power plants is owned by the Nepal Electricity Authority.

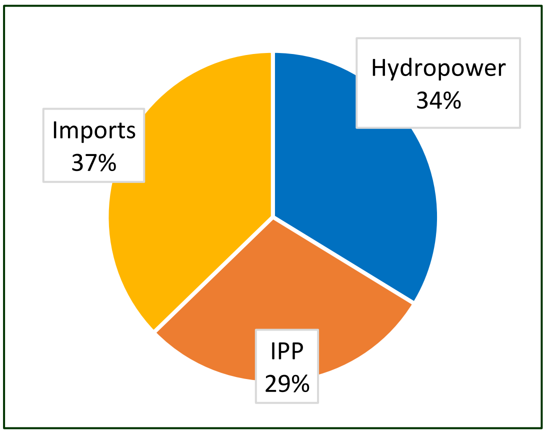


Figure 11 Power generation mix of Nepal

NEA's hydropower plants including small power stations generated a total of 2,548.11 GWh of electricity in FY 2018-19. The total power import from India was 2,813 GWh and the total power purchased from Independent Power Producers (IPPs) within Nepal was 2,190 GWh, in the same period. The total energy available in NEA's system was 7,551 GWh (Nepal Electricity Authority, 2019) (Figure 11).

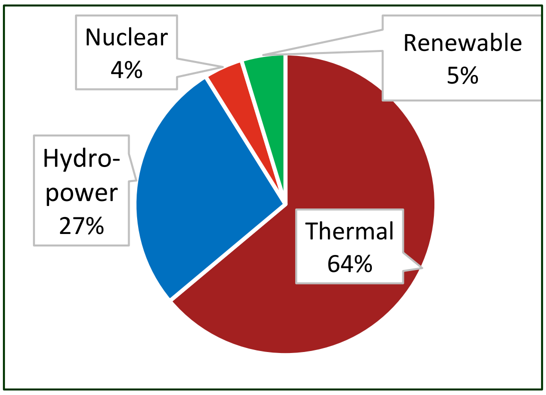


Figure 12 Installed capacity of Pakistan

Pakistan

Pakistan's total installed capacity as of FY 2018 was 35,972 MW (Finance Division, 2020). Coal, natural gas and other fossil fuel based thermal power plants form the majority of generation mix followed by hydropower with an installed capacity of 9,730 MW. Figure 12 presents Pakistan's power generation installed capacity based on energy sources.

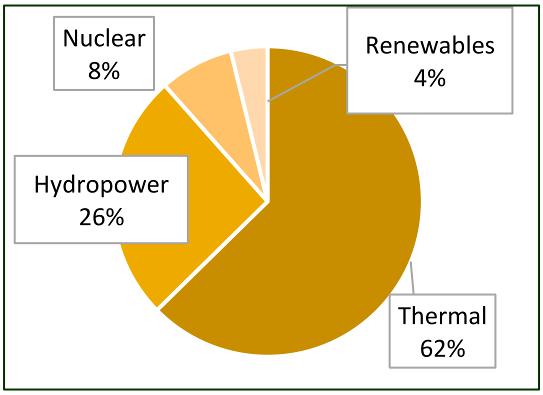


Figure 13 Power generation mix of Pakistan

The total electric power generation for FY 2018-19 was about 128,564 GWh (Pakistan Bureau of Statistics, 2019). The thermal based power plants formed the majority share (62%), followed by hydropower plants (26%), nuclear power plants (8%)

and other renewables (i.e., bagasse, solar and wind) (4%). The electricity generation mix of Pakistan is presented in Figure 13. The compound annual growth rate of electricity generation over last 5 years i.e., FY 2014-15 to FY 2018-19 was 3.14%.

Sri Lanka

The installed capacity of power generation in Sri Lanka is about 4,265 MW in 2020. Of the total installed capacity, 2,968 MW is run by Ceylon Electricity Board (CEB) and remaining by Private Power Producers (PPP). The major sources of power generation are coal, natural gas, oil, hydropower and renewables such as solar and wind. The thermal power accounts for the majority share in power generation in Sri Lanka and acts as base load. Hydropower and other renewable source follow next with nearly 34% and 14% share in installed capacity respectively. Hydropower and natural gas are broadly used for peak load in wet and dry seasons respectively. The installed capacity of Sri Lanka is shown in Figure 14. The total electricity generation in Sri Lanka in year 2020 was 15,714 GWh. About 71% of power was generated by CEB (11,138 GWh), remaining 30% by PPPs (Ceylon Electricity Board, 2020). The power generation mix of Sri Lanka is presented in Figure 15.

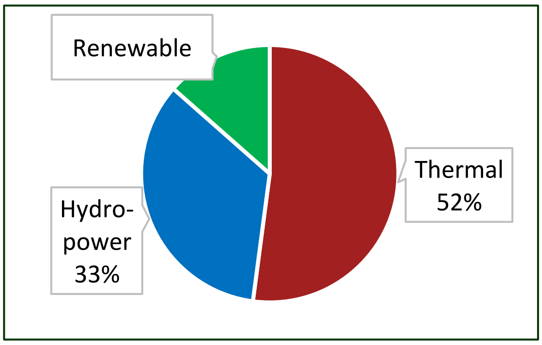


Figure 14 Installed capacity of Sri Lanka

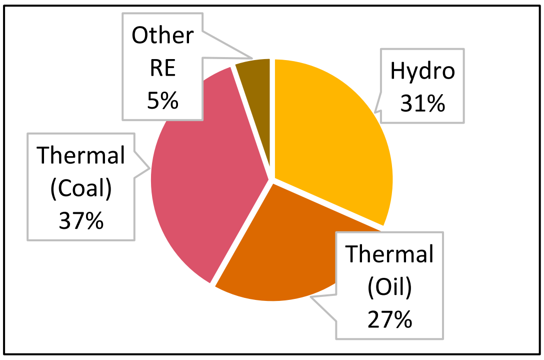


Figure 15 Power generation mix of Sri Lanka

1.3.2. Power Distribution

The SAARC Nations have highly contrasting economic profiles. The level of economic development, country's geographical spread and topography varies significantly amongst the eight SMS. The same is reflected in the distribution infrastructure of these countries. The amount of electrification in SAARC Nations varies from 30% in Afghanistan to 100% in countries such as India, Maldives and Bhutan. The country-wise electrification rate presented in Figure 16. These countries have seen progress in their grid expansion and inter country electricity trade with support from various bilateral and multilateral organisations such as ADB, JICA, and UNESCAP etc. There is still a lot of

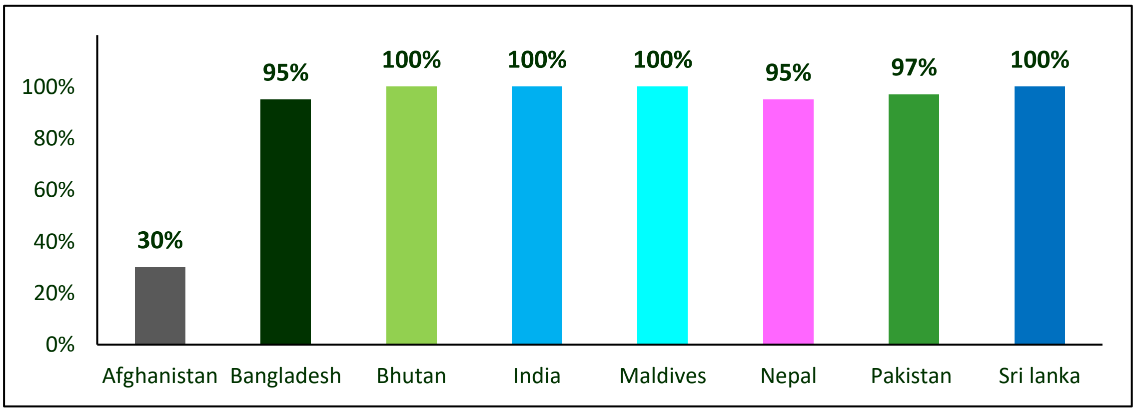


Figure 16 Electrification rate of SAARC Nations

scope in strengthening the distribution infrastructure of these nations to reap benefits such as high electrification, lower distribution losses.

Afghanistan

As of March 2017, Afghanistan's transmission network was estimated to comprise about 1,905 km of line length and about 1,544 MVA of transformer capacity at voltage levels of 110 kV to 220 kV. The distribution capacity was estimated at about 1,155 MVA, operating at the 20/15/6 kV voltage levels across 10 distribution zones (Global Transmission, 2019).

Bangladesh

Bangladesh has six power distribution utilities: (i) Bangladesh Power Development Board (BPDP), (ii) Dhaka Power Distribution Company (DPDC), (iii) Dhaka Electric Supply Company Limited. (DESCO), (iv) West Zone Power Distribution Company, (v) Bangladesh Rural Electrification Board (BREB) (which included 80 *palli bidyut samitis* (rural electricity cooperatives, abbreviated as PBS) as of June 2017), and (vi) Northern Electricity Supply Company Limited (NESCO). As of 2017, the distribution losses of DESCO, DPDC, and West Zone Power Distribution Company had reached below 10%, while those of BPDB, BREB, and NESCO ranged from 10% to 12%. Two main factors that contributed to this improvement were upgrading overloaded components and reducing commercial losses (Bangladesh Power Development Board, 2019). The average transmission & distribution (T&D) losses for Bangladesh are presented in Figure 17.

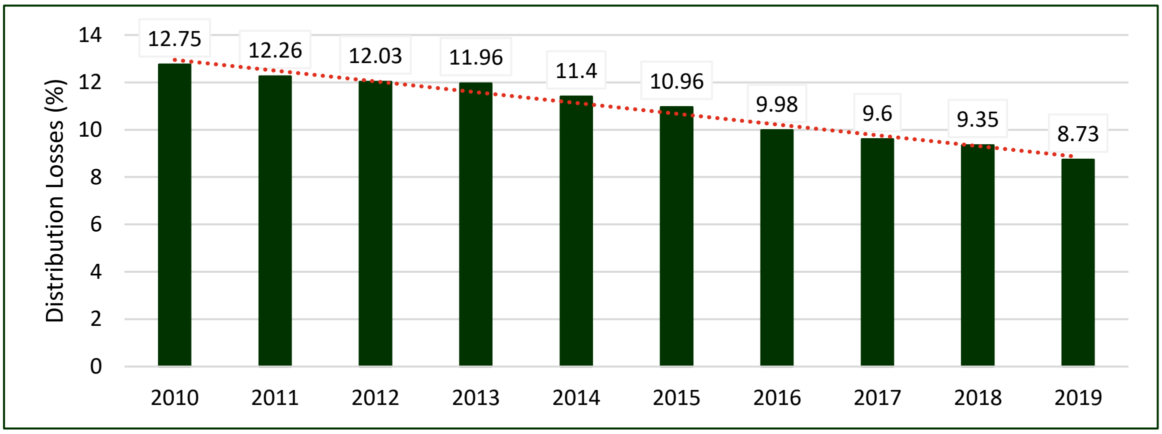


Figure 17 Distribution losses in Bangladesh (BPDB annual reports)

Bhutan

Bhutan has 100% electrification rate in both rural and urban sector. The expansion of the electricity network to rural areas has been undertaken in the context of operational improvements in network management in terms of system losses and supply reliability. Bhutan has nearly 1,709 kilometres of low-voltage lines to connect individual consumers to the power grid built by the Bhutan Power Corporation (Asian Development Bank, 2015). Due to availability of relatively cheap power from hydropower plants, the tariff for domestic consumers is nil up to certain limit of unit consumed.

India

Indian electricity distribution caters to nearly 200 million consumers with a connected load of about 400 GW that places the country among the largest electricity consumer bases in the world. The consumers are served by 73 distribution utilities – 13 electricity departments, 17 private distribution companies, 41 corporatized distribution companies and 2 State Electricity Boards. Figure 18 shows AT&C losses of India from 2007 to 2019 (Central Electricity Authority, 2008-2020).

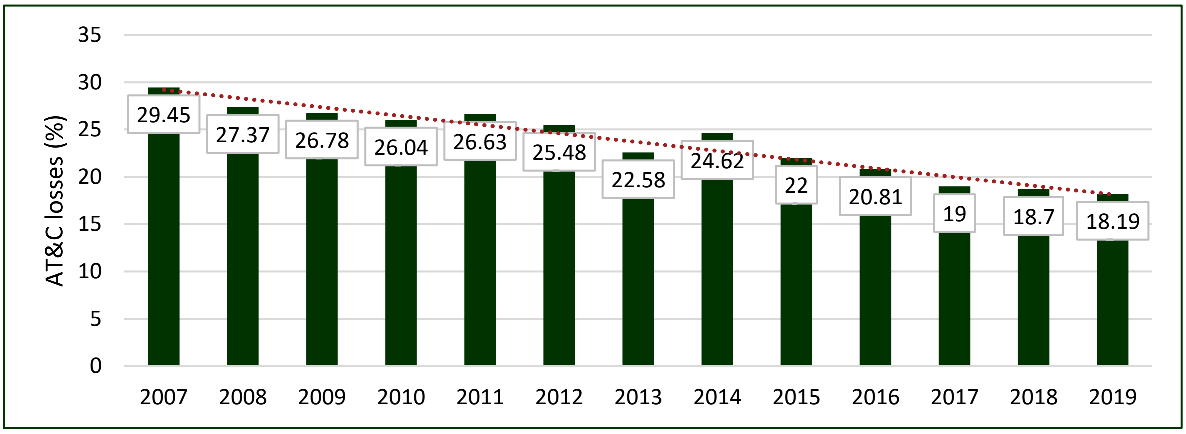


Figure 18 T&D and AT&C losses in India

Maldives

Maldives has a state-owned distribution company STELCO which manages the distribution of electricity across 28 Islands in the country. In 2016, STELCO had 37,660 consumers in Male and 14,462 consumers in different islands (STELCO, 2020). The distribution losses in the serviceable region of STELCO varied between 7% to 8% of the total power generated (Maldives Energy Authority, 2014).

Nepal

The Nepal Electricity Authority (NEA) has a monopoly over the distribution of electricity in Nepal and manages the distribution services and networks. The power distribution function involves planning, expanding, operating, maintaining, and rehabilitating the power distribution networks, including sub-stations of voltage level up to 33 kV. In addition, NEA provides consumer services such as new connections, meter reading, billing, and revenue collection (Nepal Electricity Authority, 2019).

Pakistan

The power distribution sector in Pakistan is catered by 11 distribution companies. The distribution companies (DISCOs) fall under Pakistan Electric Power Company (PEPCO) and are responsible for power distribution in an allocated region of the country. DISCOs buy power from Water and Power Development Authority (WAPDA), PEPCO and other private Independent Power Producers (IPPs) and sell it to their respective region customers. 10 DISCOs are owned by the Government of Pakistan and the DISCO in Karachi has been privatized. The distribution system is responsible for operation, maintenance and development of the grid stations and transmission network of 132 kV and below to provide electricity to consumers located in their geographical areas. Over the years, Pakistan's DISCOs have made gradual improvements on their T&D losses, except PESCO, SEPCO, QESCO and HESCO. The same has been elaborated in section 2.8.2.

Sri Lanka

The electricity distribution and sales in Sri Lanka come under the purview of two state owned organizations: (1) Ceylon Electricity Board (CEB); and (2) Lanka Electricity Company Pvt Ltd (LECO). Sri Lanka's distribution framework has improved substantially with its distribution losses reducing over the years. Figure 19 shows the range of distribution losses for the country ranging from 2008 to 2018 (Ceylon Electricity Board, 2019).

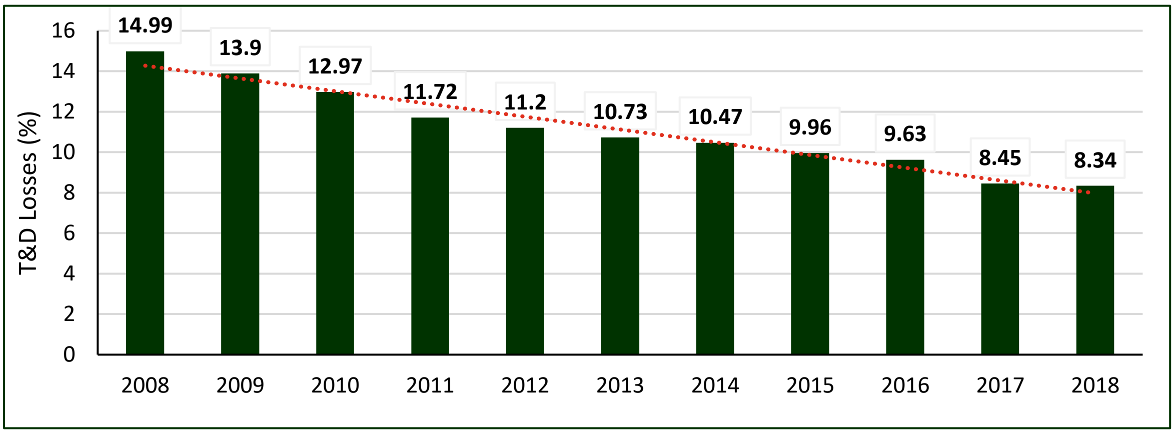


Figure 19 Sri Lanka's T&D losses 2008 to 2018

1.4. Requirement and Objective of the Study

1.4.1. Requirement of Energy Efficient Power Systems for SAARC Countries

The South Asian countries are all fast-growing economies with GDP growth rate as high as 6.86% in 2017. The current GNI growth rate has fallen to 4.8% (The World Bank, 2020) as of 2019 due to contraction of economies because of COVID-19 pandemic. The region is sufficiently endowed with natural resources including estimated hydro power of 296,431 MW, coal reserves of 133,237 million tons, natural gas reserves of 85 Tcf and large renewable potential of wind (378,594 MW), Solar (365,639 MW) as well as Biomass (SAARC Energy Centre, 2018). Despite all these factors, SMS still face acute shortage of electric power leading to frequent brown/black outs. SMS have tapped almost all the available natural resources in their region to generate power except Maldives where electricity is still being generated by imported diesel. International best practices for efficient electric power system are invariably dependent on optimization of power generation and distribution. The energy efficiency of power systems in the SAARC Nations can be improved through better operating practices, retrofits to existing systems and a shift towards new low carbon technologies. The need for energy efficient power systems is further segregated into two broad categories of power generation and distribution.

Generation Sector

The power generation efficiencies in SAARC countries are still low as compared to western benchmarks. With the advancement of technology, there is a vast improvement potential to improve inefficiencies on generation side. Typical range of efficiencies in power generation, depending on the type of fossil fuel, is presented in Figure 20. Energy efficiency in generation side can be improved by improving operating practices, retrofits to existing systems and by incorporating new technological advancements.

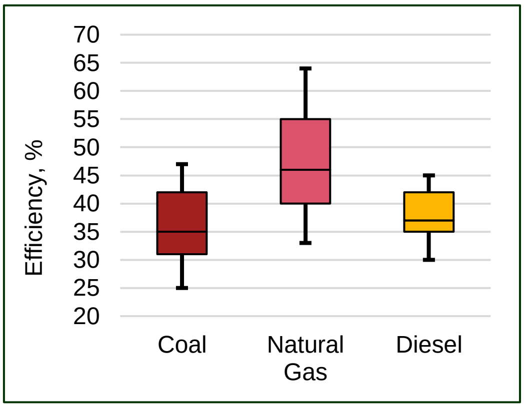


Figure 20 Efficiency of power generation by fossil fuels

There are various tools based on new technologies to optimise plant performance. Plant Analysis, Diagnosis and Optimization (PADO) for coal based thermal power plants is one such tool which gives efficiency parameters of whole plant on real time and detect any inefficiencies in real-time. For gas-based power generation, similar real time plant performance and efficiency monitoring tools are available.

Distribution Sector

Power generated in power stations pass through large and complex transmission and distribution networks comprising transformers, overhead lines, cables and other equipment, and reaches the end users. Losses in distribution network are divided in to two broad categories:

Transmission & Distribution losses (T&D losses)

- Transmission and Distribution (T&D) losses are a percentage of energy lost in the power grid in the process of transporting electricity from generating stations to points of consumption

Commercial losses (Nontechnical Losses)

- These are the losses due to manual error in meter reading, defective meter, billing of customer energy consumption, lack of administration, financial constraints, and estimating unmetered supply of energy as well as energy thefts

There are various measures which can be taken to mitigate technical and distribution losses such as converting LV Line to MV or HV Line, direct line from feeder for large commercial / industrial consumers, adopting High Voltage Distribution Service (HVDS) for agricultural customer, adopting Arial Bundle Conductor (ABC), reduce number of transformers, replacements of old conductor or cables among other initiatives.

1.4.2. Objective of the Study

The overall objective of the research study was to develop a document which could serve as a guideline for energy efficiency improvement in the power generation and distribution sectors of the SAARC Countries. The study maps the present status of power sector and energy efficiency in each Member Country. The study covers challenges, benefits and requirements for implementation of energy efficiency improvements. Figure 21 presents the objectives of the study on energy efficiency improvements in power generation and distribution sectors of SAARC Countries.

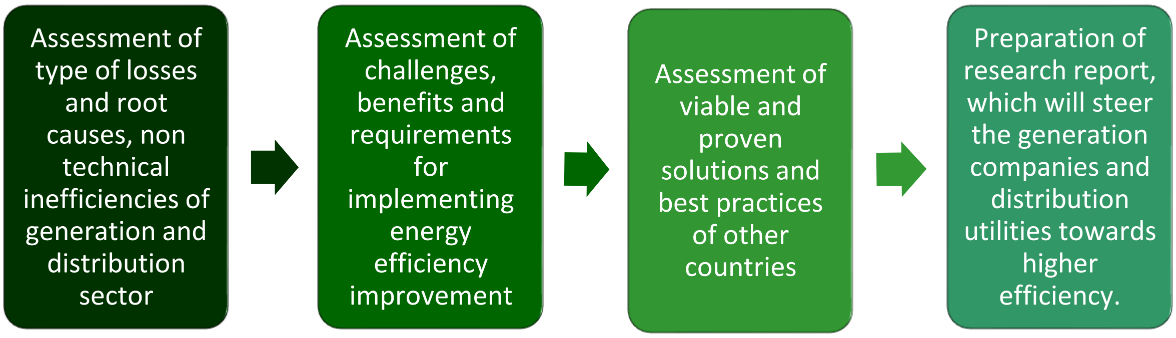


Figure 21 Objectives of the study

1.5. Scope of the Study

The scope of study was divided into four points:

- Identification of energy inefficiencies in power generation and distribution
- Challenges and barriers to implementation of energy efficiency opportunities
- Benefits of incorporating energy efficiency measures
- Recommendations based on analysis for each SAARC Member Country

Identification of barriers to energy efficiency and challenges to implement these barriers involved a detailed study of the power system infrastructure in the SAARC Nations. The primary mode of research was through interviews of identified stakeholders, desk-based studies and benchmarking from international best practices. The benefits of incorporating energy efficiency in power systems and subsequent recommendations was based on drawing conclusions from stakeholder consultations and the project team's analysis. The scope of work is presented in Figure 22.

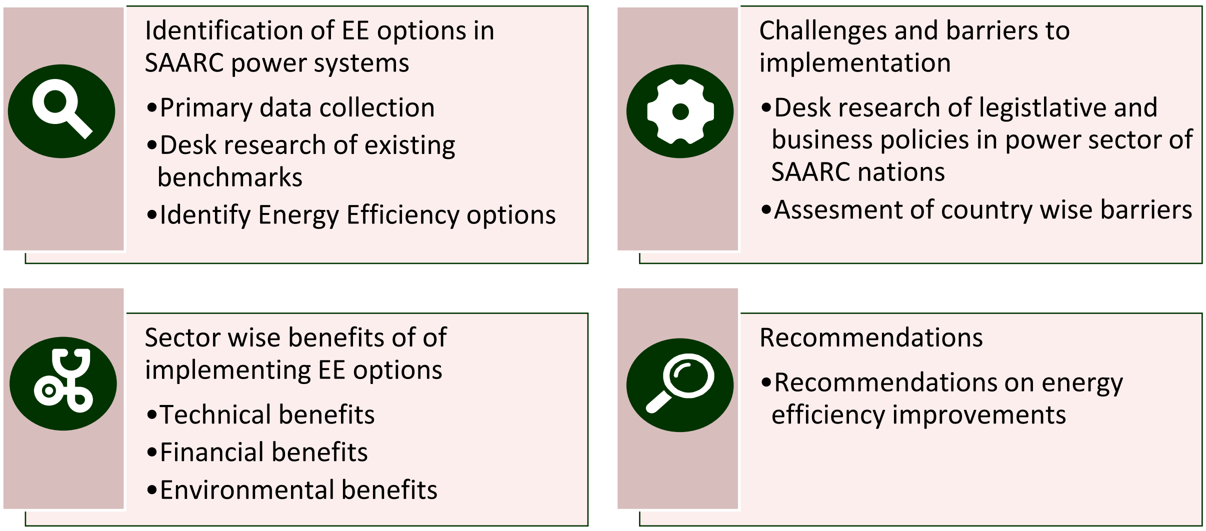


Figure 22 Scope of work

1.6. Methodology

The methodology was followed by dividing the scope of work into seven key components. These components are presented in Table 3. Detailed methodology of each component is explained in this section.

Table 3 Key components of the assignment

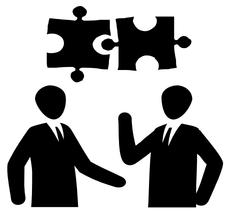
S. No	Task
1.	Stakeholder identification and secondary (desk) research
2.	Development of structured questionnaire for collating data
3.	Primary research through interviews of identified stakeholders
4.	International benchmarking for best practices and technologies
5.	Data analysis and drawing conclusions – quantitative solutions
6.	Draft report of the study for evaluation
7.	Final report submission after incorporating comments

Desk Review of Existing Documents

Conducted a desk review of the information on public domain. Some of documents reviewed are as follows:

- Power generation and distribution (PGD) sector of SAARC countries
- Power and energy sector policies and regulations
- Review of existing or past studies on energy efficiency in PGD
- Review of data availability with each of the eight SAARC nations on PGD key performance indicators
- Global benchmark study on energy efficiency in power generation and electricity distribution
- Identification of potential list of stakeholders at national level in PGD sector in each of the eight SAARC nations

Identification of Action Stakeholders and Their Mapping



The key action stakeholders involved in the EE in PGD were identified with the support from PwC's network firms and SAARC Energy Centre in each Member Country. The action stakeholders were classified as regulator (e.g., CERC), policy maker (e.g., Nepal Electricity Authority), power generation (e.g., Ceylon Electricity Board), power distribution (e.g., LESCO), OEMs & consultants and sector experts. The identified stakeholders were mapped against a pre-defined category. The categories were developed in consultation with SEC.

Development of Structured Questionnaire for Collating Data

Questionnaires were developed to conduct interviews of the identified stakeholders. The questionnaire was in two parts: (a) structured to obtain specific quantitative information and (b) a semi/unstructured part to collate qualitative information usually not present in available dataset. A different questionnaire was developed for each category of stakeholders as defined in previous point. The broad questionnaire for consulting stakeholders is presented in *Annexure: Sample questionnaire for* stakeholder consultation**.**

Primary Research through Interviews of Identified Stakeholders

With reference to the identified stakeholders and developed questionnaires, interviews were conducted. The purpose of these interviews was three-fold. Firstly, to collect data of efficiency in power generation, and technical & commercial losses in power distribution. Secondly, to gauge the efforts done on promotion of energy efficiency, present interventions and potential future polices or regulations in pipeline. Finally, to understand outlook of energy efficiency in PGD sector in near-term and long-term as per the responder/stakeholder. Digital communication platforms were used to conduct most interviews.

International Benchmarking for Best Practices and Technologies

The scouting for best available practices and technologies comprised of (a) secondary desk research i.e., reviewing studies by research institutes, government agencies and think tanks (e.g., IEA, World Energy Council), (b) consulting sector experts within SAARC and (c) leverage expertise within PwC network.

Data Analysis and Drawing Conclusions – Quantitative Solutions

The team conducted analysis of the data collated from primary and secondary sources to arrive at energy losses in power generation and distribution.

1. ***Gained learning from EE activities within SAARC Member Countries and suggested potential steps for quick adoption in other member countries.***
2. ***Gained learnings from international benchmark study from potential countries with similar attributes. The learnings were localized and customized to meet SAARC context.***

The team scrutinised potential policy and regulatory aspects which hinder the adoption of efficient practices and technologies. As a result of the data analysis, there was a long list of conclusions and recommendations. Team prioritized the recommendations based on risk assessment, ease of implementation, strategic impact and complexity.

1.7. Accuracy of the Selected Methodology

The following measures were adopted while conducting the study for achieving maximum possible accuracy of data and analysis:

- The secondary research data was sourced from reputed government agencies, annual reports and reputed research institutes for ensuring reliability of information.
- The stakeholders selected for the interview were from government institutions (who were directly responsible for executing and monitoring energy efficiency programmes in their country), well-known sectoral experts, and OEMs/technology providers.
- The recommendations for energy efficiency improvements were provided based on proven case studies and experiences of previous similar sort of measures implemented by countries around the world.
- The cost for implementation of various energy saving recommendation were considered with consultation from vender.

1.8. Limitations of the Study

The facts and data collated for the study are entirely dependent on the data available in the public domain. While undertaking this study special care was taken to cover all aspects of the terms of references. This study however has certain limitations including:

- The study did not involve any physical field visits due to COVID-19; however, interviews were conducted to gather as much primary data as possible for analysis
- Renewable energy sources (except for large hydro power) were not considered for the study.
- The data sourced for most of the countries is mainly from government sources and documents. However, due to data constraints for some of the countries such as Afghanistan, data from various bilateral and multilateral organizations was considered.
- The cost benefits provided in the study is to provide basic understanding of the level of returns possible. However, we recommend readers to carry out detailed technical and financial assessment prior to implementation.
- Some of the inefficiencies mentioned in the study are derived mainly through stakeholder consultations and focused group discussions with the stakeholders.
- The commercial values of the technologies specified in the report are for representative purposes. Quoting of any such cost/price should not be considered as the actual financial price.

2. Energy Efficiency Analysis of Power Systems of SAARC Countries

2.1. Key Performance Indicators of Power Generation and Distribution

Key Performance Indicator (KPI) can be defined as a quantifiable/measurable value that demonstrates how effectively the industry or equipment or process is performing. The KPIs for energy efficiency in power generation and distribution are presented in this section.

2.1.1. Generation Sector

The power generation of a country is primarily dependant on the available resources and the level of generation infrastructure present. The power sector of SAARC Countries varies significantly in terms of installed capacity and power generation mix by fuel type. The following fuel types are predominant in SAARC Nations:

- Thermal Power Plant using Coal, Lignite, or other liquid fuels
- Gas Turbine and Combined Cycle Power Plants using Natural Gas
- Hydro Power Plants
- Liquid or Gas fuel-based Internal Combustion (IC) Engines

In each of the SAARC nations, the specific generation type is selected for energy efficiency analysis based on the following parameters (a) predominance in the generation mix for the country such as thermal, hydro and IC engines, and (b) type of fuel used for generation within thermal such as natural gas, coal, liquid fuel. Based on the above-mentioned parameters, the selection of power generation type for each SAARC nation is presented in a matrix in Table 4.

Table 4 List of generation types analysed for different SAARC Nations

S. No.	Country	Hydro Power	Thermal Power Plants			IC Engines
			Coal	Gas	HFO/Diesel	
1	Afghanistan	✓	X	X	X	X
2	Bangladesh	X	✓	✓	✓	X
3	Bhutan	✓	X	X	X	X
4	India	✓	✓	✓	X	X
5	Maldives	X	X	X	X	✓
6	Nepal	✓	X	X	X	X
7	Pakistan	✓	✓	✓	✓	X
8	Sri Lanka	✓	✓	X	✓	X

The key energy efficiency variables for each of SAARC Nations are computed in the Table 5. The highlighted portions in the table show the factor affecting the efficiency of particular generation type for each country.

Table 5 Key energy variables for SAARC Nations in generation sector

Losses in Generation (GWh)								
Description	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Hydropower								
Losses due to resistance in path of water:								

Losses in Generation (GWh)								
Description	**Afghanistan**	**Bangladesh**	**Bhutan**	**India**	**Maldives**	**Nepal**	**Pakistan**	**Sri Lanka**
Losses due to improper maintenance of turbine								
Losses due to improper maintenance practice								
Mechanical losses between the turbine and generator systems								
Losses due to sediment in water								
Gas/Oil Based Thermal Plant (GT unit)								
Losses due to unavailability of HRSG								
Loss due to high auxiliary power consumption								
Losses due to ageing of gas power station								
Losses due to part load operation								
Loss due to improper operation and maintenance								
Losses due to low net capacity								
Losses due to outage of generating units								
Thermal Power Plant using HFO, Gas and Coal as a fuel								
Losses due to improper monitoring of critical parameters								
Losses due to excess auxiliary power consumption								
Losses due to ageing and delay in upgradation of plants								

Losses in Generation (GWh)								
Description	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Losses due to improper operation and maintenance								
Losses due to use of obsolete technology								
Losses due to improper selection of technology								
Diesel Engine								
Losses due to unsteady and unbalanced load								
Losses due to low power factor								
Losses due to inefficient operational practices								

The KPIs in power generation help us not only understand the efficiency levels but also the losses leading to those inefficiencies. A number of these losses are common among SAARC Nations, these similarities could be attributed to:

- Technologies used (coal-based power generation in India and Pakistan)
- Geographical and climatic conditions (hydro in Nepal and Bhutan: mountainous terrain)
- Economic conditions (hydro in wet season in Sri Lanka and other nations)

The following subsection captures losses in thermal power plant based on type of generation.

2.1.1.1. Thermal Power Plants

In a thermal power station typically heat energy is converted to electric power by means of a steam-driven turbine. The source of heat energy in a thermal power plant is either from fossil fuel, nuclear energy, biofuels, or waste incineration. Thermal power plants are predominant producers of electricity in countries such as India, Pakistan, Sri Lanka and Bangladesh. The efficiency level of thermal power plants varies dramatically within and among SAARC Countries. The KPIs of efficiency of typical thermal power stations are presented in Table 6.

Table 6 Key performance indicators of thermal power plant

S. No.	KPI	Unit
1	Boiler Thermal Efficiency	%
2	Turbine Heat Rate	kcal per kWh
3	Auxiliary Power Consumption	%
4	Turbine Cylinder Efficiency	%

Boiler Thermal Efficiency

The boiler system comprises of feed water system, steam system and fuel system. The feed water system supplies water to the boiler and controls it automatically to meet the steam demand. The steam system gathers and controls the steam produced. The steam pressure in the system is regulated using valves and monitored by series of steam pressure gauges. The fuel system includes equipment to deliver fuel to generate the necessary heat (Forbes Marshall, 2020). The equipment in the fuel system depends on the type of fuel used. There are various types of boilers as per the requirement of process. The major losses, which affects the overall boiler efficiency are:

a. **Dry Flue Gas Loss/Stack Loss**: Heat in the flue gas which is lost to the atmosphere is defined as dry flue gas /stack loss. The stack losses depend on fuel composition, firing conditions and flue gas temperature. There are two types of dry flue gas losses (1) sensible heat energy in the flue gas due to its temperature; and (2) heat loss due to moisture (latent energy) in the flue gas stream. There are various reasons which accounts for these losses, major ones are listed below:

High outlet temperature of flue gas	Inefficient Air Pre-Heater	Improper firing of fuel	Improper maintenance of boiler

b. **Blowdown Heat Losses**: The solids such as soluble salts accumulate on the sides of water passages. If unchecked, over a period it forms a deposit and reduces heat transfer. Chemicals are often used to reduce scaling and periodic/continuous blowdowns help remove these salts. Heat recovery equipment can minimize losses from blowdowns but, are cost-effective only for continuous blowdowns systems.

c. **Radiant Heat Losses**: Radiant heat losses occur from the outer surfaces of the boiler, when ambient temperature is lower than the boiler surface temperature. As load increases, the heat loss as a percentage of boiler output reduces, and vice-versa. Radiant heat loss can be minimized by improving insulation of the boiler surfaces and by maintaining optimum boiler temperature.

d. **Heat Loss Due to Soot Formation on Heating Surfaces**: Improper soot blowing schedule causes formation of soot on the heating surface of boiler tubes. This may cause excess fuel consumption for reaching desired operating condition and in some cases even because puncturing of tubes due to localized heating.

Turbine Heat Rate

The heat rate is defined as the total amount of energy (kcal) required to produce one kilowatt-hour (kWh) of electricity by an electric generator. The lower the heat rate higher the efficiency. Some of the typical loss which leads to increase in turbine heat rate are listed below:

a. **Losses Due to Part Load Operation**: Operation of plant at part load can result in lower plant efficiency and increased maintenance requirements. This is due to constant swings in operating temperature and pressure.

b. **Condenser Losses**: The main losses in turbine system occur in condenser. For a typical 210 MW unit, a 1 mmHg deviation in condenser vacuum leads to gain of 2.03 kcal/kWh in turbine heat rate (NTPC India, 2017). This varies with the capacity of the power plant. Various reasons of losses in condenser vacuum are as follows:

- Air Leakages within the condenser shell
- Low flow of cooling water
- Deteriorated performance of cooling tower
- Improper operation of condenser vacuum pump
- High condenser trip tank level
- Condenser tube leakage
- Improper expansion of steam in LP turbine

c. **Loss Due to Improper Control of Steam Temperature and Pressure**: Due to various operational difficulties/lack of skill-level of operator, the rated temperature/pressure are not maintained at the recommended levels. This could lead to higher turbine heat rate. The various losses occurring due to improper operating parameters are shown in Table 7.

***Table 7 Heat rate deviation due to critical steam parameters*[1]**

S. No.	KPI	Deviation	Average Loss (kcal/kWh)
1	Main Steam Pressure	1 kg/cm^2	0.085
2	Main Steam Temperature	1 ^0C	0.64
3	Reheat temperature	1 ^0C	0.59
4	Top Heater Out of Service	-	23.7
5	Second Heater Out of Service	-	17.7
6	Third Heater Out of Service	-	17.7

d. **Loss Due to Attemperation**: To prevent excessively high steam temperatures at the inlets of the high pressure and intermediate pressure turbines, water is sprayed into steam. This process is called attemperating spray. These liquid flows are taken from turbine cycle, results in an increase in heat rate. The loss due to attemperator is only considered when water for spray is taken after boiler feed pump and not considered when taken after HP heaters. The loss in heat rate due to attemperation is 0.028 kcal/kWh for 1 TPH of flow in main stream line and ~ 0.246 for 1 TPH of flow in re-heat line for a subcritical 210 MW coal fired thermal power plant.

Auxiliary Power Consumption

The auxiliary power consumption is the amount of electricity consumed within the plant boundaries to produce the power. In a coal based thermal power plant, the auxiliary power consumption nominal value is in range of 5.75% to 9.5% for plants between 200 MW and 800 MW rated capacity (Central Electricity Regulatory Commission, 2018). The auxiliary power consumption for less than 200 MW unit is in range of 12-15% of the total generation. The main auxiliary power consuming equipment along with share in the power consumption is presented in Table 8.

***Table 8 Auxiliary power use in coal-fired power plants by technology*[2]**

Component	Auxiliary Power Consumption			
	Sub-Critical	Super Critical	Ultra-Super Critical	Future Ultra Super Critical
Feed Water System	32%	41%	42%	48%

[1] (NTPC India, 2017)
[2] (Excellence Enhancement Centre for Indian Power Sector, 2013)

Component	Auxiliary Power Consumption			
	Sub-Critical	Super Critical	Ultra-Super Critical	Future Ultra Super Critical
Cooling Water System	17%	15%	15%	13%
Pollution Control System	13%	12%	11%	10%
Combustion Air and Flue Gas	19%	16%	16%	14%
Fuel Handling	05%	04%	04%	04%
Other Loads	14%	12%	12%	10%

The efficiency of thermal power plant depends on its percentage auxiliary power consumption. Major reasons of high auxiliary power consumption are listed below:

- **Coal Quality**: An inferior coal quality can lead to high auxiliary power consumption in coal pulverisers, secondary and primary fans.
- **Degradation of Equipment**: Ageing and degradation of fans, motors, pumps and other related auxiliaries in the station is one of the major reasons for high auxiliary power consumption.
- **Inefficient Operation**: Quite often, improper plant operations can lead to cascading effect causing increase in auxiliary power consumption. E.g., loading pattern for coal & ash handling.
- **Leakages in Boiler and Condensers**: There are various leakages in the boiler like air in leakage to boiler gas enclosure, fouling of boiler heating surface, higher draft loss due to air ingress and ash deposition. The leakages caused in condenser are air ingress and extent of tube plug gage and steam and water leaks from drains and vents are some of the reasons which affects auxiliary power consumption (Steag, 2013).

Turbine Cylinder Efficiency

A typical steam turbine in thermal power station has 3 types: High Pressure (HP), Intermediate Pressure (IP) and Low-Pressure (LP) turbine. For the individual turbines, the cylinder efficiency is the ratio of actual enthalpy drop across the turbine to isentropic enthalpy drop across the turbine. The IP turbine is the most efficient turbine and LP turbine is the least efficient one. Prime causes which affect turbine cylinder efficiency are listed below (Enomoto, 2017):

- **Softening**: High temperature bolts can soften and elongate after years of operation. The softened bolts lead to steam leakage and performance deterioration.
- **Creep Deformation**: HP/IP turbine casings deform by several millimetres through creep after years of operation and number of start-ups and stops. It can become difficult to seal the casing completely, resulting in steam leakage.
- **Wearing/Rubbing** seal fin, blade, or rotor rubbing can occur during start-up and shut-down or transient operating events. This could result in larger clearances and increased leakage. This is one of the main causes of turbine efficiency degradation.
- **Erosion**: It is a phenomenon where parts such as the rotating blade, nozzle, main valve, horizontal joint of blade rings are worn out, or damaged by water droplets or solid particles.
- **Oxidized Scale**: It can develop on turbine blades, stem shafts of main valves, and components in high-temperature regions. This leads to turbine efficiency decrease, and the inlet pressure of turbine blades increases as the scale reduces the throat (flow area) of the blades. This scale

can accumulate significantly on the underside of the shroud.

The efficiency in thermal power plants varies with the capacity and technology used. Typical KPIs of the thermal power plant are presented in Figure 23.

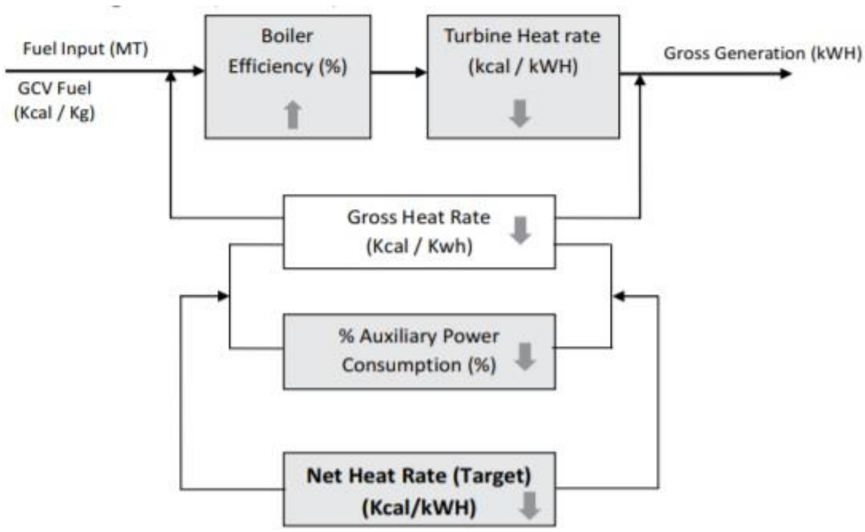


Figure 23 Energy Efficiency breakdown in a thermal power plant

2.1.1.2. Gas-based Thermal Power Plant

The gas turbine engines derive their power from burning fuel in a combustion chamber and using the fast-flowing combustion gases to drive a turbine in same way as the high-pressure steam drives a steam turbine. A simple gas turbine comprises of three main sections: compressor, combustor, and power turbine. The gas-turbine operates on the principle of the Brayton cycle, where compressed air is mixed with fuel, and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work (Zohuri, 2015). A schematic diagram of a typical gas turbine is shown in Figure 24.

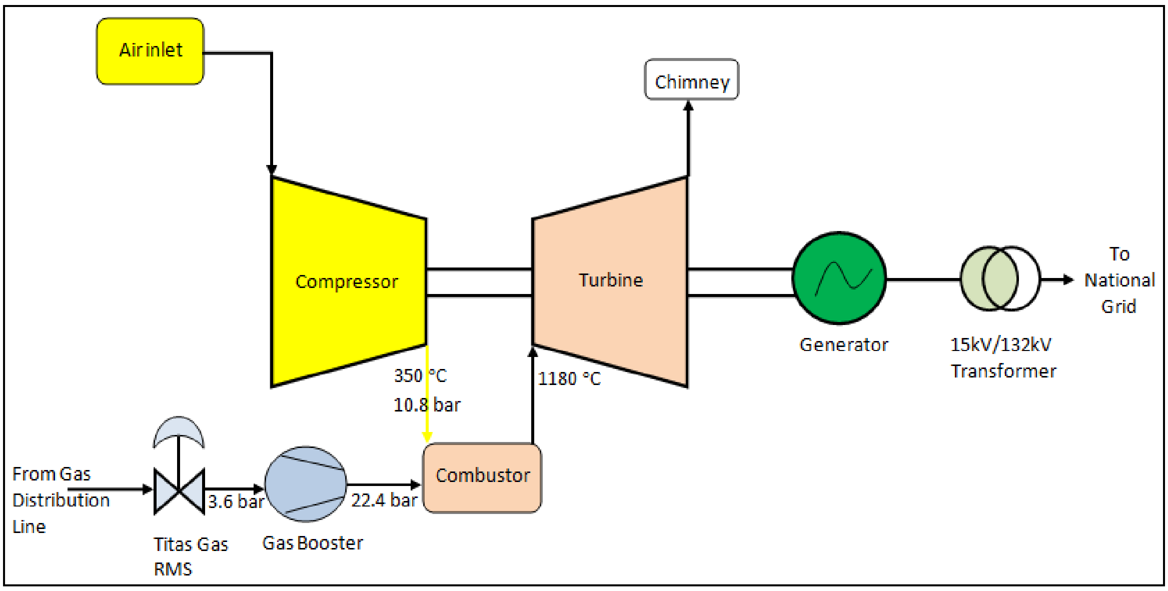


Figure 24 Gas turbine main components

The combined cycle power plants use combination of gas turbine and steam turbine cogeneration. Steam generated from the exhaust gas of the gas turbine is passed through a backpressure or extraction-condensing steam turbine to generate additional power. The exhaust or the extracted steam from the steam turbine provides the required thermal energy as shown in Figure 25[3].

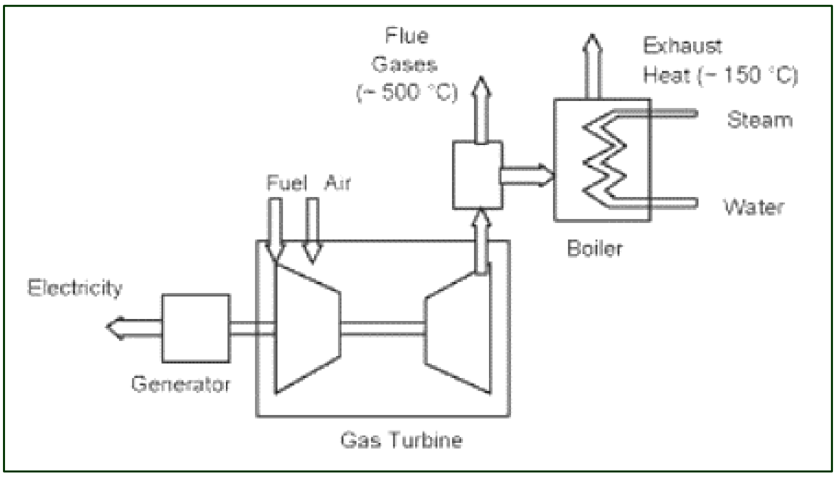


Figure 25 Combined cycle power plants

The main KPIs for energy efficiency in Gas based thermal power plant are similar to that of coal-fired thermal power plant i.e. (1) Gross Heat Rate, (2) Auxiliary Power Consumption and (3) Steam Turbine Efficiency. Typical losses which effect the gross heat rate are presented below:

- **Losses Due to Change in Ambient Temperature**: The standard conditions for a gas turbine are ambient temperature 15 °C, relative humidity 60% and ambient pressure 1.013 bar/14.7 psi. The change in ambient temperature of air entering the compressor has a direct impact on efficiency of gas turbine. With increase in air temperature its density decreases, which affects the amount of air entering the turbine. A typical correction curve showing the effect of ambient temperature on output of gas turbine is shown in Figure 26[4].

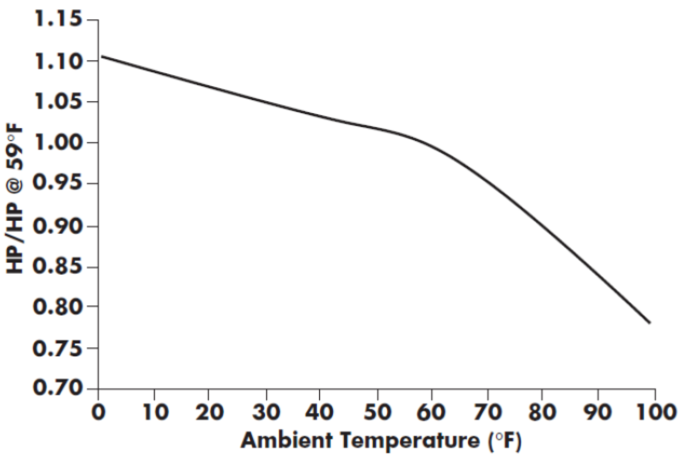


Figure 26 Gas turbine output and exhaust flow vs. temperature

- **Loss Due to Change in Atmospheric Pressure**: Ambient pressure is a site depends on the elevation. With the increase of the elevation, the density of air reduces hence ambient pressure reduces. Every 0.01 kg/cm^2 increases in ambient pressure, power output increases ~ 0.6% (K.A.B.Pathirathna, 2013).

---

[3] *(Bureau of Energy Efficiency, 2015)*
[4] *(K.A.B.Pathirathna, 2013)*

- **Losses Due to Change in Relative Humidity**: The atomic mass of the H_2O is less than N_2 and O_2. Hence, mass of the humid air is less than the mass of the dry air (same volume). Therefore, the humid air has less density than the dry air. For every 0.01 kg of water vapour /kg dry air increase in specific humidity above the rated value, gas turbine output decreases by 0.14% and heat rate increases by 0.38%. Typical correction curves showing the effect of specific humidity on heat rate and power is shown in Figure 27[5].

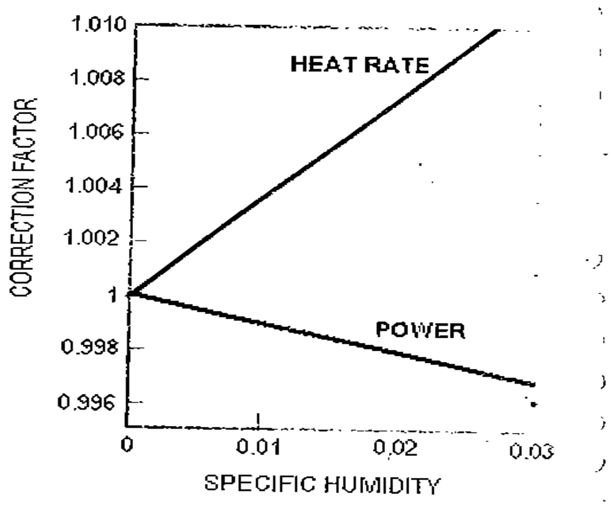


Figure 27 Gas turbine heat rate and power with respect to relative humidity

- **Loss Due to Differential Pressure Across Air Filters**: A drop in inlet air pressure drop directly affects the gas turbine performance. In practical, the inlet pressure loss is a function of inlet air system design and cleanliness of the inlet air filters. Hence, filtration system's design and maintenance are of at most importance.
- **Loss Due to High Exhaust Pressure from Gas Turbine**: Higher exhaust pressure losses increase turbine backpressure thereby reducing power output and increasing heat rate. For single cycle applications, exhaust system consists of exhaust duct, silencer and stack. Typical exhaust pressure loss in simple cycle gas turbines is 100 to 125 mmWC (water column) and for combined cycle exhaust pressure loss is 250 to 425 mmWC depending on complexity of cycle arrangement, exhaust emission control and noise abatement.
- **Loss Due to Fuel Composition**: Natural gas with large amount of inert gas components such as CO_2, N_2 have a low Wobbe index while substances with large number of hydrocarbons have a high Wobbe index. Pure Methane (CH_4) has a Wobbe index of 1220. Thus, fuel with higher Wobbe index have better heat rate. Other factors which affect turbine/combustion system life & performance include specific gravity, fuel gas temperature (K.A.B.Pathirathna, 2013).
- **Losses Due to Shaft Speed Ratio**: The efficiency of a gas turbine is maximum at an optimum speed. Thus, it is important to maintain the shaft speed ratio.
- **Losses Due to Compressor Pressure Ratio**: The ratio of compressor discharge pressure to compressor inlet pressure is defined as compression ratio. Higher compression ratio results in higher thermal efficiencies. In practice, compression ratios are limited by cost associated with compressor stages. Higher compression ratios result in higher temperature of compressed inlet

[5] *(K.A.B.Pathirathna, 2013)*

air. If compression ratios are too high, then intercooler may be required to reduce temperature of compressed inlet air. Typical compression ratio for gas turbines is 18 to 30 (Figure 28[6]).

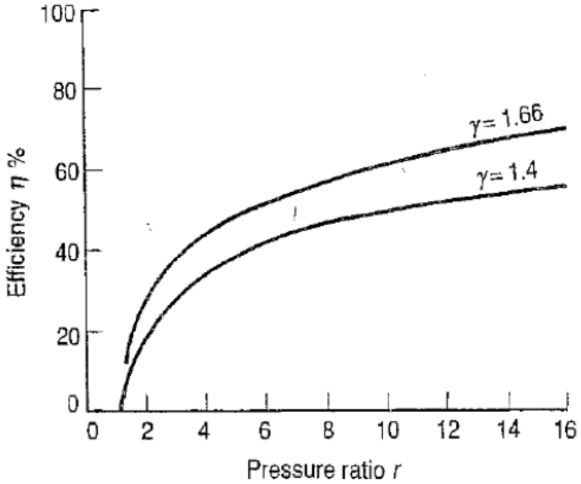


Figure 28 Comparison of pressure ratio to efficiency for gas turbine

- **Loss Due to Low Turbine Inlet Temperature**: Higher turbine inlet temperatures result in higher specific outputs and lower heat rates. In recent years, higher turbine inlet temperatures are achieved by use of ceramic & composite materials and improved turbine cooling technology. Presently, gas turbines have turbine inlet temperature of about 1300°C. The comparative graph of turbine inlet temperature to efficiency is presented in Figure 29[6].

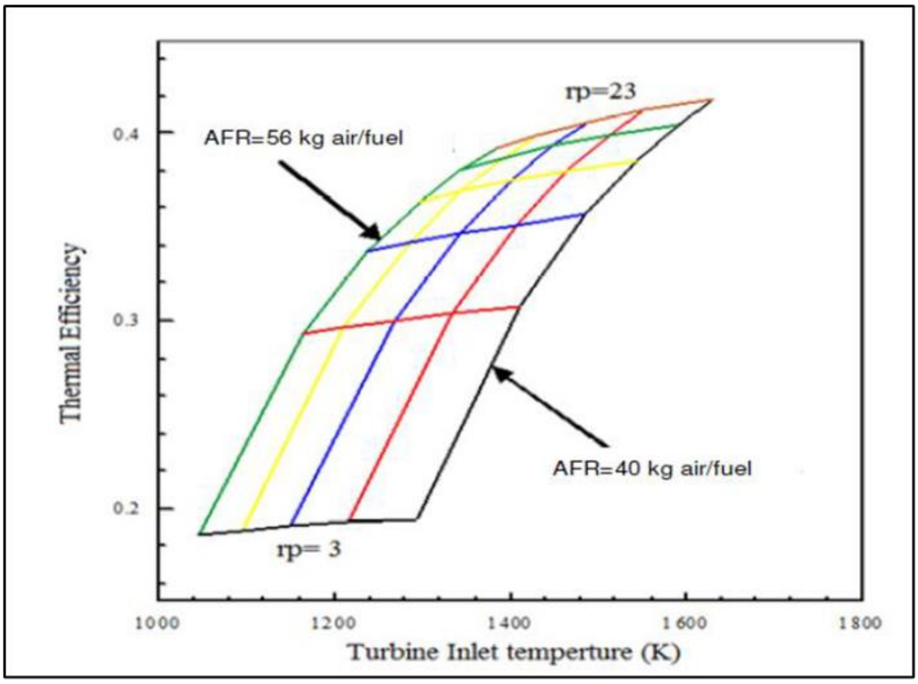


Figure 29 Turbine inlet temperature v/s efficiency

[6] *(K.A.B.Pathirathna, 2013)*

2.1.1.3. Hydro Power Plant

Hydropower is conversion of the kinetic energy in moving water to mechanical energy in turbine, which is then used to generate electricity (Ulowa WIki, 2020). The layout of a typical hydropower plant is shown in Figure 30[7].

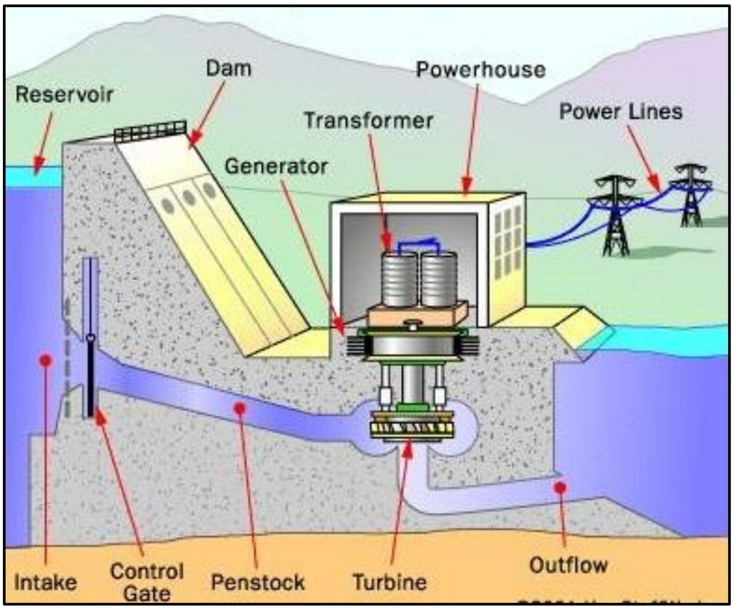


Figure 30 Typical hydropower plant layout

A select list of major losses is hydropower plant are presented below:

Hydro Mechanical Losses: In a hydro power plant, water flows from reservoir to turbine through penstock. In the process, potential energy of water at reservoir is converted into kinetic energy. A part of kinetic energy is converted into heat energy during the passage through penstock. Some of the main areas of loss are intake area, penstock and Y branches. These frictional losses are mainly due to rough surfaces and presence of unwanted particles in the penstock.

Turbine Losses: The turbine losses could be due to various reasons such as:

- **Head Loss**: The height difference between the water reservoir and the tail race in a hydroelectric facility is termed the gross head and it determines the maximum amount of power that can be produced. However, as water flows through pipes due to friction, it loses some head/pressure. The actual output from the turbine is based on the net head.
- **Wearing of Turbine Blade**: Ageing and cavitation leads to turbine blades wear and tear. This leads to drop in power generation. The vortex is formed when the reservoir water level decreases from a rated elevation and air enters the penstock. Thus, use of the anti-vortex structures in dams is recommended. Vortex formation be prevented by maintaining an optimum level of water in the reservoir and by use of anti-vortex wall at the inlet of tunnel.

Mechanical Losses between the Turbine and Generator Systems: Friction losses occurs in the shaft connecting water turbine to generator in the hydro power plant. These losses increase with the ageing of equipment and improper lubrication of bearings and shafts.

Losses from Generator Inefficiencies: The load current flows through the armature in all AC generators. Like any coil, the armature has resistance and inductive reactance. The combination of these makes up the internal impedance, which causes a loss in an AC generator. When the load

[7] (Bonsor, 2020)

current flows, a voltage drop is developed across the internal impedance. This voltage drop subtracts from the output voltage and, therefore, represents generated voltage and power that is lost and not available to the load. There are mainly three types of losses in generator:

- **Copper Loss:** The loss in the form of heat generated in armature winding is called copper loss in the generator. The copper loss is directly proportional to the current flowing in the winding. This loss can be minimised by proper selection of wire diameter used in windings.
- **Hysteresis Losses:** Hysteresis losses occur when iron cores in an AC generator are subject to effects from a magnetic field. To reduce hysteresis losses, most AC armatures are constructed of heat-treated silicon steel, which has an inherently low hysteresis loss. After the heat-treated silicon steel is formed to the desired shape, the laminations are heated to a dull red and then allowed to cool. This process, known as annealing, reduces hysteresis losses.
- **Mechanical Losses:** Rotational or mechanical losses can be caused by bearing friction, brush friction on the commutator, and air friction (called windage), which is caused by the air turbulence due to armature rotation. Careful maintenance can be instrumental in keeping bearing friction to a minimum. Clean bearings and proper lubrication are essential to the reduction of bearing friction. Brush friction is reduced by ensuring proper brush seating, proper brush use, and maintenance of proper brush tension. A smooth and clean commutator also aids in the reduction of brush friction. In very large generators, hydrogen is used within the generator for cooling; hydrogen, being less dense than air, causes less windage losses than air.

Losses from Transformer and other power conditioning inefficiencies. There are mainly two types of losses in transformers (Copper Development Association Inc., 2020)**:**

- **Load Losses**: Load losses vary according to the loading on the transformer. They include loss due to heating and eddy currents in the primary and secondary windings of the transformer.
- **No Load Losses**: No-load losses are caused by the magnetizing current needed to energize the core of the transformer, and do not vary according to the loading on the transformer. They are constant and occur throughout the year, regardless of the load, hence the term no-load losses. They can be categorized into five components: hysteresis losses in the core laminations, eddy current losses in the core laminations, I^2R losses due to no-load current, stray eddy current losses in core clamps, bolts and other core components, and dielectric losses. Hysteresis losses and eddy current losses contribute over 99% of the no-load losses. Thinner lamination of the core steel reduces eddy current losses.

2.1.1.4. Diesel Engine Driven Generator

Diesel engine is the prime mover, which drives an alternator to produce electrical energy. In the diesel engine, air is drawn into the cylinder and is compressed to a high ratio (14:1 to 25:1). During this compression, the air is heated to a temperature of 700–900°C. A metered quantity of diesel fuel is then injected into the cylinder, which ignites spontaneously because of the high temperature (Bureau of Energy Efficiency, 2017). Diesel engine powered generators are most frequently used in small power (captive non-utility) systems. The fuels burnt in diesel engines range from light distillates to residual fuel oils. For continuous operation, low speed diesel engine is more cost-effective than high speed diesel engine.

A brief comparison of different types of captive power plants (combined gas turbine and steam turbine, conventional steam plant and diesel engine power plant) is given in Table 9 (Bureau of Energy Efficiency, 2015). Diesel plant wins over the other two in terms of thermal efficiency, capital cost, space requirements, auxiliary power consumption, and plant load factor.

***Table 9* Comparison of different types of captive power plant**[8]

Description	Units	Combined GT & ST	Conventional Steam Plant	Diesel Engine Power Plants
Thermal Efficiency	%	40 – 46	33 – 36	43 – 45
Initial Investment	USD/kW	120 – 140	200 – 250	100 – 125
Space requirement	%	125 (Approx.)	250 (Approx.)	100
Construction time	Months	24 – 30	42 – 48	< 12
Project period	Months	30 – 36	52 – 60	~12
Auxiliary Power Consumption	%	2 – 4	8 – 10	1.3 - 2.1
Plant Load Factor	kWh/kW	6000 – 7000	5000 – 6000	7200 – 7500
Start-up time from cold	Minutes	About 10	120 – 180	15 – 20

The major losses in Diesel Generator (DG) sets, which affects efficient operation of system are mentioned below:

Losses Due to Ageing: Ageing affects performance of a DG set to a large extent. Due to various ageing issues, the system tends to run on de-rated capacity and the specific oil consumption increases due to wear and tear of pistons and related auxiliaries. The loss can be prevented by periodic overhaling and regular maintenance. But in some cases, maintenance or replacement of faulty equipment is expensive, so it is recommended to replace the same with more efficient DG set or any other alternate power generation system.

Losses Due to Inadequate Maintenance: Proper maintenance is key to efficient operation of DG set. There should be proper schedule for periodic overhaling and preventive maintenance. At times, due to unavailability of authentic spare parts, the company is forced to use other alternate spare parts, which affects the performance of total system. Proper vibration analysis of critical equipment should also be conducted.

Loss Due to Low-Capacity Utilization: The power requirement is determined by the maximum load. The engine power rating should be 10-20% more than the power demand by the end use. This prevents overloading the machine during start-ups. In some cases, the rated capacity is too high as compared to rated demand of the system, thus leading to operation at low utilization factor (<40%). It is recommended to install lower capacity system in parallel to overcome the utilization challenge in case peak and off-peak load differential is considerable.

Losses Due to Inefficient Operational Practices: The operational practices should be reviewed on a regular interval. Regular load analysis helps prevent under and over loading of DG sets. Typical acceptable losses in generation are summarised in Table 10.

[8] *(Bureau of Energy Efficiency, 2015)*

Table 10 Typical acceptable losses in power generation

Types of Loss	Unit	Acceptable Value	Reason
Thermal Power plants (using coal, lignite, gas and oil as fuel)			
Boiler Thermal Efficiency[9]			
Dry Flue Gas Loss/Stack Loss	% Contribution in loss of boiler efficiency	5 to 7	Due to sensible heat loss by gasses leaving the stack
Blowdown Heat Losses	% Contribution in loss of boiler efficiency	.5 to 1.5	Heat loss due to blowdown of steam
Radiant Heat Losses	% Contribution in loss of boiler efficiency	0.4 to 1	Heat loss at the surface of boiler
Heat loss due to soot formation	% Contribution in loss of boiler efficiency	1 to 1.5	Heat transfer loss due to formation of soot on the surface of tubes
Turbine Heat Rate[10]			
Losses due to part load operation	kcal contribution in rise of unit heat rate	50 to 75	Loss due to part load operation for which loss occur due to excess attemperation
Condenser Losses	kcal contribution in rise of unit heat rate	0.4 to 2.7	Loss due to leakage and inefficient heat transfer from condenser tubes
Loss due to improper control of steam temperature and pressure	kcal contribution in rise of unit heat rate	0.3 to 0.7	Loss occurs due to flaw in design and Inefficient operation
Loss due to attemperation in Main Steam and Re-heat line	kcal contribution in rise of unit heat rate	0.1 to 0.5	Improper fire ball in the boiler and localized heating of tubes
Auxiliary Power Consumption[10]			
Coal quality	kcal contribution in rise of unit heat rate	2 to 3	Variation in the coal quality from the designed coal for the plant
Degradation of equipment	kcal contribution in rise of unit heat rate	16 to 24	Ageing and improper maintenance
Inefficient operation	kcal contribution in rise of unit heat rate	Marginal	inefficient operation and lack of awareness
Leakages in boiler and condensers	kcal contribution in rise of unit heat rate	10 to 20	Ageing and improper maintenance
Losses Due to Low Turbine Cylinder Efficiency			
HPT efficiency	kcal contribution in rise of unit heat rate	4.5 to 5.4	Ageing and improper maintenance practice
IPT efficiency	kcal contribution in rise of unit heat rate	2.7 to 4.8	
Gas/Oil based Generator Turbine Power Plant[9]			
Losses due to change in ambient temperature	% Loss in efficiency	2 to 3	Improper site selection for plant

[9] *PwC internal analysis*
[10] (NTPC India, 2017)

Types of Loss	Unit	Acceptable Value	Reason
Loss due to change in atmospheric pressure	% Loss in efficiency	0.5 to 0.75	
Losses due to change in relative humidity	% Loss in efficiency	0.25 to 0.5	Atmospheric condition of plant area
Loss due to differential pressure across air filters:	% Loss in efficiency	0.5 to 0.75	Improper maintenance of filter
Loss due to high exhaust pressure from gas turbine	% Loss in efficiency	Marginal	Operational inefficiency
Loss due to fuel composition	% Loss in efficiency	1 to 1.5	Improper fuel selection for the plant
Losses due to shaft speed ratio	% Loss in efficiency	Marginal	Improper maintenance
Losses due to compressor pressure ratio	% Loss in efficiency	Marginal	Inefficiency of intercooler and degraded performance of compressor
Loss due to low turbine inlet temperature	% Loss in efficiency	2 to 3	Design issue flaw
Hydro power[9]			
Hydro Mechanical Losses	% Loss in efficiency	1 to 1.5	Resistance in penstock
Turbine Losses			
Head Loss	% Loss in efficiency	0.75 to 1	Variation in head of water at reservoir
Wearing of turbine blade	% Loss in efficiency	1 to 1.5	Ageing and improper replacement and maintenance schedule
Mechanical losses between the turbine and generator systems	% Loss in efficiency	0.1 to 0.3	Improper maintenance
Losses from Generator Inefficiencies			
Copper Loss	% Loss in efficiency	0.1 to 0.5	Inherent losses of the generators
Hysteresis Losses	% Loss in efficiency		Inherent losses of the generators and increases with improper maintenance and overhauling
Mechanical Losses	% Loss in efficiency		improper maintenance and lubrication
Losses from Transformer			
Load Losses	% Loss in efficiency	0.1 to 0.5	Inherent losses of the generators and increases with improper maintenance and overhauling
No Load Losses	% Loss in efficiency		
Diesel Engine Driven Generator[9]			
Losses due to ageing	% Loss in efficiency	3 to 4	Loss due to ageing of DG set competent

Types of Loss	Unit	Acceptable Value	Reason
Losses due to inadequate maintenance	% Loss in efficiency	1 to 2	Improper maintenance and overhauling schedule
Loss due to low-capacity utilization	% Loss in efficiency	4 to 5	Loss due to improper DG selection

2.1.2. Distribution Sector

The distribution-and-retail supply is the most critical link in the electricity market, which interfaces with the end customers and generates revenue for the entire value chain. Energy losses occur in the process of supplying electricity to consumers due to technical and commercial reasons. The technical losses are due to energy dissipated in the conductors, transformers and other equipment used for transmission, transformation, sub-transmission and distribution of power. These technical losses are inherent in a system and can be reduced only to a certain level.

Aggregate Technical and Commercial (AT&C) losses and Transmission and Distribution (T&D) losses are referred in power sector as yardsticks for measurement of performance of distribution utilities. The concept of Aggregate Technical & Commercial losses provides a realistic picture of loss situation. It is combination of energy loss (Technical loss + Theft + inefficiency in billing) & commercial loss (Default in payment + inefficiency in collection). It is the difference between energy input and the energy for which revenue is actually realized from the consumers while the T&D loss does not consider commercial losses of electrical power. The AT&C losses or T&D losses can be segregated into technical and nontechnical losses.

The key energy efficiency variables for each SAARC Nation are computed in the Table 11. The highlighted portions in the table shows the factor affecting the efficiency for distribution network in each country.

Table 11 Key energy variables for SAARC Nations in distribution sector

Distribution								
Description	**Afghanistan**	**Bangladesh**	**Bhutan**	**India**	**Maldives**	**Nepal**	**Pakistan**	**Sri Lanka**
Losses due to lengthy distribution lines								
Use of inefficient transformers								
Losses due to improper monitoring								
LV line losses								
Losses due to overloading and low voltage								
Losses due to improper planning of								

Distribution								
Description	**Afghanistan**	**Bangladesh**	**Bhutan**	**India**	**Maldives**	**Nepal**	**Pakistan**	**Sri Lanka**
distribution network								
Losses due to improper maintenance of transformers and lines								
Losses due to low power factor								
Losses due to ageing infrastructure								
Power theft & politics of power								
Losses due to operational issues								
Losses due to various technological issues								
Loss due to administration								
Losses due to geographical factor								

Technical Losses

The primary reasons for the technical losses can be associated with the poor network configuration of the system and inappropriate network/equipment maintenance. Non-standard practices, if followed during the initial planning and design stages, can lead to unnecessary long feeder lengths and over-loading of the network. Losses are inherent to the distribution of electricity and cannot be eliminated (PwC, 2016). The technical losses are due to current flowing in the electrical network and are of the following types:

- **Copper Losses** are due to heat produced by electrical currents and are inherent in all inductors because of the finite resistance of conductors.
- **Dielectric Losses** are losses that result from the heating effect on the dielectric material between conductors.
- **Induction and Radiation Losses** are produced by the electromagnetic fields surrounding conductors.

The causes of technical losses are (PwC, 2016):

- **Harmonics Distortion:** Pure electric signals (AC voltage and current) are expected to be like ideal sine wave and should only contain fundamental frequency (50/60Hz). However, in reality, electric signals are distorted instead of pure sinusoidal and are combination of multiple sinewaves of different frequencies, known as harmonics. These frequencies are multiple of fundamental frequency. Harmonics have detrimental effects on electrical system. They can increase the core loss of inductive electrical equipment such as transformers. Increased heating at neutral line is another drawback of increased harmonics in system.
- **Long Single-Phase Lines**: Long single-phase lines carry higher quantity of current in a single wire leading to higher I^2R loss. Besides, this leads to low voltage thus aggravating the technical losses.
- **Unbalanced Loading**: An electrical network where electrical parameters, i.e., voltage, current and load, in all three phases are same, is called a balanced system. In a balanced system, every phase is equally stressed and there will be no current in neutral wire. In an unbalanced system, one or two phases are overstressed leading to under voltage, overloading, unbalanced current flow in neutral wire and more technical loss.
- **Losses Due to Overloading and Low Voltage**: Technical loss is proportional to square of load or current level and inversely proportional to square of voltage. Overload means more current flow. Thus, overloading and low voltage will increase the technical loss multi-fold.
- **Losses Due to Poor Insulation Standard** of equipment are caused due to lack of regular maintenance of the substation and machinery. Lack of regular maintenance activities increases the chance of poor insulation in the system and can lead to brownouts or even blackouts.

Nontechnical Losses

The energy consumed in the distribution system but un-accounted constitutes the nontechnical losses. These losses can further be classified as internal and external nontechnical losses. Internal nontechnical losses may arise from the following (PwC, 2016):

- **Connection Mismanagement**: Efficient and accurate management of existing and new connections is an important activity of revenue cycle management. Instances such as release of connection without meters, mismanagement of billing records, cleaning of past accounts on same premises before release of new connection etc. contribute heavily to the nontechnical losses. These instances can be managed by adopting efficient and industry level connection management practices.
- **Theft**: Power theft is a common problem in SAARC Nations. Due to mismanagement and corruption, hooking and bypassing meters lead to massive commercial losses. In addition, theft leads to increased loading of transformers and lines causing huge technical losses as well.
- **Incorrect Meter Reading**: The timely, accurate recording of energy meters enables the containment of nontechnical losses. The major challenges faced with respect to meter reading may include no/faulty meter reading due to installation of the meter at inaccessible places, premises lock, devious activities, under recording, no recording, absence of any quality checks on the meter readings, inaccurate posting of the readings, tampering of the recorded data, etc. These all immensely magnify the nontechnical losses and create sizable revenue loss for the DISCOs.
- **Incorrect Billing**: Generating right bill based on the correct energy consumption data is of foremost importance for a DISCO in order to realize the right revenue. DISCOs tend to incur huge revenue losses owing to factors such as average bill due to delayed/erroneous readings, untimely delivery of bills, and faulty billing software.

- **Insufficient Field Vigilance**: Limited or no checks on the field leads to higher power pilferages, incorrect billing of theft cases, staff collusion with conniving consumers, enhance the losses further and deteriorates the health of the DISCOs. Hence, regular visits to the fields and being vigilant is very important for the DISCOs.

External Nontechnical Losses: The external nontechnical losses are due to non-collection of dues of the utility/electricity distribution company and may arise from collection and credit management. Unless the revenue recovery processes are standardized and aligned to DISCO's priorities, it is very difficult to optimize the nontechnical losses. Constraints such as limited avenues for collections, relatively no defaulter follow-ups, delayed temporary/permanent disconnection practices pose a great challenge in reducing the overall losses.

Table 12 represents a distribution loss matrix with the technical losses and the nontechnical losses and provides an indication towards their assessment as in whether they can be assessed based on assumption or in actual with help of data as recorded.

***Table 12 Distribution loss matrix*[11]**

Loss Type	Process	Permissible value of loss (%)	Design/specification/ procurement/ process related error	People/training/ capacity related concerns
Technical	Network configuration	1.5 to 1.75	• Non-standardized network planning leading to high feeder lengths, over-loading etc. • Equipment not as per prescribed quality • DT transformation loss • HT/LT line loss	• Poor workman ship e.g., Jointing • Deviating from standard design norms to accommodate specific requests
	Lack of maintenance	0.75 to 1.25	• Absence or low level of maintenance process leading to leakage of electricity through faulty equipment	• Poor or no maintenance practice
Nontechnical (Internal)	Connection management	1.5 to 2	• Meter not installed • Ghost consumers	• Incorrect billing records • Collusion with consumer to update improper billing records
	Meter reading	1 to 1.25	• No/incorrect meter reading due to meter inaccessibility etc.	• Wrong meter reading • Incorrect posting of meter reading

[11] (PwC, 2016)

Loss Type	Process	Permissible value of loss (%)	Design/specification/ procurement/ process related error	People/training/ capacity related concerns
			• Absence of field quality check on reading records • Defective meter • Faulty meter reading equipment	• Intentional mis recording/misreporting of meter reading
	Billing	0.5 to 1.5	• Bill generated on average basis due to delayed/erroneous readings • Bill not delivered on time • Inadequate billing logic of the IT application	• Error in billing database
	Field vigilance	0.25 to 0.5	• Limited or no field vigilance for power pilferage • Hostile consumer resulting in threat to staff safety	• Wrong billing of theft cases • Staff collusion with conniving consumers
Nontechnical (External)	Collection & credit management	2 to 3	• Limited avenues for collections • Inadequate defaulter follow-ups	• Improper posting of collected revenue

The succeeding sections elaborate on the country wise assessment generation and distribution sectors of the SAARC Member States.

2.2. Afghanistan

2.2.1. Generation Sector

Afghanistan imports as much as ~80% of the total power requirement from Central Asian republics (CARs), such as Tajikistan, Uzbekistan and Turkmenistan, and Iran. As of year 2019, imports from Uzbekistan, Tajikistan, Iran and Turkmenistan comprised of 41%, 30%, 15% and 13% respectively. Domestic power plants, with a cumulative capacity of 519 MW (UN Statistics Division, 2020) installed in the country, generated 1,285 GWh in year 2019. In year 2018, system losses and rampant power thefts amounted to 48.6% (NSIA, 2019).

Existing power plants continue to be underutilized. Diesel-fired plants, North West Kabul Power Plant and Tar Akhil Power Plant generate intermittent power (only during peak demand) due to high operation and maintenance (O&M) costs, expensive fuel and supply issues of diesel (vulnerable to theft). Hydro plants, which comprise 49% (Asian Development Bank, 2015) of total installed capacity, are mostly run-of-the-river schemes.

At present, there are 14 Hydro Power Plants (HPPs), 14 diesel power plants, and two oil-based plants are operational in the country. Hydropower accounted for ~85% (NSIA, 2019) of the total electricity generated in the country in FY 2018. Based on this background of the country, hydro power stations are selected for further analysis for Afghanistan (Table 13).

Table 13 Share of hydro in Afghanistan's power sector

Generation type	Total Capacity (%)	Total Generation (%)
Hydro Power Plant	49	85

2.2.1.1. Hydro Power Plant

Afghanistan has an installed capacity of hydropower of nearly 384 MW (UN Statistics Division, 2020) of medium and small size hydro units, including 100 MW and 66 MW Mahipar plant. There are number of factors which cause losses in efficiency in hydropower sector of Afghanistan:

- **Losses Due to Resistance in Path of Water**: About 3% loss occurs due to system resistance in hydropower plant. The life of Naghlu hydro plant in Afghanistan is ~50 years. Ageing leads to formation of algae, plantations and other resistance in the pathway of water from reservoir to turbine. Some system resistances are inherent and cannot be avoided but by implementing various measures, the efficiency can be increased by 3%, which is equivalent to a gain of 32.6 GWh in generation.
- **Losses Due to Improper Maintenance of Turbine**: Turbine blades get eroded gradually due to impact of cavitation, foreign particles and sediments in water. This leads to loss in generation due to inefficiency of turbine. In Afghanistan, due to financial constraints the replacement and maintenance of turbine bucket are not performed periodically. A normal range of losses in turbine is about 2-3% and is leading to loss of 21.7 GWh in Afghanistan power plants.
- **Losses Due to Improper Maintenance Practice**: Improper maintenance of critical equipment such as generators, transformers, pumps and other auxiliary equipment is causing loss due to excess auxiliary power consumption in Afghanistan. It is mainly due to inadequate training of maintenance staff and no systematic maintenance plan for regular preventive and shutdown maintenance of equipment. This leads to excess auxiliary power consumption and a drop-in net power generation. It is estimated that there is a scope of 0.5% efficiency improvement in Afghanistan's hydro power plant by implementing proper operation and maintenance practices.

2.2.2. Distribution Sector

The country's transmission system is highly fragmented and consists of isolated grid systems that source power from different generation plants and different import sources (Global Transmission, 2019). Afghanistan has to operate several separate power systems, each of which is synchronised with its neighbouring supplier or with its own domestic supply (which itself is not synchronised). The power system is divided into four different networks, namely:

- The North East Power System (NEPS), connected with Tajikistan and Uzbekistan
- The South East Power System (SEPS)
- The Herat Zone System, connected with Iran and Turkmenistan
- The Turkmenistan system

As of March 2017, Afghanistan's distribution capacity was estimated at 1,155 MVA, operating at the 20/15/6 kV voltage levels across 10 distribution zones (Global Transmission, 2019).

Electricity consumption in 2018-19 stood at 3,446.7 GWh (NSIA, 2019); Figure 31 shows level of energy losses in the system over the past 4 years. As per the Afghanistan Living Conditions Survey 2016-17, conducted by the country's Central Statistics Organization, 98% of households have access to some form of electricity supply. The rural population's access to electricity has increased rapidly mainly due to deployment of solar panels. About 73.2% of rural households use solar power as their source of electricity. Grid-based electricity supply is available to about 92% of urban and 12.7% of rural households respectively.

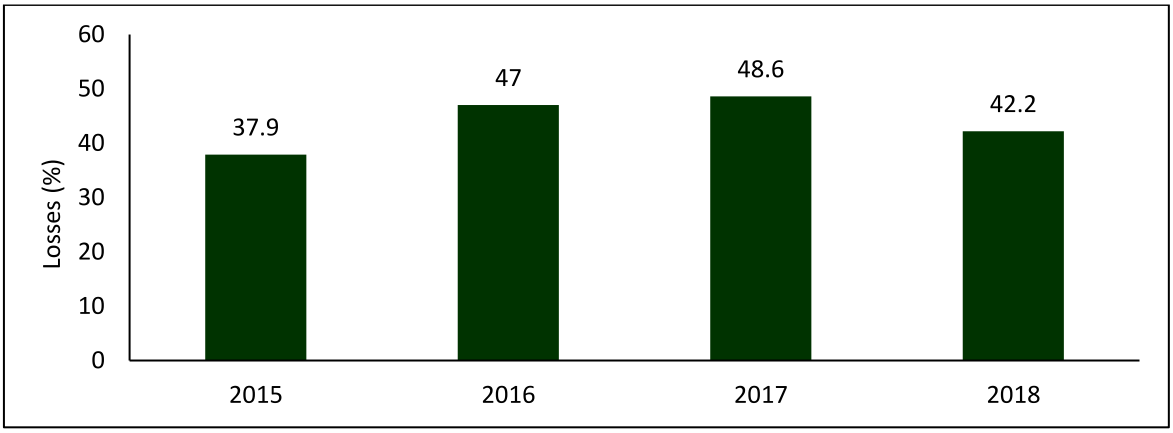


Figure 31 T&D losses for Afganistan[12]

The Afghanistan faces issue of long 220 kV transmission lines connecting the Uzbekistan with the main load centre of Kabul, which causes huge transmission losses. The other key losses in Afghanistan's distribution systems are highlighted below:

- **Losses Due to Lengthy Distribution Lines:** Afghanistan's distribution network is in phase of development. With the increase in demand of electricity, the distribution lines get overloaded and thus leads to higher line losses.
- **Use of Inefficient Transformers:** Afghanistan's distribution network houses transformers which are over two decades old. The use of latest efficient transformers can not only increase the reliability of distribution network but also reduce losses in the system.
- **Losses Due to Improper Monitoring:** The monitoring of distribution network by the DISCOs is not at par with industry standards. There is no sub metering at the feeder level. Hence, identification of commercial losses in the feeder is not possible. In addition, due to insufficient demand data DISCOs are not able to forecast load demand, thus causing losses in the network.

2.2.3. Nontechnical Inefficiencies

There are various nontechnical inefficiencies, which are affecting sustainable growth of efficient power sector across Afghanistan region as presented below.

2.2.3.1. Policy Related Issues

The Ministry of Energy and Water of Islamic Republic of Afghanistan operates in both water and energy areas that ensure source of life and economic growth of the country. This ministry's primary role in the energy sector involves planning and developing of policy, law, surveying and strategizing

[12] (NSIA, 2019)

and planning the way forward for the energy sector in Afghanistan. Further, it provides electricity for industrial institutions and organizations, preserves the security of power sector, promotes utilization of renewable energy resources, and facilitates means for private sector investment in the area of electrical energy.

The “Afghanistan Energy Efficiency Policy, 2016” states that “Afghanistan is building its energy sector to provide the backbone for its socio-economic development. Integrating energy efficiency practices to reduce losses across entire range of energy value chain starting from mining and extraction, transformation, transmission and distribution and end use sectors must become a priority for Afghanistan for long term sustainability of resources and providing access to clean energy for everyone” (Ministry of Energy and Water, 2016). Once this policy is implemented by the Afghan government, it will create awareness about the energy efficiency and will create a path for reducing losses in power sector. The government should form laws and regulations for:

- Electricity theft
- Energy auditing of energy intensive sectors
- Expansion of efficient distribution network
- Smart metering and grid

2.2.3.2. Governance and Administrative Issues

Governance in Afghanistan has had serious downfalls and is suffering from rampant corruption, weak rule of law, limited sub-national governance, and a stumbling national government (Mujib R. Abid, 2013). The Da Afghanistan Breshna Sherkat (DABS) is Afghanistan’s national power utility. It is a government corporation established under Afghanistan’s Law of Corporations and Limited Liabilities, equity shares of which are owned by the Government of Afghanistan (GOA), which controls all the grid connected generation and distribution network of Afghanistan. In practice, its independence and ability to manage its commercial affairs is circumscribed by multiple GOA stakeholders with vested interests in the power sector. The energy sector legal and regulatory framework requires DABS and the Ministry of Energy and Water (MEW) to follow global industry standards for governance of commercial utilities. In practice, however, sector governance procedures are impairing DABS’ corporate and operational performance. Due to major influence of government, there are various governance and administrative issues such as:

- The development of Afghanistan’s power sector mostly depends on various donor agencies, the main focus of donors is on intra-country grid connections and less on energy efficiency in power sector.
- The government has not established any T&D loss reduction targets/strategy for the DISCOs, as a result the DISCOs do not work towards loss reduction.
- The high T&D loss in Afghanistan is directly linked to non-availability of domestic power generation. The government needs to form policies to encourage power generation domestically.
- Afghanistan lacks timely amendment of law and regulations to curb energy losses in the power sector.
- Due to security reasons, field surveillance is hardly conducted by the utility officers, which leads to increase commercial losses.

2.2.3.3. Financial Constraints

The DABS has nearly USD 135 million in debts. Additionally, the DABS have high technical & commercial losses resulting from outdated and poorly maintained equipment, electricity theft, and improper billing and collection. In some geographies, the revenue collection efficiency is as low as 30-35% (United States Energy Assosociation, 2019). The financial constraints have a huge effect on developing energy efficient system. The power sector is depended on donor agencies for implementations of energy efficiency measures. Involvement of private investors in installing generating stations and privatization of DISCOs can minimise the financial constraints in implementation of energy efficiency measures.

2.2.3.4. Social and Environmental Issues

Afghanistan, being an underdeveloped country, faces issues such as terrorism, poverty and unemployment. Thus, theft and corruption are prevalent in power distribution sector. Some of social and environmental issues faced by power sector are as follows:

- Although peace agreement is underway, but private investors are still not confident in investing in Afghanistan's power sector.
- Lack of awareness towards conservation and illegal hooking of electricity are the main social issues leading to high T&D losses in Afghanistan.

2.2.4. Financial Impact of Losses

The various inefficiencies, technical and nontechnical in power generation, distribution leads to heavy financial impact on the utilities, DABS. A technical efficiency improvement potential of about 6% exist in power generation in Afghanistan. The financial loss due to high power distribution losses are analysed in two different scenarios:

a) T&D losses is improved to world average T&D loss i.e., 8.64%, leading to improvement by 33.56%.

b) T&D losses is improved to average T&D loss of neighbouring countries (similar geography) i.e., Iran, Turkmenistan, Uzbekistan and Tajikistan which is 12.75%, leading to improvement by 29.45% (The World Bank, 2020).

The average generation cost for Afghanistan is 0.062 USD/kWh (KTH Department of Energy Technology, 2017) and total generation and electricity sales is 1,285 GWh and 6,192 GWh (NSIA, 2019) respectively. Figure 32 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Afghanistan, if no energy efficiency improvement is implemented.

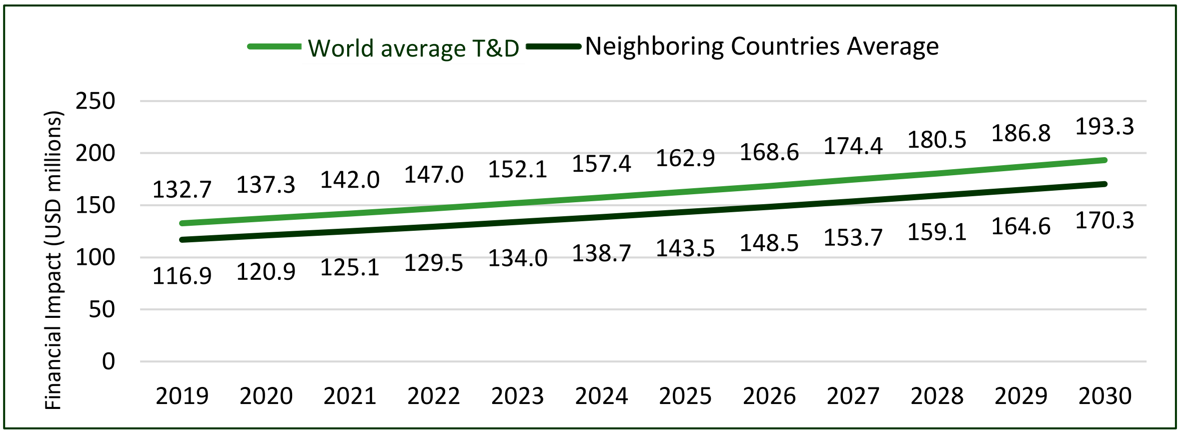


Figure 32 Financial impact of losses in Afghanistan

2.3. Bangladesh

2.3.1. Generation Sector

Gas based thermal power plants account for major share in the generation capacity, about 57%. Other sources of power generation are conventional sources such as furnace oil, high sulphur diesel oil, and hydro, coal along with viable unconventional sources such as solar and agricultural and domestic waste. The total generation capacity of the country was around 22,562 MW as of October 2019 (including Captive & renewables) (Bangladesh Power Development Board, 2019). Figure 33[13] shows major generating stations of Bangladesh.

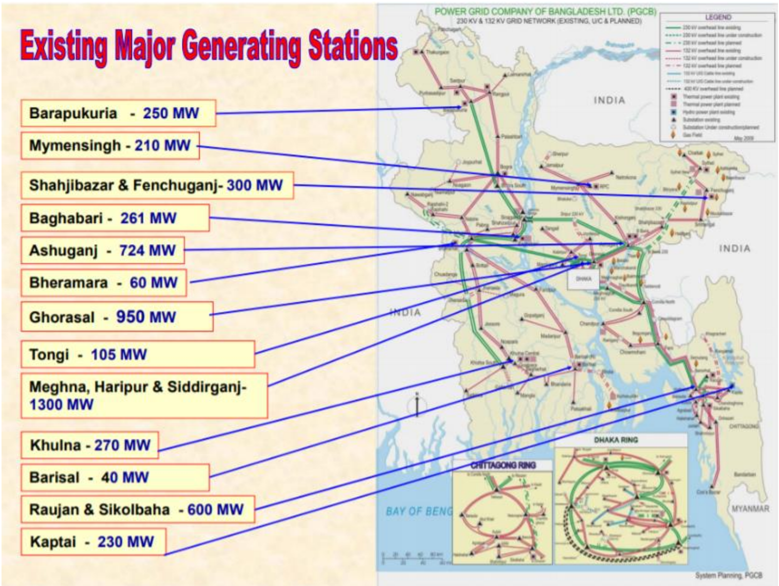


Figure 33 Major power generating stations of Bangladesh

The per capita energy generation (including captive) had increased to 433 kWh in fiscal 2017 (Ministry of Finance). Following specific generation type of power stations are selected for Bangladesh efficiency analysis (Table 14).

Table 14 Share of different generation type in Bangladesh's power sector (2017)

Type of Generation	Total Capacity (%)	Total Generation (%)
Thermal Power Plant using Gas as fuel	57.3	68.5
Thermal Power Plant using HFO/Diesel as fuel	32.0	19.0
Thermal Power Plant using Coal as fuel	2.7	1.7

2.3.1.1. Gas-based Thermal Power Plant

Majority of the power stations in Bangladesh are single cycle gas power plants in which the exhaust gas from turbine is directly released into the atmosphere. Some gas stations, such as Fenchuganj 90 MW Combined Cycle Power Station, have a heat recovery steam generator (HRSG) installed at the exhaust of gas turbine. This HRSG generates steam and the steam then is passed through a backpressure or extraction-condensing steam turbine to generate additional power.

- **Losses Due to Unavailability of HRSG**: Exhaust gases from the gas turbine emitted by the plant

[13] (United States Energy Association, 2019)

are at a temperature of 600-700°C. This heat energy is wasted in many gas plants in Bangladesh and can be captured with installation of HRSG system. A typical gas turbine has an efficiency of 37-40% and with the installation of HRSG system the same can be increased to 55-60%. Typically, a combined cycle gas power plant generates nearly 60% more power compared with the same power plant operating in single cycle. There is a huge potential of energy saving in Bangladesh power plants by installing HRSG after the exhaust of gas turbine. The total generated electricity from these gas turbines can be increased approximately by 4,754 GWh per year after installation of HRSG system in existing gas power plants.

- **Loss Due to High Auxiliary Power Consumption**: Compressor is the main auxiliary power consuming equipment in gas power plant. It consumes around 60% of total cycle energy during operation. Various energy efficiency programmes in Bangladesh have highlighted the deposition of dust, aerosols and water on the compressor blades, which decreases the overall air flow from the compressor. To prevent the losses in the compressors, there should be a proper schedule for compressor water wash. The process of water wash can be online or offline during the shutdown of the unit.
- **Losses Due to Ageing of Gas Power Station**: Most of the power stations in Bangladesh are more than two decades old and are running at 80-90% of rated capacity (Steag, 2016). Due to financial constraints, regular maintenance and overhauling are not carried out causing early degradation and derating of the gas turbine units.

2.3.1.2. Thermal Power Plant Using HFO, Gas and Coal as a Fuel

Bangladesh has a variety of thermal power plants, which can run on liquid as well as on gaseous fuel. The fuel requirement of these power stations depends on the availability of type of fuel at that time. Also, there are thermal power plants of 1,146 MW (Bangladesh Power Development Board, 2019) running on coal as a fuel. Due to continuous depreciating gas and oil reserve and dependency on imported crude oil, Bangladesh is shifting its generation capacity from gas to coal. Bangladesh has an estimated 323 million short ton total recoverable coal (Knoema, 2019) and very less of the present capacity is utilized. Due to the increased dependency on coal-based power plant, it has become very important that the existing and future power plants should be energy efficient. The working principle and equipment in all the three types of fuels are same, so analysis of losses of power plant are same. Below are the major losses which affects the overall efficiency of stations as described below:

- **Losses Due to Improper Monitoring of Critical Parameters**: Every thermal power plant manufacturer defines certain critical values of temperature and pressure, which need to be maintained within a certain range for efficient operation of thermal power plants. Due to lack of knowledge or negligence on the part of operator, the critical parameters are not maintained. The losses due to inefficient operation of thermal power plant in Bangladesh is estimated to be about 323 GWh. These losses can be prevented by efficient operation of power plant, with marginal investment required towards the training and capacity building of operators.
- **Losses Due to Excess Auxiliary Power Consumption**: Auxiliary power consumption (APC) is the amount of electricity, which is consumed within the plant boundaries to produce the power. A typical unit in Bangladesh, the auxiliary power consumption is in range of 14-17% of total generation. By implementing energy efficiency measures such as installation of VFD, arresting leakages in boiler, improving fuel quality and better operational measures can reduce the APC in the range of 12-15%, which is about 3% reduction in energy consumed and a saving of 143 GWh.

- **Losses Due to Ageing and Delay in Upgradation of Plants**: In Bangladesh, most of oil-fired power plants are more than two to three decades old and due to this the plants are running on a lower efficiency than the designed value. In addition, due to improper maintenance and operational practices the units are running on de-rated capacity.
- **Losses Due to Improper Operation and Maintenance**: Efficiency of power plant largely depends on the effective operational and maintenance practices followed by the officials. In Bangladesh, it was observed that officials need to be trained on effective operation and maintenance techniques adopted around the globe. Proper preventive and annual maintenance schedule should be followed for effective and reliable operation of unit.

2.3.2. Distribution Sector

Bangladesh's power distribution market has a single buyer: Bangladesh Power Development Board (BPDB). BPDB purchases electricity from the public and private generation entities and sales bulk electricity to all the distribution utilities including its four distribution zones. The distribution entities who purchase electricity from BPDB are as follows:

(i) Dhaka Power Distribution Company (DPDC)
(ii) Dhaka Electric Supply Company Ltd (DESCO)
(iii) West Zone Power Distribution Company (WZPDC)
(iv) Bangladesh Rural Electrification Board (BREB) (which included 80 PBSs)
(v) Northern Electricity Supply Company Limited (NESCO)
(vi) BPDB's four distribution zones

The brief details of distribution network of Bangladesh are presented in Table 15.

Table 15 Bangladesh distribution network[14]

Particular	Unit	Value
Total sale of electricity to utilities	GWh	61,836
Transmission losses	%	3.15
Average Electricity supply cost	USD/kWh	0.072
Distribution System Loss	%	9.12
Transmission and Distribution losses	%	11.96
Per capita consumption of electricity	kWh	375
Total number of Consumer	Million	37.4
Distribution Lines	ckt. km	581,000
Grid Substation Capacity (MVA)	MVA	45,277

The total number of customers covered by these six distribution utilities was about 37.4 million as of 2020 (Power Cell, 2020). Distribution losses of BPDB, DPDC, and DESCO ranged from 25% to 35% between 1980 and 1992. As of 2017, the distribution losses of DESCO, DPDC, and West Zone Power Distribution Company had reached below 10%, while those of BPDB, BREB, and NESCO ranged from 10% to 12%. Two main factors that contributed to this improvement were upgrade of overloaded

[14] *(Bangladesh Power Development Board, 2019)*

components and reduction of commercial losses. Figure 34 shows the average distribution losses in Bangladesh over the past 10 years.

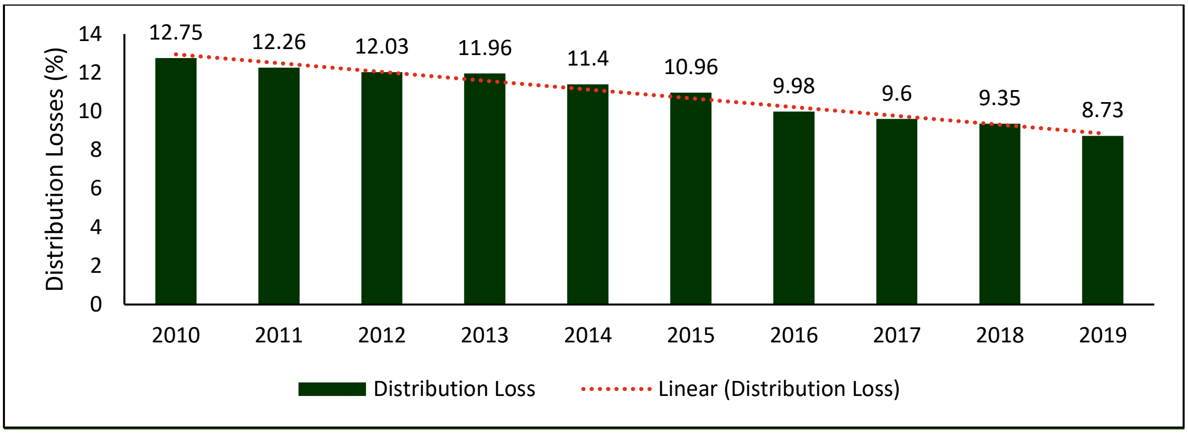


Figure 34 Distribution losses for Bangladesh[15]

Bangladesh's total net electricity generation in FY 2018 was 60,796 GWh while peak generation was 10,958 MW against an estimated peak demand of 14,004 MW (Bangladesh Power Development Board, 2019). Out of this, the transmission losses for the year accounted for nearly 2.7% of the generation for the year 2018. The aggregate value of the following distribution losses of the six distribution utilities amounted to ~10% for the year 2018 (Asian Development Bank, 2019).

Losses in Distribution Network of Bangladesh

Electricity generated in Bangladesh at a nominal voltage of 11 kV or 15 kV is at a frequency of 50 Hz. This is stepped up to 132 kV or 230 kV through transformers for feeding to the grid i.e., a high voltage transmission network that transmits the power to grid substation. From the grid substation, it is stepped down to 33/11 kV and 0.4 kV for delivery to the final consumer. There are various losses which affects the net distribution losses of the system as presented below:

- **LV Line Losses**: Bangladesh still has nearly 63% population living in rural region. Loads scattered over large areas are fed by 11 kV and 420 V lines which are extended over long distances in the country. These primary and secondary distribution lines extending over large distances in rural areas are usually radial. This subsequently results in high line losses.
- **Losses Due to Overloading and Low Voltage**: In some urban areas, the power network is stressed with overloading that leads to low voltage. Overload means more current flow than the designed capacity of the distribution network. Thus, overloading and low voltage increase the technical losses.
- **Losses Due to Improper Planning of Distribution Network**: Due to rapid increase in consumer connections across the year, unorganized growth of distribution network can increase losses. Bangladesh, being a developing nation, has more emphasis on providing electricity to all and in this process planning of efficient distribution network is lacking substantial progress.
- **Losses Due to Improper Maintenance of Transformers and Lines**: Due to financial constraints, the transformers and lines are not frequently maintained by the DISCO. This leads to increase in copper loss in lines and transformer losses. These losses can be mitigated by effective maintenance plan for whole system and increasing the capacity of distribution network.

[15] *(Power Cell, 2020)*

- **Losses Due to Low Power Factor**: In most LT distribution circuits normally the power factor ranges from 0.65 to 0.75. A low power factor contributes towards high distribution losses. For a given load, if the power factor is low, the current drawn is high and losses proportional to square of the current will be more. Thus, line losses owing to the poor PF can be reduced by improving the power factor. This can be done by application of shunt capacitors. Shunt capacitors can be connected either on the secondary side (11 kV side) of the 33/11 kV power transformers or at various points along the distribution line.

2.3.3. Nontechnical Inefficiencies

Bangladesh's current per capita average consumption of energy is significantly lower than average of Asia, even lower than those of South Asian countries. In 2006-2010, the electric power consumption including captive was 232 kWh per capita and in 2011-2015, it rose to 331 kWh per capita (KTH Department of Energy Technology, 2017). Bangladesh's economy is targeted to grow by 6.5-6.7% per year, and the power sector is expected to grow by 6-8% annually. Electricity, being the most serviceable form of energy, is of utmost importance for sustainable development of the country. There are various nontechnical inefficiencies, which are affecting sustainable growth of efficient power sector across Bangladesh.

2.3.3.1. Policy Issues

Bangladesh government over the years has formulated various policies and regulations for growth and expansion of power network in the country. The following policies and legislations are in place:

- The Electricity Act, 1910
- The Electricity Rules, 1937
- The Electricity Regulations, 1961
- National Energy Policy, 1996
- Private Sector Power Generation Policy of Bangladesh, 1996
- Policy Guidelines for Small Power Plant (SPP) in Private Sector, 2000
- The Bangladesh Energy Regulatory Commission Act, 2003
- Policy Guidelines for Power Purchase from Captive Power Plant, 2007
- Policy Guidelines for Public Private Partnership
- Guidelines for Remote Area Power Supply System (RAPSS), 2008
- Policy Guidelines for Enhancement of Private Participation in the power Sector, 2008
- Renewable Energy Policy of Bangladesh, 2008
- The Bangladesh Private Sector Infrastructure Guidelines
- The Sustainable and Renewable Energy Development Authority Act, 2012
- Energy Efficiency and Conservation Rules, 2015

Some of issues with the policies, which are restricting efficiency enhancement activities in power sector of Bangladesh are described below:

Rationalisation of Electricity Tariff

Bangladesh Power Development Board or BPDB is the single largest buyer and procures power from independent power producers (IPPs), small power producers (SPPs), corporatized generation companies and other publicly owned power plants based on negotiated bulk power tariff rates. These rates are based on fuel type, plant load factor and other operational parameters. On the other hand, BPDB sells electricity to the distribution utilities based on Bangladesh Energy Regulatory Commission (BERC) regulated wholesale tariff rates. The overall objective of tariff rationalisation should be to develop a simplified tariff framework with a reduced number of tariff categories and tariff levels that would ensure cost reflectivity, affordability and progressivity, and at the same time would encourage competition, promote efficiency, economical use of the resources, good performance and investments in the sector.

The current tariff of Bangladesh is divided into numerous categories and subcategories which may not be relevant for some areas of the country. The government should provide more flexibility and power to DISCO for providing suggestions and help in deciding the tariff for their particular jurisdictions.

The Sustainable and Renewable Energy Development Authority Act, 2012

Sustainable and Renewable Energy Development Authority (SREDA) was established to “reduce global warming, environmental hazard risk and to ensure energy security by reducing dependency on fossil fuel through the use and expansion of Renewable Energy” (SREDA, 2020).

The working of SREDA is divided between 5 wings and one of its wings is Energy Efficiency and Conservation wing, which looks after energy audit and preparation of methodology for the same. The agency has prepared Energy Audit Regulations in 2016 for facilitating certification of Energy Auditor and conducting energy audit of designated consumers. However, no clear sector-specific guideline/methodology is provided for energy audit of power plants and DISCOs.

Modernization of Existing Power Plants

Close to one third of the plants are over 25 years old. Renovation and modernization of existing power plants are the main keys for improving the efficiency of thermal power utilities. The lack in policy formation for modernization of existing plants leads to inefficient operation. There should be clear policy in place either to completely shut-down the inefficient plants or to perform renovation and modernization of the plants.

2.3.3.2. Administrative and Governance Issues

Bangladesh has majority of power sector governed by Bangladesh Power Development Board (BPDB), which has its own power plants and also it buys power from other private power plants and then distribute the same through its DISCO subsidiaries. Due to major influence of government in BPDB, there are various governance and administrative issues like:

- BPDB has initiated various programmes and studies for analysing the losses and measures to minimise. However, not all identified measures have been implemented due to various reasons such as lack of funds, lack of initiatives by the officials/firms.
- The procurement process in the public sector utilities is mainly through competitive bidding and preference is given to the lowest of all bidders. There is scope of incorporation of Life Cycle Cost based procurement to ensure shift towards energy efficient technologies.
- Major emphasis is given on expanding the distribution infrastructure rather than improving efficiency levels.
- Power theft continues to be one of the major nontechnical losses of power in Bangladesh.

Considering all above issues, following mentioned measures can be adopted to minimise the losses occurring due to governance and administrative issues:

- One of the ways of minimizing the governance issues could be privatization in generation and distribution sector. This would improve the overall efficiency of operation.
- Political intervention in vigilance done by DISCOs should be prevented by providing more authority to DISCO in case any theft is identified.
- Government should form policies which prevents underutilization of conventional power plants.
- The government should form more strict regulations for proper monitoring of energy audits and M&V of the data submitted by the power generation and distribution utilities should be carried out.

2.3.3.3. Financial Constraints

Bangladesh's power sector faces immense financial burden due to various subsidies offered by the government at different stages. There are two categories of electricity subsidies in Bangladesh.

- The first type of subsidy lowers production cost through subsidized fuel (e.g., natural gas, coal, diesel, furnace oil, etc.) in electricity generation.
- The second type offers electricity tariffs for groups of consumers (including residential customers and farmers) that are lower than production costs.

As a result of the latter, the Bangladesh Power Development Board (BPDB), which generates around 60 per cent of the country's total electricity, has consistently incurred losses by selling electricity at prices lower than the break-even point. These losses are adjusted mainly through budgetary transfers by the government every year. Due to these reasons, energy efficiency activities in power sector are kept on the lowest priority and more emphasis is given to running the system as a whole.

The financial constraints have a huge effect on developing energy efficient system. There can be various measures by which financial constraints can be mitigated:

- Introduction of an energy conservation fund in tariff and use of same for improving DISCOs AT&C losses
- Involvement of private players in implementation of energy conservation measures of profit-sharing basis (ESCO model)
- Borrowing funds from international funding agencies like World Bank, Asian development bank, government financing institutions etc.
- Liberating laws and removing hurdles for foreign direct investment in power generation and distribution sectors

2.3.3.4. Social and Environmental Issues

Bangladesh, being a developing country, faces issues like over population, poverty and unemployment. As part of climate change commitment, Bangladesh has submitted Nationally Determined Contribution (NDC) to carbon dioxide emission reduction. This has led to some focus on energy intensive sectors in the country including power generation. Below are some social and environmental issues faced by power sector:

- Due to poverty, there is theft and unmetered connections which cause overloading of lines and increase in AT&C losses.
- In a democratic country like Bangladesh, it is challenging to penalise or remove the unauthorized connections by the DISCOs.
- In the tariff, there are flat rates for agricultural and below poverty line consumers, which leads to power network issues and financial burden to DISCOs.

2.3.4. Financial Impact of Losses

Due to various inefficiencies discussed in the above sections in generation, distribution and nontechnical inefficiencies; there is a financial impact of the same on utilities. It was found that the generation sector has nearly 22% technical losses with respect to the total generation of electricity in Bangladesh. Similarly, distribution sector T&D losses can be improved by 12.52% compared with world average where T&D losses are nearly 8.64%.

The average generation cost for Bangladesh is 0.072 USD/kWh and total generation and electricity sales is 61,836 GWh and 68,616 GWh respectively (Bangladesh Power Development Board, 2019). Figure 35 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Bangladesh, if no energy efficiency improvement is done in the country.

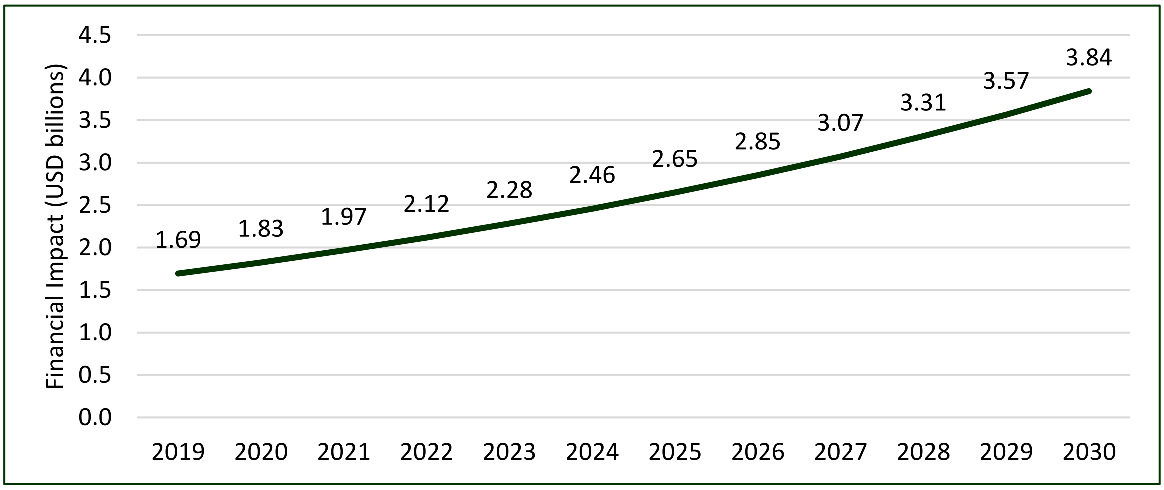


Figure 35 Financial impact of losses in Bangladesh

2.4. Bhutan

2.4.1. Generation Sector

Bhutan's total installed capacity as of 2019 was 2,326 MW (Bhutan Electricity Authority, 2019). Apart from large hydro power plants there are a number of small, mini and micro hydropower plants, with hydro capacity constituting ~99% share. As a result, the net grid emission for supply of power in Bhutan is quite low. In addition to hydro, diesel generators (for emergency purpose), wind power stations and solar home lighting system (off-grid) comprise the electricity generation ecosystem.

Hydro power meets most of the domestic demand for electricity in Bhutan; however, the generated electricity depends mostly on run-of-the-river-based hydro power plants. Therefore, power generated fluctuates seasonally. The availability of water in the river is high during the summer months and low during the winter months.

Power generation is typically high during June to October because of melting snow and the monsoon while November to April is the lean season. Although, the trend of electricity demand throughout the day is similar in winter and summer, peak demand is significantly higher during winters. This situation has improved since the commissioning of 720 MW power plant in 2019. However, based on data from 2019 BEA report in winter months there is still demand supply gap. It poses challenges as generation from hydro power plant is low in the winters when peak demand is high.

2.4.1.1. Hydro Power Plant

The conversion efficiency of a hydroelectric power plant depends mainly on the type of water turbine employed and can be as high as 95% for large installations. Smaller plants with output powers less than 5 MW have efficiencies between 80 and 85%. There are number of factors which cause losses in efficiency of hydropower plants in Bhutan:

- **Losses Due to Resistance in Path of Water**: The frictional losses are estimated to be about 3%, due to various system resistances in hydropower plants. Considering the mix of hydrogeneration in Bhutan, there is about 275 GWh loss in energy. Some of these losses are inherent of the system and some can be reduced by proper cleaning and maintenance of penstock.
- **Turbine Losses**: Based on consultation, typical range of turbine losses in Bhutan is about 2-3% and is equivalent to a loss of 183 GWh in Bhutan hydro power plants. These losses can be reduced by regular maintenance, turbine blades overhauling and reduction of cavitation.
- **Mechanical Losses between the Turbine and Generator Systems**: Friction losses occur in the shaft connecting water turbine to generator in the hydro power plant. These losses increase with the ageing of equipment and improper lubrication of bearings and shafts. These losses are in the range of 0.5 to 0.75% and are causing a loss of 45 GWh.

2.4.2. Distribution Sector

The Bhutan Power Corporation manages the power transmission and distribution network of Bhutan and has about 192,859 consumers with a peak demand of 399.35 MW (Bhutan Power Corporation Limited, 2019). The expansion of the electricity network to rural areas has been undertaken in the context of operational improvements in network management in terms of system losses and supply reliability. The transmission and distribution losses for FY 2018-19 of Bhutan was 1.22% and 9.71% respectively (Bhutan Power Corporation Limited, 2019). Although the distribution losses in Bhutan are low as compared to other neighbouring countries but there are still some losses which can be reduced, some of the key highlights are:

- **Loss Due to Lengthy Distribution Lines:** Bhutan has large scale Rural Electrification programme under the "Electricity for All" programme (Bhutan Power Corporation Limited, 2019). This has resulted in lengthy lines of low voltage, leading to losses in the distribution lines.

  Losses Due to Ageing Infrastructure: The power distribution network is quite old and many lines, transformers and substations were built in the 1980s (Bhutan Power Corporation Limited, 2019), which need upgradation. There is an increase in losses with the ageing in transformers and connectors, which should undergo periodic overhauling and replacement process.

2.4.3. Nontechnical Inefficiencies

There are various nontechnical inefficiencies, which are affecting sustainable growth of efficient power sector across Bhutan region as presented below.

2.4.3.1. Policy Related Issues

The Ministry of Economic Affairs plays a central role in the formulation of energy sector policies through its three departments:

- The Department of Hydropower and Power Systems (DHPS)
- The Department of Renewable Energy
- The Department of Hydromet Services

The following policies and legislations are in place:

- Electricity Act of Bhutan, 2001
- Distribution Code, 2008
- Bhutan Domestic Tariff Determination Regulation, 2016

Provision of Energy Audit in Electricity Policy

Detailed analysis of policies in Bhutan shows that government has not formed any regulation for constituting a body to look after energy efficiency and optimization for energy use in power generation and distribution sector. For example, Bangladesh has constituted SREDA for energy efficiency policy regulations and India has Bureau of Energy Efficiency.

Bhutan should formulate rules and regulations for continuous monitoring of energy losses and should provide framework for defining baseline for energy losses. Periodic targets setting for reduction of AT&C losses should be done region wise.

Policies for Electricity Theft

Bhutan has formulated Electricity Act, 2001; its Part 4 helps in minimizing the line and commercial losses pertaining to unauthorized tapping from main line and tampering of meters. There are rules for imposing penalty and disconnection of meter in case any irregularity by consumer. The policy could include action against inaction by supervisor/investigating officer if any irregularities are found in the process.

2.4.3.2. Governance and Administrative Issues

In Bhutan, power sector is governed by the regulator i.e., Bhutan Electricity Authority (BEA) and power generator i.e., Druk Green Power Corporation (DGPC) and transmission and distribution company i.e., Bhutan Power Corporation (BPC). A few governance and administrative issues are presented next:

- The power generation plants quite often see downtime. This could be attributed to improper maintenance and operation practices (Bhutan Electricity Authority, 2019).
- A competitive least cost-based procurement process is followed by the public sector utilities. Public utilities should integrate energy efficiency in procurement process by shifting towards life cycle cost-based procurement process.

Considering all above issues, following mentioned measures can be adopted to minimise the losses occurring due to governance and administrative issues:

- One of the ways to minimize the governance issues could be privatization in generation and distribution sector, this would improve the overall efficiency of operation.
- Strict monitoring of energy losses through energy audits and Monitoring & Verification of data collated from power generation and distribution utilities.

2.4.3.3. Financial Constraints

The Bhutan power generation being dependent on hydropower, which is one of the cheapest sources of energy does not faces major financial issues. In addition, major part of total generation is exported to neighbouring country, which generates revenue for the government.

2.4.3.4. Social and Environmental Issues

There are some social and environmental issues faced by Bhutan power sector as presented below:

- Land acquisition for developing hydro power and distribution is one of the main challenges. There is resistance from the local people in providing the land for hydropower development work.
- Due to government plan of rural electrification, electricity in remote hilly areas has to be provided which causes rise in T&D losses.

2.4.4. Financial Impact of Losses

Due to various inefficiencies discussed in the above sections in generation, distribution and nontechnical in-efficiencies; there is a financial impact of the same on utilities in Bhutan, distribution sector T&D losses can be improved by 2.36% compared with world average where T&D losses are nearly 8.64%.

The average generation cost for Bhutan is 0.034 USD/kWh (Bhutan Power Corporation Limited, 2020) and total generation and electricity sales is 10,562 GWh and 3,169 GWh respectively (30% of total generation is consumed by Bhutan and remaining is exported to India). Figure 36 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Bhutan, if no energy efficiency improvement is done in the country.

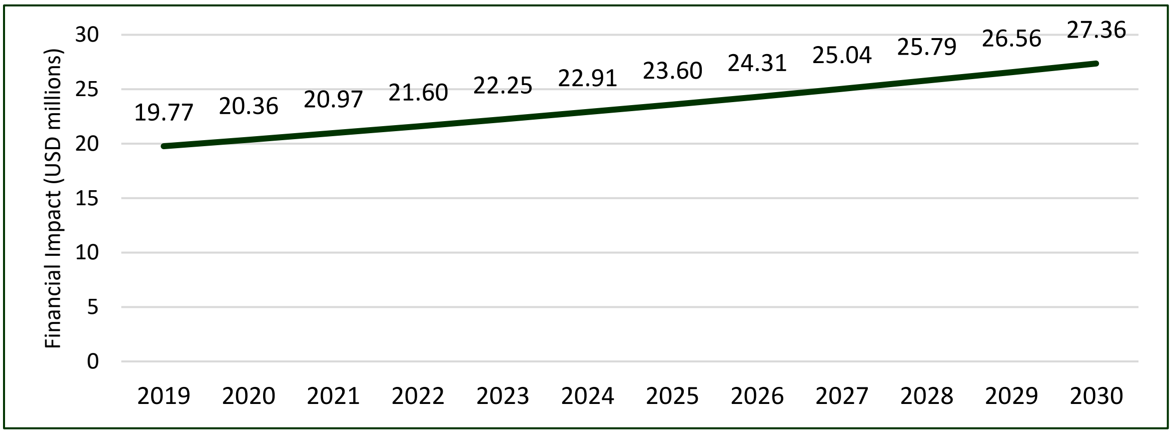


Figure 36 Financial impact of losses in Bhutan

2.5. India

2.5.1. Generation Sector

India's power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil, hydro and nuclear power to viable unconventional sources such as wind, solar, and agricultural and domestic waste. The coal-based power plants have major share in power production in India with 53% share in total generation capacity. The three major generation type power stations selected for energy efficiency analysis are presented in Table 16 (Central Electricity Authority, 2020).

Table 16 Share of different generation type in India's power sector

Type of Generation	Total Capacity (MW)	Total Generation (GWh)
Thermal Power Plant (Coal and lignite)	200,705	986,591
Thermal Power Plant (Gas as a fuel)	24,937	50,208
Hydro Power Plant	45,399	134,894

2.5.1.1. Thermal Power Plants Using Coal and Lignite as Fuel

India has varied types of coal based thermal power plants, ranging from subcritical units commissioned in 1950s to ultra-super critical thermal power plants commissioned in the recent decade (Central Electricity Authority, 2020). Despite current developments in thermal power plants, India still has 90% of thermal power coming from subcritical plants. The major losses which affect the overall efficiency of coal thermal power stations in India are as follows:

- **Losses Due to Improper Monitoring of Critical Parameters**: Due to lack of capacity and knowledge of operator, the critical parameters are often not maintained. This leads to inefficient operation of thermal power plants. In India, it is estimated that about 54,423 GWh per year are lost due to inefficiency (the losses due to improper monitoring of critical parameters in thermal power plant are presented in Table 17. These losses can be prevented by efficient operation of power plant, with marginal investment required towards the training and capacity building of operators.

Table 17 Estimate of losses in thermal power plants for improper monitoring of parameters in India[16]

S. No.	Parameters	Unit	Average Loss (kcal/kWh)	Average Deviation	Estimated loss (kCal/kWh)
1	Main Steam Pressure	kg/cm^2	0.085	4	0.34
2	Main Steam Temperature	°C	0.64	3	1.92
3	Reheat temperature	°C	0.59	3	1.77
4	Super heater spray	t/hr	0.028	20	0.56
6	Re heat spray	t/hr	0.246	30	7.38
7	Excess Air	$\%O_2$	7.41	1	7.41
8	Exit Gas temperature	°C	1.2	20	24
9	Condenser Pressure	mmHg	2.03	2	4.06
Total Loss		kcal/kWh	47.4		
Total Generation by thermal power plants		GWh	986,591		
Estimated loss due to improper monitoring of parameters		GWh	54,423		

[16] (NTPC India, 2017) *and PwC analysis through various energy audits in thermal power plants*

- **Losses Due to Excess Auxiliary Power Consumption**: The auxiliary power consumption in Indian plants is about 8-15% of total generation depending upon the type of generating station (Central Electricity Regulatory Commission, 2018). By implementing energy efficiency measures such as installation of VFD, arresting leakages in boiler, improving fuel quality and better operational measures, the auxiliary power consumption can be reduced to a level of 9% for 200 to 270 MW units and 8.5% for 300 to 800 MW units using Induced draft cooling towers (IDCT) (Central Electricity Regulatory Commission, 2018). A 2% reduction in auxiliary power consumption is equivalent to energy saving of 19,731 GWh.
- **Losses Due to Ageing and Delay in Upgradation of Plants**: India has been a pioneer in upgradation of old and inefficient power stations by implementing various policies on Renovation & Modernization (R&M) and Perform Achieve & Trade (PAT) scheme. But the implementation of these programmes is limited, and huge scope exists for upgradation of ageing plants.
- **Losses Due to Improper Operation and Maintenance**: Efficiency of power plant largely depends on the effective operational and maintenance practices followed by the officials. In India, it was observed that officials need to be trained on effective operation and maintenance techniques adopted around the globe. Proper preventive and annual maintenance schedule should be followed for effective and reliable operation of unit.

2.5.1.2. Gas-based Thermal Power Plant

India has an installed capacity of 24.9 GW (Central Electricity Authority, 2020) of gas fired power plants, which is nearly 6% of total installed capacity. All the power stations in India are combined cycle power plants which use combination of gas turbine and steam turbine for improved efficiency. Some of the major losses in India gas turbine power stations are presented below:

- **Losses Due to Part Load Operation**: A lot of gas power plants are used for meeting the instant peak demand. The gas power plants in India face issue of low plant load factor (PLF). Low PLF can lead to loss in efficiency and consumption of excess fuel in start and shutdown of the system. Reasons for low PLF are:
  - Unavailability of gas
  - High generation cost of gas-based power plant
  - Low power demand
  - Infusion of solar and other renewable source of power during daytime
- **Loss Due to Improper Operation and Maintenance**: In various studies (Steag, 2015), it was observed that the skills of the operators and maintenance are not up to the mark to extract best efficiency from a gas power plant. It has been observed that by maintaining parameters at the rated values, regular protective and shutdown maintenance can achieve about 2-5% saving.

2.5.1.3. Hydro Power Plant

India has an installed capacity of 45,399 MW (Central Electricity Authority, 2020) of large and medium size hydro power units. The annual hydro generation for 2019 contributed 12% of the total generation. There are number of factors, which cause losses in efficiency in hydropower sector of India:

- **Losses Due to Resistance in Path of Water**: It is estimated that a total of 3% of loss occurs due to various system resistance in hydropower plant. Considering the mix of hydrogeneration in India, there is around 4,046 GWh loss in energy. These losses are inherent of the system and cannot be easily reduced.
- **Turbine Losses**: In India, the turbine loss is about 2% and is leading to an estimated loss of 1,348 GWh. These losses can be mitigated by regular maintenance, turbine blades overhauling and reducing cavitation effect.
- **Mechanical & Other Losses**: Friction & high auxiliary consumption losses occur in hydro power plant. These losses increase with the ageing of equipment and improper lubrication of bearings and shafts. These losses are 0.5 to 0.75% and lead to an estimated loss of 674 GWh.

2.5.2. Distribution Sector

Consumption of electricity in India is continuously increasing due to extensive industrialization and government emphasis on supplying uninterrupted power to every consumer. The consumption for FY 2018-19 was 1,267,526 GWh against the demand of 1,274,595 GWh (Central Electricity Authority, 2020) causing a shortfall of 0.6% in supply of power.

The sector has started receiving greater investment with the restructuring of the state electricity boards (SEBs). Numerous new initiatives have been introduced to reduce aggregate technical and commercial (AT&C) losses along with a definitive regulatory framework. Electricity Act 2003, National Electricity Policy 2005 and National Tariff Policy 2006 are important regulations governing the sector today with an aim to bring competition in the sector and improve the services to the end consumers.

The Government has made substantial investments in the distribution sector through the Rajiv Gandhi Grameen Vidyutikaran Yojna (RGGVY) and Accelerated Power Development and Reforms Programme (APDRP) during the 10th Plan and has continued to extend the same in the 11th Plan as well. The aim of these programmes is to provide access of electricity to all and bring down the AT&C losses to a level of about 15% across the country. The various policies and regulations introduced by the government are set to increase competition and bring commercial viability. Participation of private players in the distribution sector has been encouraged through public-private participation in Delhi and Orissa and more recently through input-based distribution franchisee models in Maharashtra, Madhya Pradesh and Uttar Pradesh.

India has progressed towards capturing the aggregate technical & commercial losses for different utilities in the different states. State-wise AT&C loss of India is provided in Table 18.

Table 18 State wise AT&C losses in India[17]

State	AT&C Losses (As per UDAY portal, August 2020)
Andhra Pradesh	9.77
Assam	32.41
Bihar	34.32
Chandigarh	15.85
Goa	10.74

[17] (Ministry of Power, 2020)

State	AT&C Losses (As per UDAY portal, August 2020)
Gujarat	11.01
Haryana	38.43
Himachal Pradesh	5.62
Jammu and Kashmir	60.80
Karnataka	26.60
Kerala	11.00
Madhya Pradesh	24.90
Maharashtra	21.32
Manipur	21.44
Mizoram	36.37
Puducherry	16.37
Punjab	13.98
Rajasthan	42.69
Tamil Nadu	13.27
Tripura	15.72
Telangana	11.38
Uttar Pradesh	30.30
Uttarakhand	18.87

Losses in Distribution Network of India

The distribution segment continues to carry electricity from the point where transmission leaves off, that is, at the 66/33 kV level. The standard voltages on the distribution side are therefore 66 kV, 33 kV, 22 kV, 11 kV and 400/230 volts, besides 6.6 kV, 3.3 kV and 2.2 kV. Depending upon the quantum of power and the distance involved, lines of appropriate voltages are laid. The AT&C loss at all-India level was 20.7% in FY 2019. There are various losses that Indian distribution systems incur, some of the key highlights are:

- **Power Theft & Politics of Power:** Illegal hook-ups, meter tampering by households, and electricity theft by industrial enterprises are causing huge losses to distribution utilities in India. The main problem in arresting the theft is a lack of political will. Most rural areas get power for free, due to political agenda, thus causing stress on distribution network.

- **Losses in Rural Distribution Segment in India:** Rural areas are characterized by wide spreading of network in large areas with long lines, high cost of supply, low paying capacity of the consumer, large number of subsidized customers, un-metered flat rate or free supply to farmers, non-metering due to high cost. Due to these reasons, there are long lines and commercial losses.

- **Losses Due to Operational Issues:** Due to inadequate metering and data collection system in place, utilities have not been able to conduct detailed energy audits. DISCOMs do not have proper load monitoring and control mechanisms (e.g., SCADA, Distribution Control Centre, telecommunications etc.), which results into haphazard control of the demand and often leads to loss of revenue and inconvenience to the consumers.

- **Losses Due to Various Technological Issues:** Many of the distribution utilities in India are still lacking most basic requirements of consumer database and asset database which can be addressed through IT and communication solutions. Utilities do not have complete record of all consumers, which results in direct revenue loss. Most utilities maintain manual records of consumers (in the form of a register) especially in rural areas. Electromechanical meters, manual reading of meters, manual bill preparation and delivery, and inadequate bill collection facilities result into an overall delay in revenue collection and revenue leakage. Monitoring of consumer energy metering systems is critical to overall revenue. Almost all distribution companies do not have real-time monitoring system and typically use phone or radio communication for demand management.

- **Losses Due to Administrative Issues:** There are unmetered supply connections to agricultural pumps and small domestic connections to weaker sections of the society in many states in India. This causes unmetered usage of electricity, which ultimately leads to a loss for the utilities. Improper load management in various networks leads to over-loading of system. Moreover, there still is an issue of pilferage and theft of energy as High Voltage Distribution System (HVDS) is not adopted throughout the country.

- **Losses Due to Improper Maintenance of Transformers and Lines**: Due to financial constraints, the transformers and lines are not frequently maintained by the DISCOMs. This leads to an increase in copper losses in lines and transformer losses. These losses can be mitigated by effective maintenance plan for whole system and increasing the capacity of distribution network.

2.5.3. Nontechnical Inefficiencies

India has a long history of development of its power sector in terms of increasing generation capacity and diversifying generation mix, development of transmission network, which includes grid interconnections and installation of new transmission network within the country and across the borders with neighbouring countries like Bhutan, Nepal and Bangladesh. In addition, distribution network is also strengthened with the introduction of new reforms like Rural electrification, HVDS, smart meters among others. But due to continuous change in market scenario and political structure, there are various nontechnical inefficiencies which are preventing efficient operation of power generation and distribution sector of India. Following inefficiencies were found in India, which if rectified can assist in energy saving and efficient operation of power system.

2.5.3.1. Policy Issues

The Indian Electricity sector was guided by The Indian Electricity Act, 1910 and The Electricity (Supply) Act, 1948 and the Electricity Regulatory Commission Act, 1998. The generation, distribution and transmission were carried out mainly by the State Electricity Boards in various States. Due to politico-economic situation, the cross-subsidies reached an unsustainable level. To reform electricity sector further by participation of private sector and to bring in competition, Electricity Act was enacted in 2003. Below are the major policies related inefficiencies, which if rectified can be more beneficial to the power sector in India.

2.5.3.2. National Electricity Policy

Electricity Act, 2003 provides an enabling framework for accelerated and more efficient development of the power sector. The Act seeks to encourage competition with appropriate regulatory intervention. Competition is expected to yield efficiency gains and in turn result in availability of quality supply of electricity to consumers at competitive rates. Section 3(1) of the Electricity Act 2003 requires the Central Government to formulate, inter alia, the National Electricity Policy in consultation with Central Electricity Authority (CEA) and State Governments. The provision is quoted below:

> "*The Central Government shall, from time to time, prepare the National Electricity Policy and tariff policy, in consultation with the State Governments and the Authority for development of the power system based on optimal utilization of resources such as coal, natural gas, nuclear substances or materials, hydro and renewable sources of energy.*"

The aims of the policy are laying guidelines for accelerated development of the power sector, providing supply of electricity to all areas and protecting interests of consumers and other stakeholders keeping in view availability of energy resources, technology available to exploit these resources, economics of generation using different resources, and energy security issues but there are few drawbacks:

- Emphasis on reduction of AT&C losses and more rigorous follow-ups of DISCOMs for achieving the targets set by the regularity body is not done.
- Government is providing funds for Renovation and Modernization of power plant, but the old design power plant cannot improve efficiency beyond a certain threshold.
- No mention of way to fast track the permission procedure of hydro generation plant, as it is one of the most efficient power generation sources. Over the last decade, the growth of hydro power generation has been far lower than the overall power sector development rate.
- No mention of energy efficient network in rural electrification programme of government.
- Technology Development and Research & Development in providing energy efficient generation technology are not at the centre-stage. For long term improvement, these are the most important pillars.

2.5.3.3. PAT Scheme of BEE

Perform Achieve Trade (PAT) is a regulatory instrument to reduce specific energy consumption in energy intensive industries, with an associated market-based mechanism to enhance the cost effectiveness through certification of excess energy saving which can be traded. The energy intensive industries include the thermal power plants and DISCOMs. PAT is based on calculation of Specific Energy Consumption (SEC) in the baseline year and projected SEC in the target year. At the end of PAT cycle, a Measurement and Verification (M&V) audit is conducted by Accredited Energy Auditors to access the energy saving achieved in the PAT cycle. Based on the total energy saved and the set target, the designated consumer (DC) is either issued ESCerts (energy saving certificates) or is penalised if targets are not met and has to buy ESCerts from trading market. There are few shortcomings in the PAT scheme as mentioned below:

- The Accredited Energy Auditor firm for verification is appointed by the DC, the possibility of verification check can act as an effective deterrent to any potential influence that the DC can exert on the AEA firm. It will be important for BEE and SDAs (State Designated Entities) to commission a good number of verification checks (say at least 10%) in the initial cycles to maintain an effective deterrent.

- Cross checking of effectiveness of mandatory energy audit conducted by the firm is of prime importance. Due to market competitiveness, there may be an issue of quality of energy audit conducted by the firm.
- The scope of audit for DISCOMs is not well defined. A technical committee should overlook the methodology of energy audit and its outcome. Selection of feeders and substations should be clearly defined by BEE.
- An energy cell in the designated consumers is responsible for the energy efficiency activities, a mechanism should be constituted for increasing the awareness among other employees and operators in the industry/power plant.
- Training is not part of any process in PAT cycle. The training of plant personnel must be an integral part of the PAT energy audit process.

2.5.3.4. Administrative & Governance Issues

The power sector in India is governed by Ministry of Power and it has formed Bureau of Energy Efficiency, a statutory body under Ministry of Power, responsible for spearheading the improvement of energy efficiency in the economy through various regulatory and promotional instruments. Ministry of Power, through Bureau of Energy Efficiency (BEE), has initiated a number of energy efficiency initiatives in the areas of household lighting, commercial buildings, standards and labelling of appliances, demand side management in agriculture/ municipalities, SME's and large industries including the initiation of the process for development of energy consumption norms for industrial sub sectors, capacity building of SDA's. The electricity generation has good mix of public and private sector whereas the power distribution largely controlled by government institutions with few private players in the market. There are some issues due to which energy losses occur:

- The main stakeholders in electricity generation and distribution are government entities, which have lenient approach towards implementation of energy efficiency measures in the power stations. Though the approach is gradually changing, but there is a need for improvement.
- The procurement process in the public sector utilities is mainly through competitive bidding and preference is given to the lowest of all bidders. There is scope of incorporating Life Cycle Cost based procurement to ensure shift towards energy efficient technologies.
- The renewable capacity addition in generation sector, in the medium term (5 years) has adversely affected plant load factor of conventional power plants. A feasible approach and proper selection of renewable source of energy should be done to minimize the issue.
- Due to administrative negligence, unauthorized hooking on the distribution lines causes frequent overloading of transformers and lines resulting in huge AT&C losses.
- Theft is a main issue and cause of high AT&C losses in the distribution sector. Due to inaction against the defaulter, the DISCOMs are demotivated to curtail the losses.

2.5.3.5. Financial Constraints

The Indian power sector has been reeling under enormous financial pressure over the last few decades. One of the key concerns has long been the inability of DISCOMs to improve their operational and financial efficiencies. According to the Ministry of Power's (MoP) payment ratification and analysis portal, PRAAPTI (Ministry of Power, 2020), outstanding dues from

DISCOMs to power generators at the end of June 2020 stood at ₹100.3 billion (~USD 1.34 billion). A significant challenge faced by DISCOMs in India is the high technical and commercial losses (AT&C), which are primarily caused by power theft, poor payment collection procedures, and inadequate tariff hikes. Thus, DISCOMs cannot focus on implementing energy efficiency measures.

The generating stations in India face problems of low PLF and plant efficiency. Many central and state utility power plants are >25 years old, which have completed their service life and continue to operate due to delay in replacement/future projects. The operational cost of these stations is too high, which adds to the per unit cost of generation. The financial constraints have a huge effect on developing energy efficient system. There can be various measures by which financial constraints can be mitigated:

- Involvement of private players in implementation of energy conservation measures of profit-sharing basis (ESCO model[18])
- Introduction of an energy conservation fund in tariff and use of same for improving DISCOs AT&C losses
- Borrowing funds from international funding agencies like The World Bank, Asian development bank, government financing institutions etc.
- Allowing foreign direct investment in power generation and distribution sector

2.5.3.6. Social and Environmental Issues

India is a developing country facing issues like over population and unemployment. These issues pave way for theft and corruption in power distribution sector. Further, due to an increasing environmental concern, government faces pressure to reduce its greenhouse gas emissions. Some social and environmental issues faced by power sector are as follows:

- Due to poverty, there is theft and unmetered connections, which cause overloading of lines and increase in AT&C losses.
- In a democratic country like India, it is very difficult for the DISCOMs to penalise or remove the unauthorized connections.
- In the tariff, there are flat rates or zero tariff for agricultural and below poverty line consumers, which lead to misuse by consumers and ultimately causes overloading of transformers and lines causing energy losses.

2.5.4. Financial Impact of Losses

Utilities face financial impacts due to various inefficiencies, as discussed in the above sections, in generation, distribution and administration. It was found that generation sector has nearly 7% technical losses, similarly distribution sector AT&C losses can be improved by 12.4% as compared with world average where T&D losses are nearly 8.64% (Central Electricity Authority, 2020).

The average generation cost for India is 0.042 USD/kWh (Wood Mackenzie, 2019), and net generation available and electricity sales are 1,307,685 GWh and 1,037,518 GWh (Central Electricity Authority, 2020) respectively. Figure 37 provides the financial impact of losses due to

[18] ESCO (Energy saving companies) model helps utilities to save energy without investing their own capital for energy saving measures. The amount of energy saved is then distributed among the utility and ESCO company.

various technical and nontechnical inefficiencies in India, if no energy efficiency improvement is done in the country.

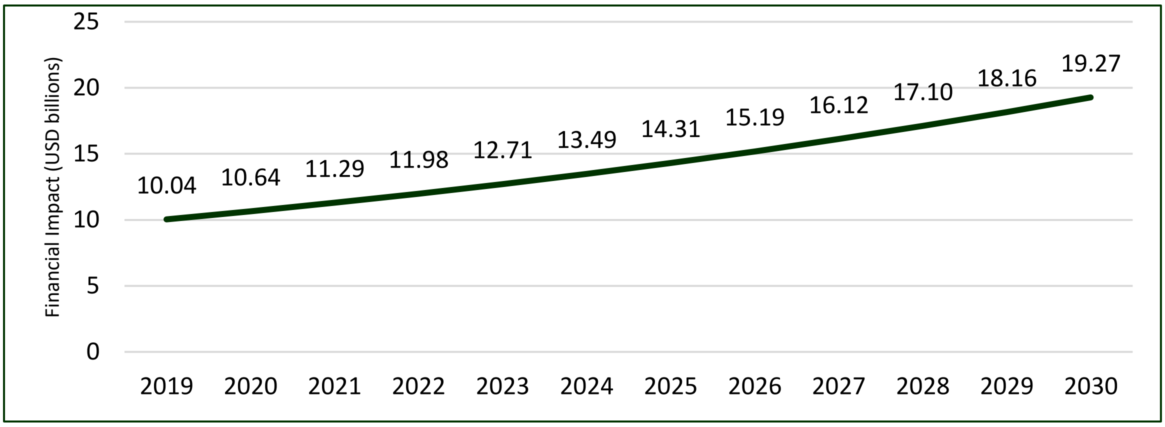


Figure 37 Financial impact of losses in India

2.6. Maldives

2.6.1. Generation Sector

The total installed capacity of power generation in the inhabited islands of Maldives stood at 251 MW (Ministry of Environment, 2018), including 240 MW of diesel-based capacity and 11 MW of renewable energy capacity. Electricity Generation for the greater Malé region (Malé, Villingili and Hulhumalé) accounts for 56.9% of the total electricity generation of all the inhabited islands i.e., about 400 GWh, with an installed capacity of 101 MW. The IC engines form major part of power generation in Maldives (Table 19), hence are considered for detailed analysis.

Table 19 Share of diesel fuelled IC engines in Maldives's power sector

Type of Generation	Total Capacity (MW)	Total Generation (GWh)
IC Engine fuelled by Diesel	240	704

2.6.1.1. Diesel Engine

The total installed capacity of individual Male Island is about 80 MW with generator sets of (in kW): 1000x6, 1600x9, 2000x2, 2160x3, 4320, 5760x1, 6500x2, 8730x2 & 8,900x1 capacity, consuming a total diesel fuel of 86,055 kilo litres per year producing 337 GWh per year (Ministry of Environment, 2018). By direct method of efficiency, the net efficiency of power plant is around 38%, which is low as compared to standard efficiency of 42-45% for IC engine power generators using diesel as fuel (Bureau of Energy Efficiency, 2020). There are number of losses in diesel generators, which are causing low efficiency in DG set as presented below:

- **Losses Due to Unsteady and Unbalanced Load:** Except Malé region, all other islands in the Maldives have independent distribution network. Due to frequent demand fluctuation, there is continuous variation in the loading of DG set causing underloading and overloading, which in turn leads to higher loss in DG sets. In addition, unbalanced load can cause heating in DG set and may lead to unbalanced voltage output.

- **Losses Due to Low Power Factor**: Most of the islands in Maldives are either small fishing communities or tourist resorts, which have a major inductive load and as per analysis, in various hotels and resorts, the power factor is likely to be in range of 0.7 to 0.8. Due to lower power factor, the generator requires high excitation currents, which results in increased losses.

- **Losses Due to Inefficient Operational Practices**: The operational practices should be reviewed at regular intervals. Regular load analysis should be done to prevent under- and over-loading of DG sets. Also, emphasis should be given on loading that DG set which is more efficient in terms of efficiency and specific fuel consumption.

Considering the above-mentioned losses, there are various energy conservation measures which should be implemented for more energy efficient operation of DG set (Bureau of Energy Efficiency, 2015):

- Ensure steady load conditions on the DG set, and provide cold, dust free air at intake (use of air washers for large sets, in case of dry, hot weather, can be considered)
- Heat recovery from flue gas should be recovered to increase the overall efficiency
- Improve air filtration
- Ensure fuel oil storage, handling and preparation as per manufacturers' guidelines data
- Consider fuel oil additives in case they benefit fuel oil properties for DG set usage
- Calibrate fuel injection pumps frequently
- Ensure compliance with maintenance checklist
- Ensure steady load conditions, avoiding fluctuations, imbalance in phases, harmonic loads
- In case of a base load operation, consider waste heat recovery system adoption for steam generation or refrigeration chiller unit incorporation; even the Jacket Cooling Water is amenable for heat recovery, vapour absorption system adoption.
- In terms of fuel cost economy, consider partial use of biomass gas for generation. Ensure tar removal from the gas for improving availability of the engine in the long run
- Consider parallel operation among the DG sets for improved loading and fuel economy thereof

2.6.2. Distribution Sector

The State Electric Company Ltd (STELCO) and FENAKA Corporation Limited are organization responsible for the generation, distribution and supply of electricity to customers throughout the Maldives. Around the nation, STELCO operates in 35 islands and FENAKA manages 148 of the 194 inhabited islands. STELCO has expanded the public electricity supply from modest beginnings to today when it serves a total of around 40,000 customers on Male' and the Outer Islands. However, the company's balance sheet & profits have been adversely affected by rising fuel costs, since 2003.

The T&D losses in area governed by STELCO is around 8% (Asian Development Bank, 2016) and commercial losses are very minimum due to small area and strict vigilance by the government. The other islands in Maldives have their own captive power generation and distribution network within the island and the same is not accounted by government. There are various losses that Maldives distribution system incurs, some of the key highlights are:

- **Losses Due to Overloading of Transformers**: STELCO supplies majority of electricity need for city of Greater Male with electricity consumption of about 400GWh, and an installed capacity of 101 MW (Ministry of Environment, 2018). The island of Male has a peak load of 56 MW with an installed capacity of around 80 MW generation and distribution infrastructure. The transformers are more than 70% loaded causing losses in transformer. The transformer loading can be improved by installing a higher capacity transformer and use of compact transformers where space constraints are present.

- **Losses Due to Overloading and Low Voltage**: Technical loss is proportional to square of load or current level and inversely proportional to square of voltage. The 11 kV lines in Male are overloaded due to increasing peak load demand. So overloading and low voltage has increased the technical loss manifold. It is recommended to replace existing 11 kV lines with 33 kV HV lines to reduce the line losses.

2.6.3. Nontechnical Inefficiencies

Maldives is an archipelago of over 1,100 islands, covering 900 kilometres of the Indian Ocean from north to south. It is famed for its turquoise seas and luxury tourism. But the large distances between islands and the small local communities—sometimes of just a few hundred residents—make the provision of utility services a difficult and costly proposition. A shortage of power aggravates development gaps, prompting many members of remote communities to flee for greater job opportunities of larger centres. Various nontechnical inefficiencies as follows:

2.6.3.1. Policy Issues

Maldives is a group of 1,100 islands and except Male and Kaffi Atoll, Ari Atoll and Vaavu Atoll, all other inhabitant islands have their own power generators and government helps in installing their power infrastructure and provide subsidy for it.

Maldives does not have policies related to energy efficiency as of 2020. There is no mandate for energy audit of power generation and distribution network. STELCO is mainly committed to provide uninterrupted power supply to consumers.

2.6.3.2. Administrative & Governance Issues

The power sector of Maldives is governed by The Ministry of Environment and Energy which has formed Maldives Energy Authority for regularization of tariff and other license related issues. The electricity generation and distribution are mainly controlled by (Ministry of Environment, 2018) :

- FENAKA Corporation Ltd. (FENAKA): 148 powerhouses
- State Electric Company Ltd. (STELCO): 35 powerhouses
- Male' Water and Sewerage Company Pvt. Ltd. (MWSC): 1 powerhouse
- Island Council: 2 powerhouses

Private hotels and resorts own their own power generation and distribution systems. There are some issues due to which energy losses occur:

- Maldives state electricity utilities are trying hard to reduce losses but due to redundancy and long approval process, the development work got delayed.
- The cost of power generation in Maldives is one of the highest in the region, basically due to dependency of diesel-based power generation. Due to this, the chances of commercial losses in the form of theft are present and administrative negligence further increases these losses.
- The government has very less control on power system of private islands and resorts, which hinder the implementation of energy efficiency measures.
- The delay in feasibility study of interconnection of distribution network within the neighbouring islands and identifying other cheap source of generation has caused huge loss in the power sector of Maldives.

2.6.3.3. Financial Constraints

There are various financial constraints, which affect the implementation of energy efficiency measures in Maldives. Some are presented below:

- Maldives state utilities are under immense financial strain due to variable cost of diesel and less frequent tariff revision.
- The power sector of Maldives is mainly dependent on donor agencies for development of its power infrastructure.

2.6.3.4. Social and Environmental Issues

Maldives being a developing nation has various social and environmental issues, which affect the effective implementation of energy efficiency measures. Maldives has one of the highest costs of power generation but due to increasing fuel prices, the electricity tariff could further rise. Maldives government subsidises electricity cost, which leads to financial stress on the utility.

2.6.4. Financial Impact of Losses

Utilities face financial impacts due to various inefficiencies as discussed in the above sections in generation, distribution and nontechnical inefficiencies. It was found that on a generation sector has nearly 6% technical losses with respect to the total generation of electricity in Maldives, similarly distribution sector T&D losses can be improved by 2% as compared with similar countries like Mauritius where T&D losses are nearly 6% (The World Bank, 2020).

The average generation cost for Maldives is 0.351 USD/kWh (SAARC Energy Centre, 2018) and total generation and electricity sales is 704 GWh and 648 GWh (Ministry of Environment, 2018) respectively. Figure 38 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Maldives, if no energy efficiency improvement is done in the country.

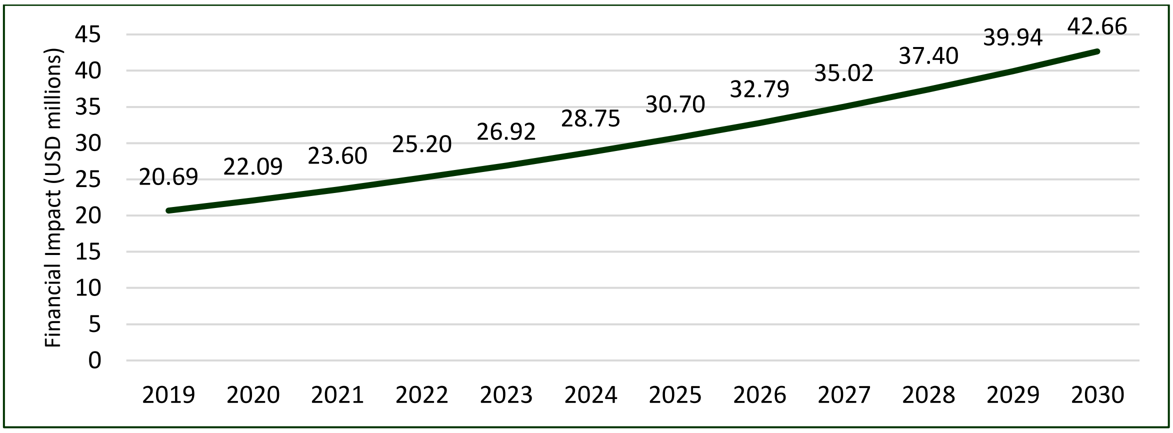


Figure 38 Financial impact of inefficiencies in Maldives

2.7. Nepal

2.7.1. Generation Sector

In Nepal, hydro stations are the key sources for electricity supply, accounting for ~95% of the total power installed capacity of the country. In addition to hydro, solar (0.1 MW) and oil-based thermal power plants (53.4 MW) also contribute to total electricity production in Nepal. At present, Nepal has an installed capacity of 1,020.6 MW of hydro power stations (SAARC Energy Centre, 2018). As per NEA's annual report the total installed capacity of NEA is 612 MW (Nepal Electricity Authority,

2019) and out of which 559 MW is hydro power plants. The average plant load factor is 51% (Nepal Electricity Authority, 2019) basically due to unavailability of power stations during dry seasons.

As power supply from the present installed capacity is not adequate to meet the total electricity load, the country relies on power imports from India, which grew 19% on year in fiscal 2018. Power imports from India contributed to ~37% of the total power requirement of the country.

At present, most of the hydro stations are run-of-river type and generation drops in the dry season. Due to inadequate installed capacity and unavailability of the existing capacity on account of low river discharge in the dry season, system operators relied on load shedding to manage demand. The country has suffered greatly on the economic front due to load shedding over the past decade. It faced up to 14 hours of load shedding in the dry season in 2016 (Timilsina, 2018).

2.7.1.1. Hydro Power Plant

The conversion efficiency of a hydroelectric power plant depends mainly on the type of water turbine employed and can be as high as 95% for large installations. Smaller plants with output powers less than 5 MW have efficiencies between 80 and 85%. There are number of factors which cause losses in efficiency in hydropower sector of Nepal:

- **Losses Due to Sediment in Water:** Himalayan rivers have large quantity of sediments in water (mainly in wet months), which causes excess degradation of components like turbine blade, control valve etc. causing loss in net generation capacity of turbine and in some cases the unit is forced to shut down.
- **Losses Due to Resistance in Path of Water**: It is estimated that a total of 3% of losses occurs due to various system resistance in hydropower plant. Hydrogeneration in Nepal has about 89 GWh loss in energy.
- **Turbine Losses**: A normal range of losses in turbine is around 2-3% and is occurring a loss of 60 GWh in Nepal Power plants. These losses can be mitigated by regular maintenance and overhauling of turbine blades and reducing the cavitation effect.
- **Mechanical Losses between the Turbine and Generator Systems**: Friction losses occurs in the shaft connecting water turbine to generator in the hydro power plant. These losses increase with the ageing of equipment and improper lubrication of bearings and shafts. These losses are in the range of 0.5 to 0.75% and are causing a loss of 15 GWh.

2.7.2. Distribution Sector

The NEA is responsible for planning, developing, implementing, and operating the distribution system in Nepal. It monitors, operates, and constructs lines and substation facilities to evacuate power generated by NEA and IPP-owned power plants, and undertakes transmission system reinforcements. The main load centre in Nepal is in the central zone, which includes Kathmandu Valley. The main transmission system consists of 66 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.

Distribution and Consumer Services Directorate (DCSD) is responsible for overall management of electricity distribution network & services of NEA. The major activities of this directorate include planning, expansion, operation, maintenance & upgradation of the electricity distribution networks including substations up to 33 kV voltage level and consumer services activities such as new consumer connections, meter reading, billing, and revenue collection.

In FY 2018-19, total number of consumers under DCSD reached 3,909,641, an increase of 10.09% over the last financial year's figure. FY 2018-19, a total of 6,306 GWh of energy was sold earning gross revenue of Rs. 66,101Million (Nepal Electricity Authority, 2019). Industrial and Commercial consumer categories combined together represent only 2.01% of the total number of consumers but shared 45.79% of total sales. Similarly, the domestic consumer category represents 93.54% of total consumers and contributed 42.20% to the total sales. The consumer's category distribution is shown in Table 20.

Table 20 Consumer category wise distribution for Nepal [19]

Category name	% of total consumers	Sales (%)	Revenue (%)
Domestic	93.50	42.2	37.7
Non-Commercial	0.60	2.95	4.29
Commercial	0.66	7.39	10.19
Industrial	1.35	38.4	40.13
Others	3.85	9.06	7.62

The average T&D losses for Nepal are around 11.28%. The details of regional wise T&D losses are presented in Table 21.

Table 21 T&D losses for Nepal [20]

S. No.	Regional Office	Loss (%)
1	Biratnagar	12.15
2	Janakpur	23.36
3	Hetauda	8.38
4	Kathmandu	7.40
5	Pokhara	9.79
6	Butwal	12.39
7	Nepalgunj	11.57
8	Attariya	14.39
9	Average	11.28

There are various losses that Nepal distribution system incurs, some of the key highlights are:

- **Losses Due to Outdated Infrastructure:** Nepal Electricity Authority has seen a long trend of financial losses. Due to this the development and modification of distribution network is badly affected in the country. Also, there are delays in implementation of loss reduction measures such as smart meters, energy efficient transformers, upgradation of distribution lines etc, which adds to the already high T&D losses for Nepal.
- **Loss Due to Lengthy Distribution Lines:** Nepal has large scale Rural Electrification programme. This has resulted in long lines and extension of distribution network done without strengthening the back-up transmission, sub-transmission and distribution system. This has resulted in quite a few power failures and losses in the distribution lines. To overcome these

[19] *(Nepal Electricity Authority, 2019)*
[20] *(Nepal Electricity Authority, 2019)*

losses, micro hydro power projects or other renewable source of generation can be adopted for reduction of losses due to lengthy distribution lines.

- **Losses Due to Geographical Factor:** Nepal being a hilly region with challenges terrain faces issues of high T&D losses. Due to government focus on electrification to all, there are long LV lines for consumers, which cause high line losses.
- **Losses Due to Power Factor:** Nepal has nearly 93% of domestic consumers, which consume 42% of total power. Due to large number of domestic loads, the power factor is low for Nepal. This causes increased losses in distribution conductors/cables and transformers.

2.7.3. Nontechnical Inefficiencies

There are various nontechnical inefficiencies, which are affecting sustainable growth of efficient power sector across Nepal region as presented below.

2.7.3.1. Policy Issues

In Nepal, Ministry of Energy, Water Resources and Irrigation forms policies and regulation for energy sector of Nepal. It has formulated various laws and policies in power sector for regulation and providing significant impact on the pace and direction of economic development. To attain the objectives of electrification through development of conventional energy and preventing energy thief, the following policies and legislations are in place:

- Electricity Leakage Control Rules, 2059 (2002)
- Electricity Theft Control Act, 2058 (2002)
- Irrigation Rules, 2056 (2000)
- Electricity Rules, 2050 (1993)
- Electricity Act, 2049 (1992)
- Water Resources Rules, 2050 (1993)
- Water Resources Act, 2049 (1992)
- Nepal Electricity Authority Act, 2041 (1984)

Provision of Energy Audit in Electricity Policy

The Nepal government should form an autonomous body for implementing energy efficiency measures and developing rules/regulations for energy audit in the country, particularly for power generation and distribution sector. Although, The Nepal's Energy and Environment Division (EED)/Federation of Nepalese Chamber of Commerce and Industry (FNCCI) has established a nodal agency named Energy Efficiency Centre for introducing concept of energy efficiency in Nepal. The agency being an affiliated body of FNCCI, which is representative body of business organizations in the country has no legislative right to implement energy efficiency measures in the county. Hence, the power of the body is limited to supporting utilities in implementing projects.

Policies for Electricity Theft and Leakages

Nepal has formulated policies like Electricity Leakage Control Rules (2002) & Electricity Theft Control Act (2002) for minimizing the line and commercial losses pertaining to unauthorized hooking of main line and tampering of meters. There are rules for imposing penalty and disconnection of meter in case any irregularity is found at the consumer end. The policy should include action against inaction if any irregularities are found in the process.

2.7.3.2. Governance and Administrative Issues

In Nepal, power sector is governed by Nepal Electricity Authority (NEA) which has its own power stations (mainly Hydro) and purchase electricity from other IPPs across Nepal and then distribute the same through its distribution network. Due to major influence of government in NEA, there are various governance and administrative issues like:

- The administrative delay in procurement and decision for adopting energy efficient technology has caused huge loss in the power sector of Nepal.
- Due to administrative negligence, some regions in Nepal like Attariya and Janakpur have high losses and problem of hooking and tempered meters is still present in these areas.
- Due to administrative issues, planned expansion of distribution network was not carried in many urban regions of Nepal, which is now causing high transformer and distribution line loading.

2.7.3.3. Financial Constraints

The financial constraints have a huge effect on developing energy efficient system. The power sector of Nepal has been facing the following constraints:

- The energy efficiency measures in hydropower plants are capital intensive and more focus is given on expanding generation capacity rather than increasing the efficiency.
- The government of Nepal is still in process of achieving 100% electrification. Thus, the expansion of network is given more priority and is allocated more funds.

2.7.3.4. Social and Environmental Issues

Nepal, being a developing country, faces issues like poverty and unemployment, thus theft of power is a concern. Although there is a huge improvement of system loss shrinking to 15.32% in the FY 2018-19 over the previous figures of 25.78% in FY 2015-16. Below are some social and environmental issues:

- Nepal has been facing issues of poverty and due to this many low-income consumers are not able to pay electricity bills resulting in loss of revenue.
- Nepal has encountered with number of natural calamities like floods, earthquake etc. As a result, focus is on maintain then system rather than implementation of energy efficiency measures due to unavailability of funds.

2.7.4. Financial Impact of Losses

Utilities face financial impacts due to various inefficiencies as discussed in the above sections in generation, distribution and nontechnical inefficiencies. It was found that on a generation sector has nearly 6% technical losses with respect to the total generation of electricity in Nepal, similarly distribution sector T&D losses can be improved by 2.64% as compared with world average of where T&D losses is nearly 8.64% (Central Electricity Authority, 2020). The average generation cost for Nepal is 0.1 USD/kWh (Nepal Electricity Authority, 2019) and total generation and electricity sales is 2,979 GWh and 6,306 GWh respectively. Figure 39 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Nepal, if no energy efficiency improvement is done in the country.

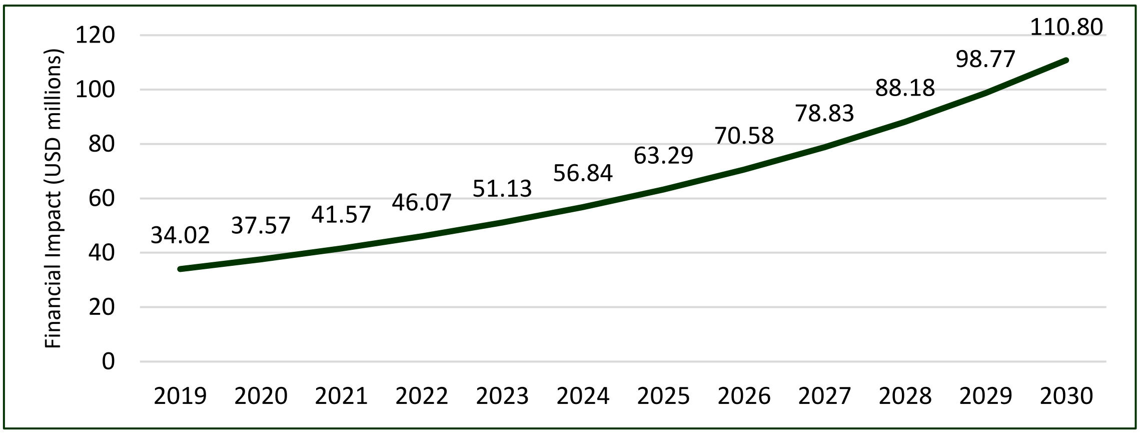


Figure 39 Financial impact of inefficiency for Nepal

2.8. Pakistan

2.8.1. Generation Sector

The total installed capacity of Pakistan stood at 35,972 MW as on FY 2020 (Finance Division, 2020). The country has significantly added fuel oil (FO) and nuclear-based power plants. Natural gas and FO based thermal plants are the major fuels presently contributing ~29% each to the total mix. Pakistan's Water & Power Development Authority is responsible for planning and execution of large hydropower projects. At present, WAPDA operates at 6,902 MW of hydropower capacity (WAPDA, 2019). Hydropower generation has been lagging owing to falling PLF from lack of water availability and unreliable rainfall patterns.

Five nuclear power plants with a combined net capacity of 1,320 MW are operational in the country at a healthy PLF of 73% (SAARC Energy Centre, 2018). Overall, annual generated electricity reached 128,564 GWh in FY 2018-19 (Pakistan Bureau of Statistics, 2019). Renewable energy generation has improved steadily over the years but it is still at a nascent stage contributing about 2.4% of the total electricity generated in 2020 (July- April) (Finance Division, 2020).

In Pakistan, 31 thermal independent power producers (IPPs) with a total installed capacity of 12,427 MW, and 5 hydro IPPs with a total installed capacity of 213 MW are operational (International Atomic Energy Agency, 2019). In addition, there are four public sector GENCOs operating in Pakistan:

- Jamshoro Power Company (GENCO-I) (generation capacity: 1,024 MW)
- Central Power Generation Company (GENCO-II) (generation capacity: 2,437 MW)
- Northern Power Generation Company (GENCO-III) (generation capacity: 2,151 MW)
- Lakhra Power Generation Company (GENCO-IV) (generation capacity: 150 MW)

The below mentioned specific generation type power stations are selected for Pakistan (Table 22).

Table 22 Share of different generation type in Pakistan's power sector

Type of Generation	Total Capacity (MW)	Total Generation[21] (GWh)
Thermal Power Plant (Gas as fuel)	11,769	80,540[22]

[21] *(Ministry of Planning Development and Reforms, Government of Pakistan, 2020)*
[22] *Total generation is inclusive of all thermal means of generation like Coal, Gas, HFO and other liquid and solid fuels.*

Type of Generation	Total Capacity (MW)	Total Generation[21] (GWh)
Thermal Power Plant (HFO/Diesel, Coal as fuel)	5,887	
Hydro Power Plant	9,730	33,198

2.8.1.1. Gas-based Thermal Power Plant

Pakistan has an installed capacity of 10 GW (Qazi & Jahanzaib, 2018) of the gas-based power plants and they contributed to nearly 30% of total generation in FY 2020 (Finance Division, 2020). The main gas power plants in Pakistan are owned by GENCOs which come under Pakistan Electric Power Company (PEPCO), a holding company that operates as a division of Ministry of Water and Power (Pakistan). All the power stations in Pakistan are combined cycle power stations, which have a HRSG installed at the exhaust of Gas turbine. HRSG uses heat rejected by gas turbine which is at high temperature and pressure to produce steam and the same is then expended in steam turbine to generate electricity. The major gas-based generation plants in Pakistan are:

- Gas Turbine Power Station Kotri (144 MW)
- Thermal Power Station Guddu (1,655 MW)
- Guddu 747 Combined Cycle Power Plant (776 MW)
- Gas Turbine Power Station Faisalabad (144 MW)
- Combined Cycle Power Plant Nandipur (565 MW)

In addition, some private power stations such as Bhikki RLNG-based Power Project (1,180 MW), Haveli Bahadur Shah Power Plant (1,230 MW) and other stations are in operation. There are various kind of inefficiencies encountered by gas-based power stations in Pakistan. Some they are presented below:

- **Losses Due to Low Net Capacity**: Net Capacity of a number of units/machines of different power stations of GENCOs remained lower than that approved by NEPRA in their respective tariff determinations. This resulted into a cumulative energy loss of about 260 GWh (NEPRA, 2015-2020), translating into a financial impact of Rs. 1.7 billion for FY 2016–17 and 2017-18. The main factors causing this loss are derating of power station and improper maintenance of equipment.
- **Losses Due to Outage of Generating Units**: In Pakistan, due to rising gas prices and increasing penetration of coal based thermal power stations, gas-based power stations are becoming costly to operate. This caused frequent starting and stopping of units based on the peak load. The outage of units is both planned and unplanned, which has caused energy loss of around 8517 GWh translating into a financial impact of Pakistan Rs. 55.7 billion for FY 2016-17 and 2017-18.
- **Loss Due to Improper Operation and Maintenance**: In various studies, it was observed that the operators and maintenance staff were not aware about the efficient operation and maintenance practices of gas power plant. Pakistan, being an energy deficit country, need to conserve the existing natural resources by capacity building and training of plant officials in more efficient operation and maintenance of existing power plants. It is observed that by maintaining parameters at the rated values and regular protective and shutdown maintenance can achieve about 2-5% of the total generation.

- **Auxiliary Power Consumption**: Compressors are the main auxiliary power consuming equipment in a gas power plant. They consume around 60% of total cycle energy during operation. The main reasons of compressor performance deterioration are deposition of dust, aerosols and water on the compressor blades, which decreases the overall air flow from the compressor and the compressor needs to work extra to compress the same quantity of air. To prevent the losses in compressors, there should be a proper schedule of compressor water wash. The process of water wash can be online or offline during the shutdown of the unit.
- **Losses Due to Ageing of Gas Power Station**: The average age of most of the gas-based power station is 20 years and they are running at 80-90% of rated capacity. Due to financial constraints, regular maintenance and overhauling are not carried out as required causing early degradation and derating of GT unit.

2.8.1.2. Thermal Power Plant Using HFO and Coal as a Fuel

Pakistan has a variety of thermal power plants, which can run on liquid as well as on gaseous fuel. To reduce dependency on gas- and oil-based power plants, Pakistan is shifting its generation capacity from gas to coal. Pakistan has an estimated coal reserve of 185 billion tonnes and dependency on coal-based power station is increasing as a result of installation of Hub Coal Power Project (1,320 MW), Pakistan Port Qasim Power Project (1,320 MW) and Sahiwal Coal Power Project (1,320 MW). Due to the increased dependency on coal-based power plant, it becomes very important that the existing and future power plants should be energy efficient. The working principle and equipment in all the two types of fuels are same, so analysis of losses of power plant are same. The major losses which affect the overall efficiency of stations as described below:

- **Losses Due to Use of Obsolete Technology**: All the coal and oil based thermal power stations in Pakistan are based on subcritical technology which have lower efficiency and higher heat rate as compared to super and ultra-super critical technologies available worldwide. A typical sub critical thermal power plant has an overall efficiency of 35% as compared to 42% efficiency of super critical plants. Proper planning of future expansion should be done and only the most efficient technology available should be chosen, if possible. There is a loss of approximately 100 kcal/kWh is born by the generation company if subcritical technology is chosen over super critical technology. The comparison of both technologies is shown in Table 23.

Table 23 Comparison of super-critical and sub-critical technology [23]

Parameters	Unit	Sub-critical	Super-critical
Design Pressure	MPa	<18	>22
Design Temperature	°C	545	560-600
Plant Cycle Efficiency	%	34-38	40-42
Station Heat Rate	kcal/kWh	>2300	<2200
CO_2 Emission	Unit	1	0.95

- **Losses Due to Improper Monitoring of Critical Parameters**: Every thermal power plant manufacturer defines certain critical values of temperature and pressure, which need to be maintained within a certain range for efficient operation of thermal power plants. Due to lack of knowledge or negligence on the part of operator, the critical parameters are not maintained. The losses due to inefficient operation of thermal power plant in Pakistan is estimated to be

[23] (Power Today, 2015)

around 3,210 GWh. These losses can be prevented by efficient operation of power plant, with no investment required.

- **Losses Due to Excess Auxiliary Power Consumption**: Auxiliary power consumption is the amount of electricity, which is consumed within the plant boundaries to produce the power. The overall efficiency of thermal power plant depends on the percentage of auxiliary power consumption of different equipment. For a typical unit the auxiliary power consumption is in range of 10.38% for oil fired and 26.73% for coal fired power plant (Memon, 2017). By implementing energy efficiency measures like installation of VFD, arresting leakages in boiler, improving fuel quality and better operational measures can reduce the APC.
- **Losses Due to Ageing and Delay in Upgradation of Plants**: In Pakistan major oil-fired thermal power plants are very old and need to be renovated to improve their thermal efficiency and heat rate. Due to ageing of these plants, they are bearing an energy loss of 229.1 GWh, which translate into a financial impact of Rs. 2.3 billion for FY 2016-17 and 2017-18 (NEPRA, 2015-2020).
- **Losses Due to Improper Operation and Maintenance**: Efficiency of power plant largely depends on the effective operational and maintenance practices followed by the officials. In Pakistan, it was observed that officials need to be trained on effective operation and maintenance techniques adopted around the globe. Proper preventive and annual maintenance schedule should be followed for effective and reliable operation of unit.

2.8.1.3. Hydro Power Plants

Pakistan has an installed capacity of 9,730 MW of large and medium size hydro power units. The annual generation for 2019 from these power generation units were 33,198 GWh (Pakistan Bureau of Statistics, 2019). The conversion efficiency of a hydroelectric power plant depends mainly on the type of water turbine employed and can be as high as 95% for large installations. Smaller plants with output powers <5 MW have efficiencies between 80-85%. There are number of factors which cause losses in efficiency in hydropower plants of Pakistan:

- **Losses Due to Resistance in Path of Water**: It is estimated that a total of 2% of losses occur due to various system resistance in hydropower plant. Considering the mix of hydrogeneration in Pakistan, which has majority of medium size power units there is around 663 GWh loss in energy. These losses are inherent to the system and cannot be easily reduced.
- **Turbine Losses**: A normal range of losses in turbine is around 1-3% and are occurring a loss of 331 GW in Pakistan Power plants. These losses can be mitigated by regular maintenance and overhauling of turbine blades and reducing the cavitation effect.
- **Mechanical and Auxiliary Power Consumption Losses**: These losses increase with the ageing of equipment and improper lubrication of bearings and shafts. These losses are in the range of 0.5 to 1% and are causing a loss of 331 GWh.

2.8.2. Distribution Sector

Electricity distribution sector is the end of entire power chain. Betterment of the distribution sector not only benefits the consumers but other stakeholders of the power chain. Structural transformation of WAPDA initially gave rise to eight distribution companies. These DISCOs were responsible for electricity distribution to different consumer categories. Later, two more distribution companies were established (TESCO and SEPCO). In total, there are 11 distribution companies in Pakistan, with 10 government operated and one privately operated.

Distribution network loss has adverse impacts on efficiency of a distribution company. Due to these losses, it is impossible for DISCO to recover its operational cost effectively. To recover the operational cost, DISCOs put extra burden on consumers in the form of overbilling. So, these losses also affect consumers as well. Ineffective recovery due to losses also contribute to circular debt.

Over the years Pakistan's DISCOs have made gradual improvements on their T&D losses, but losses are still very high particularly for PESCO, SEPCO, QESCO and HESCO (Table 24).

Table 24 T&D losses of Pakistan's DISCO's[24]

DISCO	2015-16	2016-17	2017-18	2018-19	2019-20
IESCO	9.10	9.02	9.13	8.86	8.69
PESCO	33.80	32.60	38.10	36.56	38.69
GEPCO	10.58	10.24	10.01	9.87	9.51
FESCO	10.20	10.60	10.50	9.81	9.62
LESCO	13.90	13.80	13.80	13.17	12.40
MEPCO	16.40	16.90	16.60	15.79	15.23
QESCO	23.80	23.10	22.40	23.56	26.68
SEPCO	37.72	37.80	36.70	36.97	36.27
HESCO	26.50	30.80	29.80	29.49	28.82
TESCO	18.96	15.40	12.46	11.97	16.19
K-Electric	22.24	21.71	20.40	20.10	19.73

Particularly, if the values of losses in 2018-19 are compared with the values of 2019-20, it has been observed that all have shown improvement except QESCO, TESCO and PESCO (Figure 40).

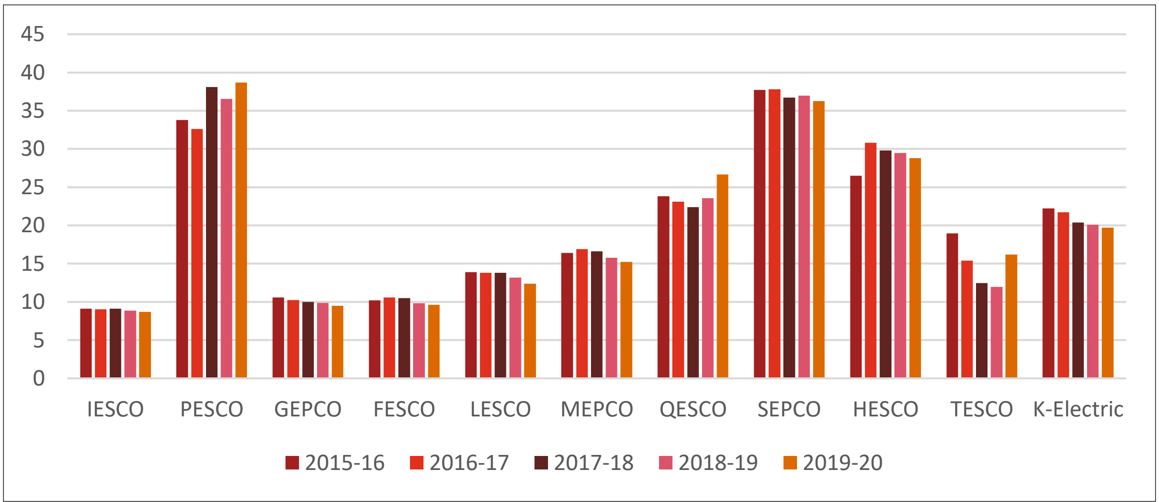


Figure 40 Transmission and distribution losses in Pakistan DISCOs (%)

Losses in Distribution Network of Pakistan

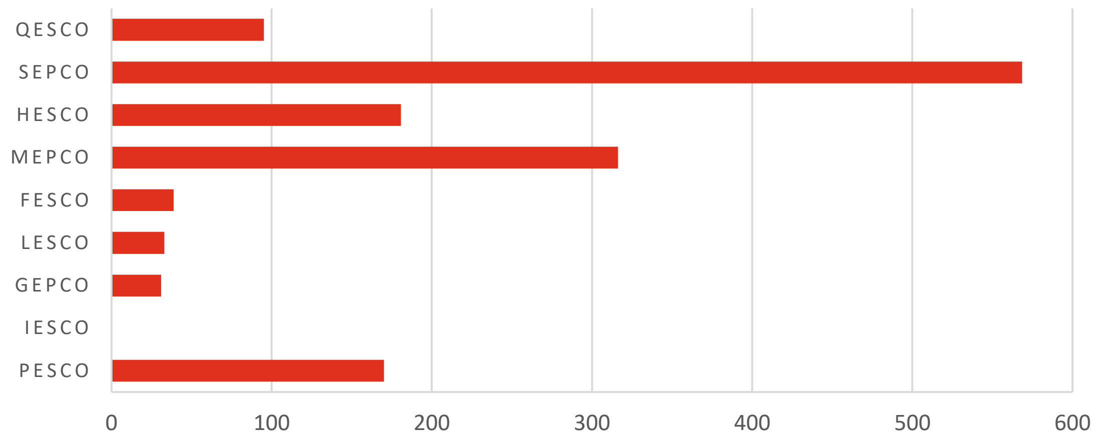
The high voltage grid of Pakistan goes from south to north following the Indus River Valley, where the majority of the population lives. However, the grid coverage is not nationwide - about one third of the population (about 60 million people) has no access to the electricity grid. One of the major causes is the scale of the country and the remote locations of many settlements. Table 24 indicates

[24] (NEPRA, 2015-2020)

T&D loss differences among the DISCOs. These losses included both technical and nontechnical losses. Technical losses are due to over-loaded distribution circuits and the high ratio of LT to HT line. Nontechnical losses include theft by consumers in form of meter tampering, and illegal line taps. Moreover, frauds have been identified in meter reading. Overall, the status of network losses is unsatisfactory and needs serious attention (Qazi & Jahanzaib, 2018).

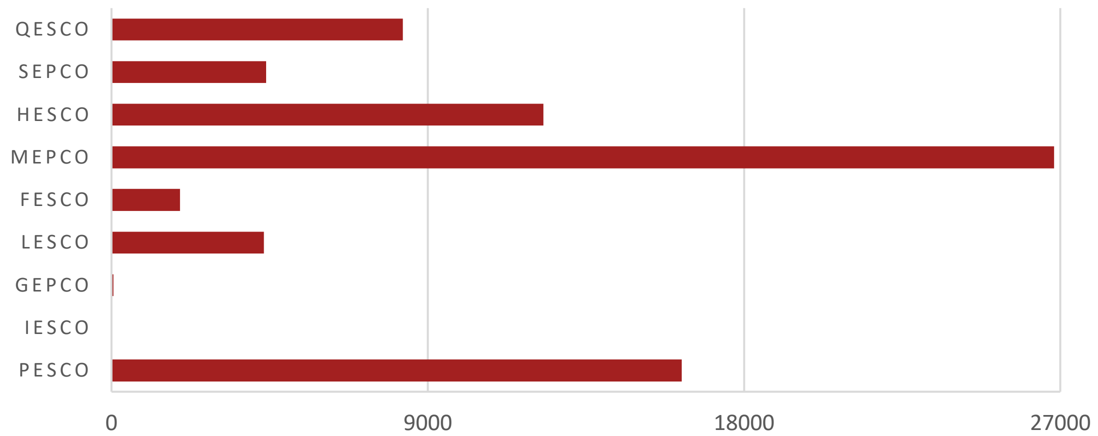
Technical Losses

Over Loaded Distribution Circuits: DISCO-wise comparison of reliability of distribution companies using System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) is presented in Figure 41 and Figure 42 (NEPRA, 2019). Lower values of SAIDI and SAIFI indicate reliable power supply. As evident, most of the DISCOs in Pakistan need to substantially improve reliability of power supply to customers. Overloaded transformers and feeders have been identified as the primary contributors of interruptions of power supply in Pakistan's DISCOs.



	PESCO	IESCO	GEPCO	LESCO	FESCO	MEPCO	HESCO	SEPCO	QESCO
2017-18	170.1	0.04	30.97	32.92	38.87	316.22	180.74	568.59	95.18

Figure 41 Average SAIFI value for DISCOs (No.)



	PESCO	IESCO	GEPCO	LESCO	FESCO	MEPCO	HESCO	SEPCO	QESCO
2017-18	16222.79	0.73	53.67	4338.23	1951.38	26822.35	12292.57	4397.44	8287.9

Figure 42 Average SAIDI value for DISCOs (Minutes)

Electricity Theft: Pakistan has seen a sharp increase in its electricity demand over the years. This has led to a rapid increase in the electricity prices in the region. Consumers have started stealing electricity by illegally hooking up a wire to overhead electricity cables, tampering with their meters or tapping power lines to avoid recording electricity usage to avoid the burden of the high electricity bills. Power theft, being a major contributor to power deficit, represents huge revenue loss and increases load shedding. The magnitude of the problem is abnormally large in Pakistan where legitimate customers bear the cost of illegal electricity and the power service becomes less reliable for paying customers. The situation has improved in cities where digital meters have replaced older electromechanical meters.

Lengthy Distribution Line Losses: Pakistan has a large and scattered share of rural population. In order to supply electricity to these regions, lengthy and scattered distribution lines are spread across the country, which account for technical losses in the distribution system. Largely, 11 kV and 415 Volts lines are extended over long distance to feed load in rural areas.

Losses Due to Improper Maintenance of Transformers and Lines: Due to financial constraints, the transformers and lines are not frequently maintained by the DISCOs. This leads to increase in line losses and transformer losses. These losses can be mitigated by effective maintenance plan for whole system and increasing the capacity of distribution network.

2.8.3. Nontechnical Inefficiencies

There are various nontechnical inefficiencies, which are affecting sustainable growth of efficient power sector across Pakistan region as elaborated below:

2.8.3.1. Policy Issues

Pakistan has formulated various laws and policies in power sector for regulation and providing significant impact on the pace and direction of economic development. It can create the required enabling environment for the involvement of the private sector and to attract private investments in economic activities. To attain the objectives of electrification through development of conventional and alternative sources of energy, the following policies and legislations are in place:

- National Environmental Policy, 2005
- National Power Policy, 2013
- National Energy Conservation Policy, 2016
- National Climate Change Policy, 2012
- National Sustainable Development Strategy, 2012
- Framework of Implementation of Climate Change Policy, 2013
- Vision 2025 by Ministry of Planning Development and Reforms, 2014
- National Energy Efficiency and Conservation Act, 2016

Some of issues with the policies which are restricting efficient growth of energy efficiency activities in power sector of Pakistan is described below:

National Power Policy, 2013

The National Power Policy 2013, issued by the Government of Pakistan, aims to develop an efficient and consumer centric power generation, transmission and distribution system that meets the needs of the people, and boosts the economy in a sustainable and affordable manner. Targets include: eliminating load shedding; decreasing the average cost of electricity generation to below Pak Rupees 10/kWh; decreasing transmission and distribution losses from 23–25% to 16%; increasing revenue collection from 85% to 95%; and reducing the time required to a minimum for decision making at the ministry level and other related departments. However, implementation of these policies has still resulted in a supply–demand gap and load shedding.

National Energy Efficiency and Conservation Act, 2016

This act was introduced for institutional development to improve energy efficiency, specifically mandating the creation of the National Energy Efficiency and Conservation Authority (NEECA, transformed from former National Energy Conservation Centre - ENERCON); the Authority Fund; and the National Energy Efficiency and Conservation Board.

As per this act, energy audits will be conducted by certified energy auditors of different designated consumers, but no proper measures were taken by the authority to force these designated consumers to implement energy efficiency measures. Also, no baseline or targets were defined for loss reduction and penalty for not achieving the same.

There are provisions of developing energy audit infrastructure and training of professionals as energy auditors, but proper training and subsequent assessment are required periodically of these energy auditors to confirm the quality of deliverables by them.

Modernization of Existing Power plants

Renovation and modernization of existing power plants is a main key for improving the efficiency of thermal power utilities. The lack in policy formation for modernization of existing plants has led to inefficient operation and consumption of more fuel. There should be clear policy in place either to completely close the inefficient plants or to perform renovation and modernization activity. Also, attractive policies should be formed for more private investment in the power sector.

2.8.3.2. Administrative and Governance Issues

Pakistan power sector is governed by Ministry of Water and Power, Pakistan Electric Power Company (PEPCO), and various government utilities under it. There are 4 GENCOs and 10 DISCOs, which are directly influenced by government. Due to major influence of government in Pakistan, there are various governance and administrative issues like:

- The centralized control of Ministry of Water and Power over the utilities entities causes continuous deterioration in performance and net generation.
- Due to confutations between different government agencies in Pakistan, there is delay in policy implementations, which has a cascading effect on performance of utilities.
- Delay in approval process has caused old and inefficient power plants to run beyond their normal operating life. This has significantly decreased the plant performance.
- The issues of illegal hooks and tempering of meters in some part of the country has been possible due to political influence. The lack of monitoring and strict actions by government has further raised these losses.

2.8.3.3. Financial Constraints

The establishment of a financially sound power sector in low-income developing countries is a common problem, and Pakistan is continuing to struggle to reduce losses, improve collections, and rationalize tariffs. The power crisis in Pakistan has received much attention including front-page stories in major Western papers. Though Pakistan has become power surplus but deficit in collections and pervasive circular debt from the past has hindered growth and implementation of energy efficiency measures. At the root of the problem are both high technical and commercial losses and especially nonpayment by the government and its state companies. Various reasons for financial constraint faced by the utilities are presented below (Hafeez, 2019):

- **Less Cost Recovery:** National Electric Power Regulatory Authority (NEPRA) determines electricity generation tariff for electricity generation power plants. These tariffs are based on cost of fuel and other variables which keep on changing with fiscal market etc. NEPRA also determines electricity tariff for end consumers that includes DISCOs' purchase price and their Operations and Maintenance margin. This tariff by NEPRA does not fully account for the cost incurred by DISCOs. Furthermore, GOP provides subsidy which is the difference between the tariff determined by NEPRA and tariff notified by GOP. This tariff differential accumulates as circular debt and is bridged by subsidy and/or by STFF from commercial banks through PHPL. Failure or reluctance to pass on the actual cost of electricity to end consumers is one of the key causes of circular debt (Hafeez, 2019).
- **Delay in Tariff Notification by Government**: NEPRA determines end user tariff and sends it to Ministry of Power, to notify and make the tariff effective. This approval process in Ministry and then by Government of Pakistan (Federal Cabinet) can take months and hence any upward revision in tariff keeps on accruing at consumer end. This delay is another reason for circular debt.
- **Slow Structural Reforms:** The process of unbundling of ex-WAPDA DISCOs was started in late 1990s. However, privatization process of DISCOs is quite slow and stalled because of intervention by several interest groups. One such interest group is Collective Bargaining Agent (CBA) in the form of labour unions in power sector. They resist efforts aimed at privatization of the sector claiming that it could intrude their job security. This leads to inefficiency and administrative challenges. Additionally, it hinders development of retail market for electricity. As a result, any inefficiency results in high commercial losses and low recovery of billed amount, which add to the circular debt (Hafeez, 2019).

2.8.3.4. Social and Environmental Issues

Pakistan being a developing country is prone to issues like over population, poverty and unemployment. Due to these and number of other issues, there is a trend of theft and corruption in power distribution sector. Also, due to the increasing environmental concern in globe, there is pressure on government to reduce its greenhouse gas emissions. Below are some social and environmental issues faced by power sector:

- Capacity addition measures like installation of substations, expansion of distribution lines needs land space, and, in some cases, vegetation is needed to be removed for creating space for the infrastructure. In some areas due to delay in NOC by Ministry of Climate Change causes delay in expansion, thus increasing T&D losses in the network.
- Average bill recovery by all DISCOs during FY 2019-20 was 88.77% (NEPRA, 2020). This means on average ~12% of electricity generated went without bill recovery. This is due to the inefficiency, collusion of power sector officials with consumers and unwillingness of pay bill and government not penalising such elements due to political reasons.
- Cross-subsidy of tariff such as providing subsidy to agriculture consumers leads to high tariff for commercial and industrial consumers.

- Due to environmental concern, thermal power plants are bound to install Electrostatic Precipitators (ESPs) and bag filters which in turn increases the differential pressure across the air preheater and ID fans thereby causing increase in power consumption by fan. Also, electricity consumption in charging ESP fields is substantially high.

2.8.4. Financial Impact of Losses

Utilities face financial impacts due to various inefficiencies as discussed in the above sections in generation, distribution and nontechnical inefficiencies. It was found that generation sector has nearly 7% technical losses with respect to the total generation of electricity in Pakistan, similarly distribution sector T&D losses can be improved by 12.02% as compared with world average T&D losses, which is nearly 8.64% (Central Electricity Authority, 2020). Also, losses due to nontechnical inefficiencies is 2% for generation sector and 4% for distribution sector.

The average generation cost for Pakistan is 0.06 USD/kWh (Umbreen Fatima, 2019) and total generation and electricity sales is 113,738 GWh and 101,959 GWh respectively. Figure 43 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Pakistan, if no energy efficiency improvement is done in the country.

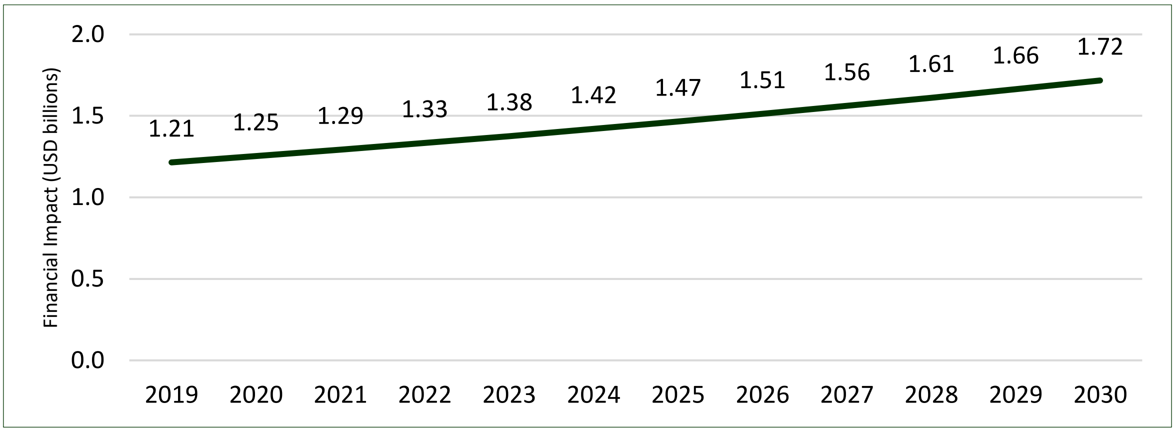


Figure 43 Financial impact of losses in Pakistan

2.9. Sri Lanka

2.9.1. Generation Sector

Sri Lanka's current grid-connected electricity generation is dominated by the CEB, there is also a significant presence of private independent power producers. Off-grid systems on the other hand are few, consisting of mostly diesel or renewable powered setups (Asian Development Bank, 2017).

Both the CEB and private power producers generate electricity and supply the national grid. The CEB currently owns all the large-scale hydro power plants, the only coal-based power project and a significant amount of the oil-fired capacity in the country. Apart from generation, CEB is also the only buyer of electricity in the country; it purchases electricity from private Independent Power Producers (IPPs) with whom it has 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. Electricity generation in Sri Lanka was dominated by major hydro in the beginning and continued to be so until about 1996. Once all economically feasible major hydro schemes reached saturation, there was an increase in the share of thermal plants in power generation. At present, over 50 percent of electricity generated (energy output in GWh) in Sri Lanka is carried out through thermal power (Asian Development Bank, 2017). Specific generation type selected for Sri Lanka are shown in Table 25.

Table 25 Share of different generation type in Sri Lanka's power sector

Type of Generation	% of total capacity[25]	% of total generation	Energy efficiency[26] (%)
Hydro Power Plant	32%	31.6%	85-89
Thermal Power Plant using coal as fuel	21%	36.6%	36.7
Thermal Power Plant using oil as a fuel	30%	26.6%	25.8 single Cycle 38.6 combined cycle

2.9.1.1. Hydro Power Plant

Sri Lanka has an installed capacity of 1,809 MW of large and medium size hydro power units. The annual generation for 2019 from these power generation units were 4,795 GWh and are contributing to a total of 30% of total generation (Ceylon Electricity Board, 2019). Hydro power plants output in Sri Lanka has been impacted by variability in monsoon patterns, which has significantly increased over recent decades due to climate change. Water use for domestic and irrigation purposes also takes precedence over hydropower affecting availability.

The conversion efficiency of a hydroelectric power plant depends mainly on the type of water turbine employed and can be as high as 95% for large installations. Smaller plants with output powers less than 5 MW have efficiencies between 80 and 85% in Sri Lanka. There are number of factors which causes losses in efficiency in hydropower plants of Sri Lanka:

- **Losses Due to Resistance in Path of Water**: It is estimated that a total of 3% of loss occurs due to various system resistance in hydropower plant. The hydrogeneration in Sri Lanka has loss of around 143 GWh.
- **Turbine Losses**: A normal range of losses in turbine is around 2-3% and is occurring a loss of 96 GWh in Sri Lanka Power plants. These losses can be mitigated by regular maintenance and overhauling of turbine blades and reducing the cavitation effect.
- **Mechanical Losses between the Turbine and Generator Systems**: Friction losses occur in the shaft connecting water turbine to generator in the hydro power plant. These losses increase with the ageing of equipment and improper lubrication of bearings and shafts. These losses are in the range of 0.5 to 0.75% and result in an estimated loss of 24 GWh.

2.9.1.2. Thermal Power Plant Using Coal as a Fuel

Sri Lanka has a total of 900 MW coal fired thermal power utility at Norocholai, Puttalam. It has a capacity of 3x300 MW and the first unit was commissioned in year 2011 and completed with commissioning of third unit in 2014. The units installed are of sub critical technology and have an estimated efficiency of 35% and average turbine heat rate of 2,200 kcal/kWh. There are considerable opportunities in reducing the overall heat rate and increase in boiler efficiency. Below are the major losses which affect the overall efficiency of stations as described below:

[25] (Ceylon Electricity Board, 2020)
[26] *(Government of Sri Lanka, 2018)*

- **Losses Due to Improper Monitoring of Critical Parameters**: Every thermal power plant manufacturer defines certain critical values of temperature and pressure, which must be maintained within a certain range for efficient operation of thermal power plants. Due to lack of knowledge or negligence on the part of operator, the critical parameters are not maintained. The losses due to inefficient operation of thermal plant in Sri Lanka are estimated 323 GWh.
- **Losses Due to Excess Auxiliary Power Consumption**: The auxiliary power consumption for thermal power plant using coal is 10.1% of total generation for year 2018. By implementing energy efficiency measures like installation of VFD, arresting leakages in boiler, improving fuel quality and better operational measures can reduce the APC to the range of 8 – 9%, which is up to 2% reduction in energy consumed and a saving of 107 GWh.
- **Losses Due to Improper Selection of Technology**: Sri Lanka power generation has been hit by improper planning of future expansion of generation plant. The thermal power plant was commissioned in year 2011 and in the same time super critical technology was already tested and used in neighbouring countries like India, which has an average efficiency of 42%. In the absence of futuristic planning, subcritical plant was installed.

2.9.1.3. Thermal Power Plant using Oil Fired Generator

Sri Lanka has an installed capacity of 1,282 MW (Ceylon Electricity Board, 2020) of oil-fired plants. 85% of the total generation capacity of power plant are single cycle power stations and only Kelanitissa Power Station has one unit of 110 MW Gas Turbine and 55 MW steam turbine commissioned as combined cycle power station. Most of the power stations are run during dry season of Sri Lanka when hydropower generation is low. The average PLF for gas turbine power station is 40% (Ceylon Electricity Board, 2020), which indicate use of power plant during peak period and during dry season. Few reasons which are causing losses in these power plants are:

- **Losses Due to Unavailability of HRSG**: Exhaust gases from the gas turbine usually leaves at a temperature of 600 – 700°C. The heat energy is wasted in many gas plants in Sri Lanka due to unavailability of HRSG system. A typical gas turbine has an efficiency of 37-40% and with the installation of HRSG system the same can be increased to a level of 55 – 60%. The rise inefficiency is mainly due to increase in generation from steam turbine. Typically, a combined cycle gas power plant generates nearly 60% more power compared with the same power plant operating in single cycle. There is a huge potential of energy saving in Sri Lankan power plants by installing HRSG after the exhaust of gas turbine. The total generated electricity from these gas turbines can be increased by up to 784 GWh per year after installation of HRSG system in CEB owned power plants.

- **Loss Due to Improper Operation and Maintenance**: In various studies, it was observed that the operators and maintenance staff were not aware about the efficient operation and maintenance practices of gas power plant. Sri Lanka being an energy deficit county need to conserve the existing natural resources by capacity building and training of plant officials in more efficient operation and maintenance of existing power plants. It is observed that by maintaining parameters at the rated values and regular protective and shutdown maintenance can achieve around 2-5% of total generation. A total of 108 GWh of power per year can be saved by efficient operation of power plants by improving efficiency by 3%.

- **Auxiliary Power Consumption**: Compressor is the main auxiliary power consuming equipment in gas power plant. It consumes around 60% of total cycle energy during operation. So, the performance of compressor plays an important role in overall auxiliary power consumption of plant. The main reasons of compressor performance deterioration are deposition of dust, aerosols and water on the compressor blades, which decrease the overall air flow from the compressor and the compressor needs to work extra to compress the same quantity of air. To prevent the losses in the compressors, there should be proper schedule of compressor water wash. The process of water wash can be online or offline during the shutdown.

- **Losses Due to Ageing of Gas Power Station**: Most of the power stations in Sri Lanka are more than two decades old and are running at 80-90% of rated capacity. Due to financial constraints, regular maintenance and overhauling are not carried out as required causing early degradation and derating of GT unit.

2.9.2. Distribution Sector

The electricity distribution and sales in Sri Lanka come under two state owned organizations: (a) Ceylon Electricity Board (CEB); and (b) Lanka Electricity Company (Pvt) Ltd. (LECO).

The transmission and distribution losses in Sri Lanka were much higher before the year 2000 (nearly 21%), however a significant reduction in the losses has been seen thereafter. The energy loss in the Sri Lanka transmission network for the year 2012 was 3.62% of the energy purchased by the utility from the generation plant. The energy loss in distribution for the year 2016 was nearly 10% of the power purchased by the utility in Sri Lanka. The total transmission and distribution (T&D) loss in 2015 was ~10% of the power purchased. Although Sri Lanka's distribution efficiency is far superior to many South Asian countries, Sri Lanka can further improve the efficiency of its electricity distribution to reduce is electricity losses. The values of T&D losses for 2019 is shown in Table 26.

Table 26 Performance of Sri Lanka's power distribution in 2019[27]

Distributor	Percentage loss (%)	Loss in GWh
CEB region 1	7.5	326
CEB region 2	8.4	414
CEB region 3	8.3	222
CEB region 4	8.3	174
Lanka Electricity Company (LECO)	3.98	66.82

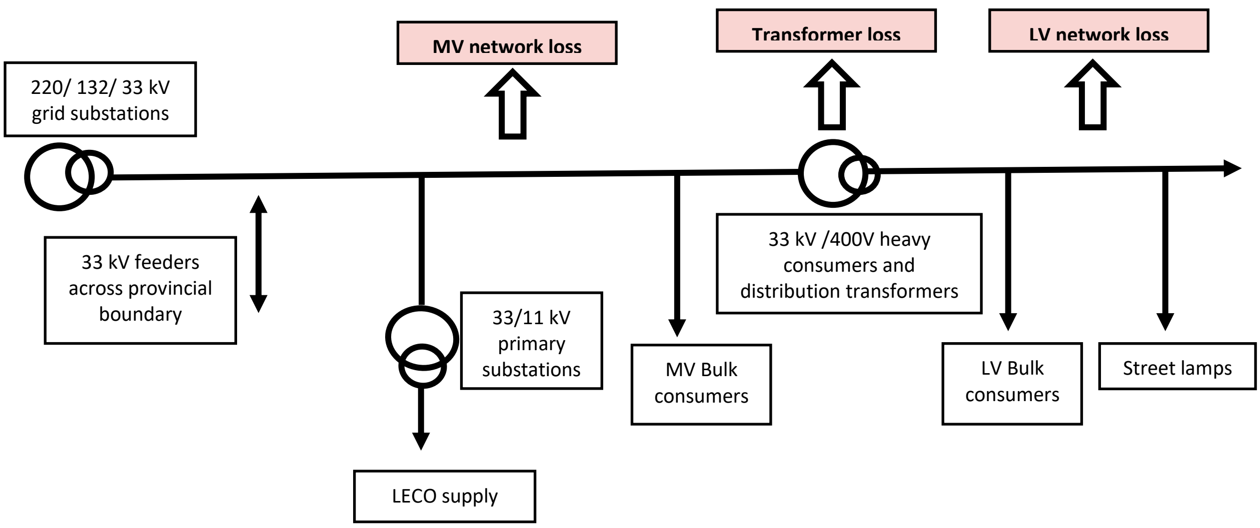


Figure 44 Sri Lanka's energy flow diagram

[27] (Ceylon Electricity Board, 2020; Lanka Electricity Company, 2020)

As mentioned previously, electricity distribution in Sri Lanka is done by two organizations, namely, Ceylon Electricity Board and Lanka Electricity Company. Primary distribution in Sri Lanka is done mainly at 33 kV level by CEB. Figure 44[28] illustrates the major components and the electrical energy flow in the electricity distribution system.

Losses in Distribution Network of Sri Lanka

The CEB transmission system comprises 220 kV and 132 kV transmission networks interconnected to switching stations, grid substations and power stations. At grid substations, a 132 kV transmission line is converted to 33 kV for distribution within the locality. In some instances, the electricity at 33 kV is again converted to 11 kV at primary substations and then distributed to consumers. Distribution networks operated by LECO use 11 kV as the distribution voltage. However, both CEB and LECO supply at 400 V to small scale consumers such as households and commercial buildings. There are various losses which result in an increase in the net distribution system losses, some of the key losses in Sri Lanka's distribution network are shared below:

- **Losses Due to Lengthy Distribution Lines:** Sri Lanka has a major share, nearly 81% of the population, living in rural regions. There have been numerous programmes and projects in the region to increase the rural electrification undertaken by Sri Lankan government and many multilateral and bilateral organisations. These large-scale rural electrification programmes have resulted in long LT lines and extension of exiting distribution networks, which has subsequently increased the losses in distribution network.
- **Losses Due to Low Power Factor:** In most LT distribution circuits, normally the power factor ranges from 0.65 to 0.75. A low power factor contributes towards high distribution losses. For a given load, if the power factor is low, the current drawn is high and losses proportional to square of the current will be more. Due to pumping loads in rural areas, and air conditioners, coolers and industrial loads in urban areas, the Sri Lankan distribution system has a low power factor which subsequently results in higher losses.
- **Losses Due to Improper Planning of Distribution Network**: Sri Lanka has seen a rapid electrification, nearly 98% of the total country has electricity supply, making it one of the highest electrified nations amongst the SAARC nations. Although this is a positive trend, there is an unorganized growth of distribution network which has caused increase in distribution losses. Moreover, new connections are being provided to customers by the utilities without adequate reinforcement.
- **Losses Due to Improper Maintenance of Transformers and Lines**: Due to financial constraints, the transformers and lines are not frequently maintained by the DISCO. This leads to increase in conductor loss in lines and transformer losses. These losses can be mitigated by effective maintenance plan for whole system and increasing the capacity of distribution network.

Table 27 presents the system losses of Sri Lanka from 2006 to 2015. It shows Sri Lanka's T&D losses as a percentage the gross generation. It can be inferred from the table that there are losses other than T&D losses reducing the gross generation. In 2009, these losses accounted to 165 GWh of electricity, which has further reduced to 58 GWh for the year 2015. Although Sri Lanka is taking steps to ensure reduction in these losses, they are still prevalent in the country. These electricity losses are primarily because of theft, corruption, meter tampering etc. A study identifies these key reasons for losses (H.R.P.Wanniarachchi & Wijayapala, 2012).

---

[28] *(Rodrigo & Gunatillaka, 2019)*

Table 27 Sri Lanka's system losses 2006- 2015[29]

Year	Gross generation in GWh	Total losses as % of gross generation	T&D losses as % of gross generation	Other losses (%)
2006	9,535	17.78	16.37	1.41
2007	9,938	17.04	15.40	1.64
2008	9,998	16.40	14.70	1.7
2009	9,964	16.03	14.37	1.66
2010	10,718	14.78	13.87	0.91
2011	11,528	13.10	11.72	1.38
2012	11,801	11.20	10.67	0.53
2013	11,962	11.20	10.76	0.44
2014	12,418	10.90	10.47	0.43
2015	13,154	10.40	9.96	0.44

The following losses were validated through consultation with industry experts in Sri Lanka:

- **Loss Due to Theft:** Theft by direct tapping usually occurs in the following places in Sri Lanka's distribution system:
  - Cut-out
  - Service wire- exposed connections/joints in service cables
  - Overhead bundled conductors x overhead "bare" conductors
  - Street lamps
  - Open junction boxes (in cable systems)
- **Losses Due to Erroneous Meter Systems:** Meters can be tampered with or bypassed by the consumers to steal electricity. Further, there is also a lack of effort made by the meter readers in issuing correct bills. Some of the reasons have been identified in Sri Lanka's context:
  - Meter tampering by consumers (accuracy adjustments)
  - Meter tampering in connivance with the CEB employees
  - Intentional damages to meters
  - Faulty / inaccurate meters (old, poor quality, incorrect rating, etc.)
  - Assessed readings (defective meters, inaccessibility, meter readers involvement)
  - Non-reading of meters (unbilled consumers) or errors in reading

[29] (Rodrigo & Gunatillaka, 2019)

2.9.3. Nontechnical Inefficiencies

There are various nontechnical inefficiencies, which are affecting sustainable growth of efficient power sector across Sri Lanka.

2.9.3.1. Policy Related Issues

Sri Lanka has formulated various laws and policies in power sector for regulation and providing significant impact on the pace and direction of economic development. To attain the objectives of electrification through development of conventional and alternative sources of energy, the following policies and legislations are in place:

- Ministry of Power and Renewable Energy – Gazette No: 1933/13 dated on 21/09/2015
- Right to Information Act No.12 of 2016
- Public Service Commission of the Democratic Socialist Republic of Sri Lanka Gazette NO 1589/30 dated on 20/02/2009
- Sri Lanka Electricity Act No. 20 of 2009
- Sri Lanka Electricity Act (Amendment) No.31 of 2013
- Ceylon Electricity Board Act (Include all amendments up to 1987)
- Sri Lanka Atomic Energy Act No. 40 of 2014
- Sri Lanka Sustainable Energy Board Act No. 35 of 2007

The Influence from the Legal Framework in the Country (New Electricity Act)

As per Act No. 17 of 1969, CEB officers had the authority to visit consumer premises at any time, without a prior notice, in order to inspect the energy meter fixed by the CEB. If any illegal connection or meter tampering was noted, CEB officers had the authority to disconnect the power-supply and issue a revised (or estimated) electricity bill, in general for a period of 12 months. Due to the rigid legal framework in function during this period, there was a significant reduction in tampering and other illegal activities.

As at present, one of the main barriers for reduction of nontechnical loss is being the Clause 8 of section 31 of schedule 11 in the New Electricity Act no.20 of 2009. According to this clause, the licensee has to give three-day' notice of the intended entry by stating fully and accurately as possible, the nature of the work that intended to be done. In case of illegal connections and meter tampering, consumers could remove or reverse the acts before the officer of the CEB visits the premises. This fact has been brought to the notice of all relevant authorities including the Ministry of Power & Energy and Public Utility Commission of Sri Lanka. The necessary amendments for the new act are under discussion.

Sri Lanka Sustainable Energy Authority Act, No. 35 OF 2007

The Sri Lanka Sustainable Energy Authority (or SLSEA) is the primary body responsible for the issuance of licenses for sustainable energy developments in Sri Lanka. In addition, being the key licence provider, it is also the organization responsible for promoting renewable energy and sustainable developments in the country. The agency has formulated rules and regulations for energy auditing for energy intensive sectors, but no emphasis is given on auditing of power plants and electric utilities. The authority should lay clear instructions for auditing and formation of baseline energy consumption for power plants and DISCO AT&C losses.

2.9.3.2. Governance and Administrative Issues

Sri Lanka has majority of power sector governed by Ceylon Electricity Board (CEB), which has its own power plants. The CEB also buys electricity from other private power plants and then distributes the same through its distribution network. Due to major influence of government in CEB, there are various governance and administrative issues like:

- The Sri Lanka power generation plants face issues of storage of fuel especially coal. Due to this, there are problem of low power factor and frequent shutdowns.
- Lack of government focus on local research and development of energy efficiency measures and equipment.
- Lack of government policies to allocate funds for implementing energy efficiency measures.
- The forecasted of future demand in the country is not robust, due to which there are frequent power outages and over loading of distribution network.

2.9.3.3. Financial Constraints

The Sri Lanka power sector has faced huge financial constraints in improving its generation and distribution network. One main reason for the poor financial condition of Sri Lanka's power sector has been the ad-hoc and negotiated pricing for power tariffs, dictated by different governments over the years. This practice of charging tariffs inadequate to cover actual costs has burdened the CEB with accumulated debts.

2.9.3.4. Social and Environmental Issues

Sri Lanka, being a developing country, has a number of social issues. Below are some social and environmental issues faced by power sector:

- Sri Lanka power sector has been in immense pressure due to increasing demand of electricity, but capacity addition plan by government faces huge public agitation like for Lakvijaya Power Station (3x900 MW).
- The problem of theft and tempering of meters is prominent; agitation among the DISCO officials and consumers are not scarce.
- Due to space constraints in the main load centre city of Colombo, identifying land space for distribution network expansion is a huge problem.
- Due to uncertainty of power generation by hydropower plants, the government is exploring opportunities like coal or gas-based power generation. But due to environmental issues, funding from international agencies for these proposals is difficult to arrange.

2.9.4. Financial Impact of Losses

Utilities face financial impacts due to various inefficiencies as discussed in the above sections in generation, distribution and nontechnical inefficiencies. It was found that generation sector has nearly 11% technical losses with respect to the total generation of electricity in Sri Lanka, similarly distribution sector T&D losses can be improved by 2.34% as compared with similar countries like Mauritius where T&D losses are nearly 6% (The World Bank, 2020).

The average generation cost for Sri Lanka is 0.1 USD/kWh (Ceylon Electricity Board, 2019)and total generation and electricity sales is 15,168 GWh and 14,611 GWh respectively. Figure 45 provides the financial impact of losses due to various technical and nontechnical inefficiencies in Sri Lanka.

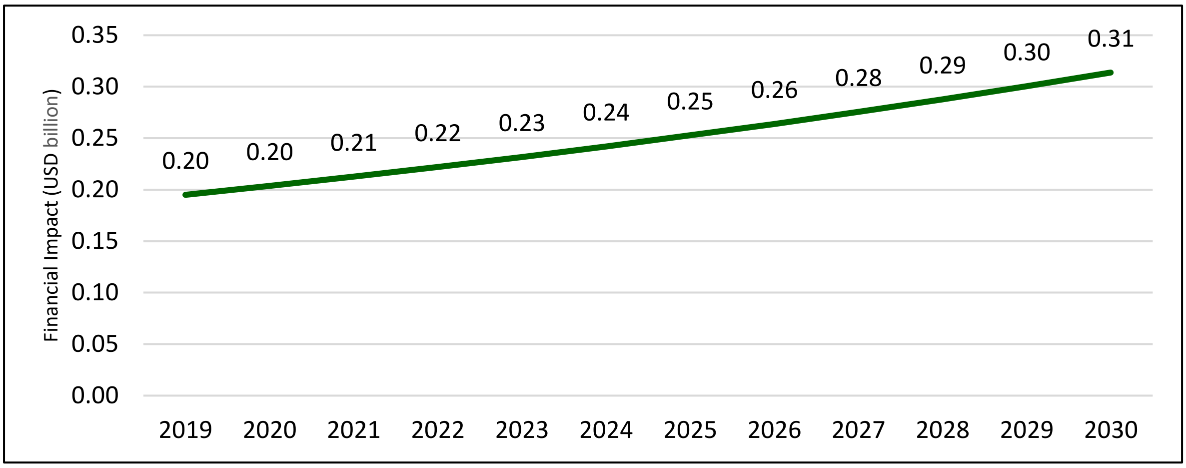


Figure 45 Financial impact of losses for Sri Lanka

3. Challenges, Benefits and Requirements for Implementation of Energy Efficiency Improvements in SAARC

3.1. Afghanistan

Afghanistan has been developing its basic infrastructure since 2001, the key areas of development include electricity distribution, cross border transmission and generation infrastructure. The country is continuously increasing the share of access to electricity for its citizen and working on developing an integrated grid system of whole country.

Afghanistan has enough energy resources to provide reliable electricity to its people and industries. Based on Ministry of Energy and Water estimates, it has about 318 GW of renewable energy production capacity. In addition, there are significant hydrocarbon and coal resources in the country. Despite being rich in natural resources, the country is not able to meet its electricity demands, with electrification rates ranging from 30-38%.

3.1.1. Challenges and Barriers

The implementation of energy efficiency measures in Afghanistan face is hindered by various issues faced by the nation:

- The main share of power requirement in Afghanistan is imported from Central Asian republics (CARs), such as Tajikistan, Uzbekistan and Turkmenistan, and Iran. The power is supplied at a subsidized rate due to poor economic condition of Afghanistan, thus causing financial stress.
- The grid in Afghanistan runs asynchronously causing high T&D losses. Due to the rough terrain and distance of load centres from electricity exporting countries, there are lengthy transmission lines causing increase in T&D losses.
- Afghanistan largely depends on financial aid from various agencies such as ADB, USAID, The World Bank etc., for their development work. In the past and present, these agencies focused on development of basic infrastructure of the power system rather than implementing the energy efficiency measures in country.
- Afghanistan faces problem of corruption, which could affect the effective implementation of energy conservation programme.
- The generation sector in Afghanistan is still in development stage and the technology used for installing generating units largely depends on the donor agency and government has no policy for installing energy efficient system.
- The distribution companies have not invested in vigilance due to security concerns.
- The government has no policies for promoting energy efficiency system in the generation and distribution network.

3.1.2. Financial Benefits

Implementing energy efficiency measures to curtail losses in system can have a huge financial impact on the country. There are various direct and indirect financial benefits as mentioned below:

- The cost of generation is high in Afghanistan due to inefficient operation of power stations and unreliability of power generation due to maintenance issues.
- Improving efficiency in power generation and distribution, can help save direct foreign exchange by reducing the import of power.
- The reduction in T&D losses will increase the revenue of DISCOs and will help in strengthening their distribution network.

- A stable and efficient distribution system will attract private investment, which will increase government revenue.

3.1.3. Consumer Side Benefits

Efficient generation and distribution network will lead to more reliable and affordable electricity supply. Some of the benefits of efficient system:

- Improvement in efficiency will lead to reduction in load shedding and consumers will reap its benefits.
- The average cost of supply of power is US¢ 6.2. Improvement in governance to bring down the commercial losses of power distribution can help DABS supply power at lower, affordable cost to commercial and industrial consumers, thus leading to higher prospect of economic activities.
- Better and reliable distribution systems will help industrial consumers in proper planning of their production schedules, increasing their yield and subsequently revenues.

3.1.4. Social and Environmental Benefits

There are various social and environmental benefits of implementation of energy efficiency measures in country, some are listed below:

- Energy is directly linked with economic development. Energy efficient power system can boost economy by providing affordable power to consumers.
- Increased efficiency can lower greenhouse gas (GHG) emissions.
- With the efficient and reliable power supply, use of backup diesel generators can be avoided. This helps in reducing cost of electricity and emissions caused by them.
- Efficient hydro power generation could help in increasing the generation with the same installed capacity, resulting in lower import of electricity and increase in reliability of domestic generation network.

3.1.5. Prerequisites for Implementation

The success of energy efficiency measures largely depends on how the measures are planned and implemented in the system. There are few prerequisites for efficient implementation of energy efficiency measures as mentioned below:

- The main prerequisite of effective energy efficiency implementation is willingness of government to implement the measures. The government should formulate policies/strategies to provide annual loss reduction target to DISCOs.
- Capacity building of the utility officials/personnel though workshops to build understanding and enhance knowledge on energy efficiency opportunities.
- The security situation needs to be improved for encouraging private investment in the country. Energy efficient technology should be made readily available for the utilities in the country and regular awareness events should be organised for them.
- Financial institutions should be able to finance the energy efficiency projects at subsidized interest rates.
- There must be proper framework and reference documents prepared by the government with the help of nodal agency formed by government, which will overlook the progress and help in mitigating any difficulties arising in implementation of energy efficiency measures.

3.1.6. Future Challenges

The challenges in the power sector are never ending. Due to continuous evolution of technologies, growth of network and change in policies, there are many future challenges which power sector may face after implementation of energy efficiency measures:

- The growth of development of power generation and distribution sectors of Afghanistan is less as compared to growth in population, as a result the electrification rate is not improving.
- Although measures are being adopted by government to establish peace in the country, but security issues may still arise in the future.

3.2. Bangladesh

The performance of Bangladesh's power sector in the last five years has improved due to the progressive efforts of policymakers, support from developing partners, and effective project implementation by public and private developers. The growth in terms of capacity addition in the last 10 years has been remarkable, from around 4.5 GW in 2007–08 to 12.8 GW in 2016–17. Private sector participation in generation accounts for about 60% of the total installed capacity.

3.2.1. Challenges and Barriers

The energy efficiency in power generation and distribution in Bangladesh faces various challenges and barriers, and they are:

- Bangladesh power sector faces huge financial deficit, which is primarily due to increasing fuel price. This causes delay in funds allocation for energy efficiency measures.
- There is no policy or incentives defined by government in energy efficiency for power sector such as energy audits of power generators and DISCOs. As a result, there is lack of motivation in the sector to implement energy efficiency measures.
- The investment costs are high due to the lack of domestic market for energy efficiency. Bangladesh should work towards better ecosystem for procurement/import of low carbon/energy efficient technologies.

3.2.2. Financial Benefits

The various direct and indirect financial benefits for Bangladesh are listed below:

- The cost of generation in Bangladesh is high due to excess dependency on conventional sources of energy such as gas, oil and coal. The inefficiencies in the plants have led to increase in generation cost and raise in tariff for end users. Implementing efficient systems will have a direct impact on cost of electricity supply.
- Due to depleting gas reserves, Bangladesh imports part of fossil fuel requirement of the country, leading to loss of foreign exchange. Increasing efficiency can reduce the amount of imported fuel.
- Due to gap in demand and supply of power, there is frequent load shedding in the distribution networks. Load shedding causes heavy losses to commercial and industrial consumers. Reduction of T&D losses in the distribution network can assist in reducing load shedding up to a large extent.

3.2.3. Consumer Side Benefits

The consumers are the main beneficiary of efficient power system in the country. Efficient generation and distribution network in-turn lead to more reliable and affordable electricity supply. Some of the benefits of efficient system:

- In Bangladesh, there is frequent load shedding due to over loaded distribution network and unscheduled line loading due to electricity theft primarily by hooking on lines. Installation of energy efficient systems will minimize load shedding and will benefit the consumers.
- Bangladesh is main exporter of ready-made garments to other countries and this sector is facing problem of increasing electricity tariff. With the increase in energy efficiency of power sector, it can considerably reduce the power cost for the industrial consumers.
- The average cost of supply of power is US¢ 7.2. Improvement in governance to bring down the commercial loss of power distribution can help Bangladesh to bring the cost supply down for commercial and industrial consumers, thus leading to higher prospect of economic activities.

3.2.4. Social and Environmental Benefits

There are various social and environmental benefits due to implementation of energy efficiency measures in country, some are listed below:

- Bangladesh has almost 90% of power generation by conventional sources of energy such as Gas, Coal and HFO, the rising inefficiencies in these plant cause consumptions of more fuel and thus causes more GHG emissions. Increased efficiency can lower GHG emissions.
- Bangladesh is facing shortage of gas and oil. Efficient power system can lead to optimised utilization of these precious natural resources.

3.2.5. Prerequisites for Implementation

There are few prerequisites for efficient implementation of energy efficiency measures as mentioned below:

- The government needs to define the energy efficiency target based on fuel type of power plants. As Bangladesh has number of gas-fired power plants, which have exceeded their lifetime and implementing energy efficiency measures may not be feasible in these plants.
- The first step for electricity loss reduction in the distribution system of Bangladesh is an effective capacity building of officials of DISCOs. The utility manpower must be trained on global best practices in energy efficient DISCO operation.

3.2.6. Future Challenges

There are many future challenges that power sector may face after implementation of energy efficiency measures in Bangladesh; important ones are:

- Timely amendments and modifications in the policies of government to attract private sector investment for energy efficiency.
- The country is shifting focus from gas to coal-based generation. The plan should be focussed around the super-critical or ultra-super critical coal-based plants or towards investment in the alternative sources of energy.

3.3. Bhutan

Bhutan's power sector has a long history of development and introduction of various policies and agencies for streamlining the power sector generation and distribution issues. Earlier the main development challenges faced by Bhutan's power sector were:

- Lack of regulations and framework for energy efficiency in power sector
- Due to capital intensive nature of hydropower plant projects, Bhutan was more dependent on donor agencies for development.
- Mobilizing investments for expanding access to rural communities and export-oriented hydropower projects.

3.3.1. Challenges and Barriers

The challenges in implementation of energy efficiency measures in power generation and distribution sectors of Bhutan are:

- Power generation in Bhutan is largely dependent on hydro power, which is not expensive as compared to conventional fossil fuel-based power generation. However, due to low cost of generation, the payback of energy efficiency measures is less attractive (payback >3 years).
- Bhutan being a developing nation is largely dependent on financial aid from neighbouring countries and financial institutions such as ADB, The World bank for implementing projects.
- The size of energy efficiency market is too small, and Bhutan is already carbon neutral country. As a result, the penetration of new efficient technologies is very low in Bhutan.
- The power sector in Bhutan is managed by government agencies, thus needs strong policy push to implement energy efficiency.

3.3.2. Financial Benefits

Implementing energy efficiency measures can help Bhutan to export the saved power to neighbouring countries thus increasing revenue generation. The resulting financial benefits are mentioned below:

- The net export of electricity of Bhutan is ~70% of total generation and by saving energy in generation and distribution network, there will be direct increase in revenue of the country by increase in exports.
- The reduction in T&D losses will increase the revenue of DISCOs and will help in increasing reliability of their distribution network.

3.3.3. Consumer Side Benefits

The consumers are the main beneficiary of efficient power system in the country. Efficient generation and distribution network in turn lead to more reliable and affordable electricity supply. Also, the average cost of supply of power is US¢ 3.4. Reduction in losses may further bring down the cost of power and will ultimately benefit the end users.

3.3.4. Social and Environmental Benefits

There are various social and environmental benefits due to implementation of energy efficiency measures in country, some are listed below:

- The energy efficiency measures can result in reduced cost of supply of electricity; thus, utility can pass the benefits directly to consumers.
- Efficient hydro power generation could help in increasing the generation with the same installed capacity. This shall assist Bhutan in planning of new hydro capacity in the country, which may lead to deforestation and land being converted into catchment areas.
- Efficiency improvement programmes for generation and distribution system would create and promote an energy efficient ecosystem and behavioural change towards EE in the country.

3.3.5. Prerequisites for Implementation

Energy efficiency measures in the country needs some prerequisites before implementation. Some of the measures are mentioned below:

- As the cost of supply of power is quite low, the payback period of energy efficiency measures is long. Thus, the Bhutan government should formulate policy for incentivizing adoption of energy efficiency measures by the utility.
- The country being carbon neutral, technology advancement in low carbon space might not be implemented in the country. The government should conduct frequent capacity building events for providing insight to utilities about the latest technologies available and show business cases of tailoring these technologies to Bhutan’s conditions.
- Government could subsidise or waive duty on import/procurement of energy efficient transformers, smart meters and other equipment.

3.3.6. Future Challenges

The potential future challenges for Bhutan power sector may face after implementation of energy efficiency measures:

- The major share of power is exported to neighbouring countries, a long-term stable cross-border energy policy is important, otherwise it may endanger the investment done by utilities in implementing energy saving measures in generation sector of Bhutan.
- Due to global warming and climate change, there is frequent rainfall variation affecting output of hydropower generation. The government should form guidelines for forecasting/identifying the variations to ensure efficient operation of power systems.

3.4. India

India’s power sector is one of the most diversified in the world (India Brand Equity Foundation, 2020). The Government of India’s focus on attaining ‘Power for all’ has accelerated capacity addition in the country. At the same time, the competitive intensity is increasing at both the market and supply sides (fuel, logistics, finances, and manpower). By 2022, wind energy is estimated to contribute 60 GW, followed by solar power at 100 GW, and biomass and small hydropower at 15 GW (UN, 2020). The target for renewable energy has been increased to 175 GW by 2022. Below described are the benefits and challenges, which power sector for India.

3.4.1. Challenges and Barriers

There are various challenges and barriers in implementing energy efficiency measures in India. Some of the key challenges are presented below:

- DISCOMs have faced issues of high commercial losses and operational inefficiencies, which have affected their financial stability. DISCOMs often do not have financial resources to invest for energy efficiency improvement.
- India's thermal power stations are currently running at low PLF, the payback of the energy efficiency options is longer than usual, and project is unviable in some cases.
- The cost recovery from utilities is a tough task for ESCOs working on energy efficiency measures, which demotivates them for any future investment.
- India has a vast experience in implementation of EE measures in thermal utilities but for DISCOMs and hydro power generation, it is still in early stages. This prevents the DISCOMs in implementing the energy conservation measures (ECMs) in their utilities.
- Utilities lack awareness in latest developments in energy efficient technologies available in the market.
- PAT (Perform Achieve Trade) scheme by Bureau of Energy Efficiency (BEE) needs to be more vigilant. The data submitted by utilities should be cross-checked for establishing actual energy efficiency measures adopted by the utilities.
- Presently, energy losses in hydropower generation plants in India are not accounted for by any agency. Thus, there is no urgency towards implementation of energy efficiency in their plants.
- Electricity theft and low collection efficiency in DISCOMs cause overloading of lines and transformers. In this scenario, proper planning for loss reduction becomes difficult as line loading cannot be determined properly.

3.4.2. Financial Benefits

The following are the possible financial benefits of implementing energy efficiency measures in India:

- India is a net importer of electricity from Bhutan and is exporting electricity to Nepal and Bangladesh. By improving energy efficiency in power generation, country can potentially increase export and decrease import, and earn a substantial amount of foreign exchange.
- Some of the power generating stations have long term power purchase agreements with the distribution utilities and utilities are bound to sell electricity at a lower rate than the cost of actual generation at the generation station end. By increasing the efficiency of power stations, the utility can reduce or eliminate the financial losses.
- The cost of generation in India is high due to excess dependency on conventional sources of energy. The inefficiencies in the plant leads to increase in generation cost and rise in tariff.
- India has a major power generation share from gas based thermal power plants for which gas is imported from gulf countries. The increase in efficiency of other sources of electricity can reduce requirement of gas-based power stations and thus saving in foreign exchange. In this way, gas fired power plants may only be used to cater peak demand.

3.4.3. Consumer Side Benefits

Consumers are the main beneficiaries of efficient power system in the country. The more efficient generation and distribution networks are, the more reliable and cheap electricity supply will be there. Below are some benefits of efficient system:

- Although India has considerably improved the AT&C losses in DISCOMs but some DISCOMs still have high losses causing huge financial burden, which is transferred to consumers in the form of raised tariff.
- Due to continuous fluctuation in voltage, industries are forced to use alternate sources of power or relocate to another state with reliable power supply. This in turn causes huge loss to the respective DISCOM as well as consumers.

3.4.4. Social and Environmental Benefits

Some of the potential social and environmental benefits of energy efficiency measures are listed below:

- India has almost 62% of power generation by conventional sources of energy, the rising inefficiencies in these plants cause excess GHG emissions. Increased efficiency can lower GHG emissions.
- The energy efficiency measures in power generation and distribution can assist in achieving India's NDC targets.

3.4.5. Prerequisites for Implementation

Few prerequisites for efficient implementation of energy efficiency measures are:

- Despite strict government laws, electricity theft is still prevalent in Uttar Pradesh, Madhya Pradesh, Bihar. Often, the defaulters are not identified and penalized. For effective loss reduction strategy, interference from local leaders should be minimised.
- India has effectively implemented ESCO mode of financing but still considering the size of country, promotion of ESCO in implementation of EE measures for utilities needs attention.
- India's power distribution utilities are in continuous financial burden and without financial support by the government, implementation of EE measures is not possible.

3.4.6. Future Challenges

The potential future challenges are as follows:

- The shift in power generation mix towards renewable could endanger investment done by private players in implementation of energy efficiency measures in conventional power plants.
- The government is introducing reforms in power sector and one of the major reforms is gradual privatization of utilities. Due to this uncertainty, the public distribution companies may be reluctant to implement EE measures.

3.5. Maldives

Maldives is highly dependent on imported oil. The state-owned electric company supplies electricity to the country's capital Male' while rest of the island inhabitants' resort to privately managed small diesel sets. For the nearly 80 islands, diesel remains the main source of power generation. Maldives has its own unique challenges and barriers in implementing energy efficiency measures. Also, various benefits of implementation of effective EE measures are described in following sections.

3.5.1. Challenges and Barriers

There are various challenges and barriers in implementing energy efficiency measures in Maldives. Some of the key challenges are presented below:

- Maldives power sector is highly scattered; state owned SETLCO owns power distribution and generation sector for Male and neighbouring islands. Due to unavailability of single utility, it becomes difficult to implement EE measures.
- Maldives mostly depends on donor agencies for development of power sector infrastructure, so government has no regulations to restrict energy inefficient units to be installed.
- Due to geographical condition of the country, it is unviable to install more-efficient sources of generation like gas fired power units.
- Maldives has no regulatory policy that binds the independent islands to implement energy efficiency measures in their jurisdiction.
- The size of energy efficiency market is too small, and the geography of small islands is difficult. As a result, the penetration of new efficient technologies is very low in Maldives.

3.5.2. Financial Benefits

Some likely financial benefits for Maldives are:

- The cost of generation in Maldives is one of the highest amongst the SAARC Nations, mainly due to dependency on diesel-based power generation. Thus, the increase in efficiency of generators can help in reducing the cost of electricity.
- Maldives has no fossil fuel reserves in the country, so it is mainly dependent on imported fuel from other countries. Inefficiencies in the generation systems add to the loss of foreign exchange.

3.5.3. Consumer Side Benefits

Below are some benefits of energy efficient system for the consumers:

- In Maldives due to high tariff, industries and commercial consumers have their own generation arrangements. If energy generation process is cheap, the consumers will not need to maintain their own DG sets.
- The losses in distribution network are extended to end consumers in the form of tariff rise. Energy efficiency measures can help in reducing the financial burden for end consumers.
- Tourism industry has a major share in Maldives economy; with the reduction in cost of generation, the hospitality industry can enhance profitability.
- The efficient distribution network will increase the standard of living of people and will create more employment and commercial activities.

3.5.4. Social and Environmental Benefits

There are various social and environmental benefits that can potentially arise through implementation of energy efficiency measures in country, some are listed below:

- Presently, Maldives has almost 99% of power generation by DG sets; the rising inefficiencies in these plant causes excess GHG emissions. Increased efficiency can lower GHG emissions and other pollutants.
- The efficiency improvement programmes for generation and distribution system will create an

ecosystem of energy saving in the nation, which will help society to optimize energy use at their end.

3.5.5. Prerequisites for Implementation

The prerequisites of implementation of energy efficiency measures in Maldives are mentioned below:

- Due to geographical limitations of the country, a careful approach needs to be drawn before planning any measures for power generation and distribution.
- An effective implementation agency or private investor must be available for utilities through foreign collaborations for effective implementation of energy efficiency measures.
- An awareness programme should be planned for various stakeholders in the country regarding the energy efficiency measures.

3.5.6. Future Challenges

Some identified future challenges for Maldives are:

- The fossil fuel prices are increasing at an alarming rate, which means energy efficiency projects for DG set will have a quick payback. But on the contrary, it is important for the government to plan judiciously. If they plan to shift to renewables in short term, then the investment in energy efficiency may not have attractive payback period.
- Space availability is a major issue for small islands. Power distribution infrastructure revamp for improving energy efficiency may see this as a major challenge, e.g. instead of typical transformers, Maldives must procure/utilise energy efficient and compact transformers.

3.6. Nepal

The state-owned Nepal Electricity Authority (NEA) is responsible for the electricity supply through the national grid. The generation is heavily dependent on hydropower, as nearly 93% of the total electricity is generated by either NEA-owned or private hydropower plants. In order to meet the growing hunger for more electricity, imports from India have caused an additional burden on the government.

3.6.1. Challenges and Barriers

There are various challenges and barriers in implementing energy efficiency measures in Nepal. Some of the key challenges are presented below:

- Power generation in Nepal is largely dependent on hydro power, which is not expensive as compared to conventional sources such as coal, oil. However, due to low cost of generation, the payback of energy efficiency measures is less attractive (payback period >3 years).
- Nepal, being a developing nation, is largely dependent on financial aid from financial institutions such as ADB, The World bank for implementing projects in the country.
- The penetration of new efficient technologies is very low in Nepal, mainly due to small size energy efficient market in the nation. Foreign agencies need to be involved in implementation of various energy efficiency programmes.
- Nepal distribution sector is still in development stage and the investment on energy efficiency measures is low on priority.

3.6.2. Financial Benefits

Implementing energy efficiency measures to curtail losses in the power system can have a huge financial impact on the country. There are various direct and indirect financial benefits as mentioned below:

- A large part of total domestic electricity consumption is imported from India. Increasing energy efficiency in generation and distribution can reduce loss of foreign exchange.
- The losses in distribution network are compensated by end consumers in the form of higher tariff rise. As Nepal has T&D losses in the range of 7% to 23 % in some regions, a large part of these losses is passed on to commercial and industrial consumers, which increases the cost of end products and services provided by them.
- The reduction in T&D losses will increase the revenue of the utility and will help in strengthening their distribution network.
- Due to supply and demand gap, load shedding is done by the utility which causes consumers to rely on costly alternatives such as DG sets.

3.6.3. Consumer Side Benefits

Some potential benefits for consumers in Nepal are:

- Nepal in the past has faced problem of load shedding during peak hours. With the improvement of distribution infrastructure, the problem of load shedding has been improved but still consumers have to install backup power supply source like storage batteries, DG set etc. for uninterrupted power supply. An increase in energy efficiency can help in reducing problem of unplanned outages.
- The improved distribution infrastructure will ensure better quality of power supply (minimum voltage fluctuation, phase balancing, power factor improvement etc.), which will help industrial consumers to increase their production.
- Although low unit consuming customers have to pay electricity bills at a subsidized rate, but middle class have to bear impact of high tariff rates in Nepal. With the decrease in losses, the cross-subsidy of tariff can be lowered.

3.6.4. Social and Environmental Benefits

- The increased energy efficiency can help government in reducing the electricity tariff and increasing access to electricity, which will ultimately help in improving standard of living.

3.6.5. Prerequisites for Implementation

Some of the prerequisites for effective implementation of energy efficiency programme in power generation and distribution sectors of Nepal are:

- The Nepal government should provide institutional and technical support to utility for implementing energy efficiency measures.
- Due to dependency of the country on import of electricity from India, the focus of government is still to expand generation capacity. The government should consider sustainable development of generation sector and funds should be provided to utilities for implementing energy efficiency measures.

- Although Nepal government in the past has been successful in involving private investment in generation sector with the installation of various IPPs. But the penetration of private investors in distribution sector is quite meagre.

3.6.6. Future Challenges

Nepal being dependent of single source of power generation and also the distribution of electricity is done by single entity may face various future challenges:

- Nepal, being a land locked country, is dependent on neighbouring countries for technological and logistic support. Effective implementation of energy efficiency measures is largely dependent on relations with neighbouring countries.
- A change in policies of government (no long-term commitment) can endanger investment done by various private players in energy efficiency measures

3.7. Pakistan

The electricity market of Pakistan in unbundled at the generation and distribution but is bundled at the Transmission point. The National Transmission and Dispatch Company (NTDC) is the only entity responsible for transmission and dispatch of electricity. Electricity is generated by the state-owned Water and Power Development Authority (WAPDA), 4 GENCOs and by several private power produces; except WAPDA, all of other utilities operate within one system under the Pakistan Electric Power Company. Electricity distribution is handled by 11 DISCOs, out of which 10 are government owned and one is private DISCO for supplying electricity to Karachi city and its sub-urban region.

3.7.1. Challenges and Barriers

Some of the key challenges for Pakistan are:

- Pakistan's generation sector is predominated by government owned power utilities and major contribution to the generation mix comes from gas and oil based thermal power plants. Due to increasing prices of these fuels, these utilities have higher generation costs.
- 4 GENCOs in Pakistan are currently running at a very low PLF (NEPRA, 2019); so, the payback of the energy efficiency measures is longer than usual, and such project may become unviable in some cases.
- Utilities lack awareness in latest developments in energy efficient technologies available in the market.
- The lack of domestic market for energy efficiency implementing agencies makes investment cost high, the same is imported from other Asian and European countries.
- Due to increased T&D losses of government DISCOs, the EE measures may get delayed due to financial issues. Also, Pakistan DISCOs are more concerned about expanding the distribution network.

3.7.2. Financial Benefits

- The cost of generation in Pakistan is high due to excess dependency on conventional source of energy like gas, oil and coal. The inefficiencies in these plants lead to an increase in generation cost.
- Energy efficiency measures when implemented properly always save energy and money, which will strengthen the financial condition of utilities.

- Pakistan has a proven fossil fuel and coal reserve, but it needs to import gas and oil from gulf countries to meet its energy demand. Increase in efficiency can reduce import of fuel.
- The reduction in T&D losses could increase the revenue of DISCOs and help in strengthening their distribution networks.

3.7.3. Consumer Side Benefits

The increased energy efficiency of generation and distribution system has various benefits for consumers:

- Pakistan, despite being power surplus, faces frequent load shedding in rural areas and areas with high power theft. The energy efficient system will minimize these load shedding incidents and benefit the consumers.
- Due to high tariff rates for commercial and Industrial consumers, commercial losses, like theft, low collection efficiency, are high in Pakistan. Implementation of EE measures will reduce the tariff and subsequently minimize the commercial losses.
- A better and reliable distribution system will help industrial consumers in proper planning of their production schedule and will increase the yield of production and subsequently the revenue.

3.7.4. Social and Environmental Benefits

Social and environmental benefits of energy efficient power generation and distribution in Pakistan are:

- Pakistan has a major share of conventional sources of energy like gas, coal and HFO in its generation mix; the rising inefficiencies in these plant causes consumption of more fuel and emission of excess GHG. The increased efficiency can lower GHG emissions and other pollutants, as well as decrease water use.
- Though the power situation has improved over last 5 years, the unreliable distribution system creates feeling of dejection in the society. This can be prevented by more transparency and building confidence of consumers in the distribution network.
- Increased efficiency of power station will reduce the net-generation cost and the savings in generation cost can be passed to consumers in the form of reduced electricity tariff.
- The efficiency improvement programmes for generation and distribution system will create an ecosystem of energy saving in the nation, which will help society to optimize energy use at their end.
- Pakistan, being one of the leading economies in the world, has a responsibility to reduce their net GHG emissions, this can be achieved by implementation of EE measures in generation and reducing T&D losses in distribution network.

3.7.5. Prerequisites for Implementation

- Pakistan, like other developing countries, relies on financial aid from international agencies for implementing programmes in the country; the government should project more attractive and feasible energy efficiency programmes to these agencies for mobilizing funds for implementation of programmes.
- Pakistan government should invest more on local research and development of energy saving equipment for reducing the cost.

3.7.6. Future Challenges

- The Pakistan power generation is largely dependent on oil and gas-based power generation. A shift in focus of government for coal and renewable source of energy may endanger investment made in increasing efficiency of these power plants. Government must communicate long term plan of energy scenario and generation mix, to ensure private sector's interest in energy efficiency of these plants.
- Due to dependency of importing energy efficiency equipment, there is a possibility of scarcity of spare parts and service support in future.
- With the rising population of the country, there should be planned execution of EE measures.

3.8. Sri Lanka

The power sector of Sri Lanka is majorly managed by CEB and few other private power generating plants and DISCOs. Both the CEB and private power producers generate electricity and supply the national grid. The CEB currently owns all the large-scale hydro power plants, the only coal-based power project and a significant amount of the oil-fired capacity in the country. Apart from generation, CEB is also the only buyer of electricity in the country; it purchases electricity from private Independent Power Producers (IPPs) with whom it has entered into contracts.

3.8.1. Challenges and Barriers

There are various challenges and barriers in implementing energy efficiency measures in Sri Lanka. Some of the key challenges are presented below:

- Years of civil war have adversely affected the financial health of State DISCO and generation plants, which are currently plagued with massive outstanding debts; this makes investment for energy efficiency measures very difficult to implement.
- In Sri Lanka, the hydro power plants normally run in wet and winter season, and during dry season's oil-based power generation plants are used. Due to underutilization of plants, in some cases, the implementation of energy efficiency may become unviable.
- Utilities are not much aware about the latest energy efficient technologies available in the market.

3.8.2. Financial Benefits

Implementing energy efficiency measures to curtail losses in power system can have a huge financial impact on the country. The resulting financial benefits can be:

- Lower cost of generation in Sri Lanka through reduced usage of oil and coal
- Reduced import of fuel and loss of foreign exchange
- Lower tariff achieved by reduced cost of generation, as mentioned above

3.8.3. Consumer Side Benefits

Electricity is one of the main requirements for survival in modern era and efficient generation and distribution of same affects the overall living standard of the community. Some of the benefits of EE measures are listed below:

- Sri Lanka has gap in demand and supply, there is frequent load shedding (2019 & 2020 Sri Lanka electricity crisis), which causes consumers to rely on expensive alternative like DG sets. The energy efficient system will minimize these load shedding incidents and will benefit the consumers.

- The better and reliable distribution system will help industrial consumers in proper planning of their production schedule and will increase the yield of production and subsequently the revenue.
- The efficient distribution network will increase the standard of living of people and will create more employment and commercial activities.

3.8.4. Social and Environmental Benefits

- Sri Lanka has coal as well has oil-based power generation. Increasing efficiency will reduce the GHG emission of these plants.
- Unreliable distribution system creates feeling of dejection in the society as seen during the incidents in 2019 and 2020 electricity crises in Sri Lanka. This can be prevented by improved performance of the distribution network.

3.8.5. Prerequisites for Implementation

There are few prerequisites for efficient implementation of energy efficiency measures as mentioned below:

- There should be proper feasibility study of EE measures before implementation as Sri Lanka has faced failure of such programmes in the past.
- Sri Lanka is dependent on countries like China and India for import of new technologies. For effective implementation of EE programme, Sri Lanka must develop local manufactures and use of domestically available technologies.
- As the country is shifting focus from gas to oil to coal, the capacity of manpower to operate the power plants efficiently is limited. There is a need for capacity building of operators and officials on energy efficiency in their stream (i.e., coal, gas, oil or hydro based generation).

3.8.6. Future Challenges

Some of the challenges faced in implementation of energy efficiency measures are listed below:

- Due to dependency on coal and gas based thermal power stations, which are imported from other counties, there is continuous financial burden on the utility due to fluctuating price of fuel. In absence of funds, EE measures may be difficult for them to implement.
- The demand of electricity in Sri Lanka is largely concentrated in and around Colombo and nearby areas. Hence, implementation of EE measures in other parts of country may be difficult due to high payback period.

4. Recommended Energy Efficiency Improvements

4.1. Best Practices Followed Globally

4.1.1. Power Generation Sector

The bulk of generation in the SAARC Nations is coal-fired thermal, followed by gas-fired thermal and hydropower. These plants are operational in the SAARC Countries with nearly 2-3% less efficiency if compared with the USA (Campbell, 2013). Though these countries have different operating conditions, it can be noted that there is indeed a good potential to build more efficient plants in the SMS. Further, there are also possibilities to retrofit existing power plants to improve their efficiencies.

Table 28 gives a broad level comparison of USA with Sri Lanka and India in terms of power plant efficiencies. There is net variation of 2% for Sri Lanka in its operation of steam cycle coal-based plant with USA and nearly 3% for India. These efficiency enhancements can be achieved by following global best practices. This will not only lead to reduction in capacity enhancement requirements but will also ensure low carbon footprint of the countries.

Table 28 Comparison of efficiencies in power generation

Country	Technology	Fuel	Net Efficiency (%)
United States[30]	Steam Cycle	Coal	33.9
	CCP	Natural gas	44.6
	Various	Oil	34.4
India[31]	All Steam	Coal (All India)	30.1
		Coal (NTPC)	33.3
Sri Lanka[32]	Steam cycle	Coal	31.9
	Combined cycles/ reciprocating engines	Oil	35.6

The efficiency gains in plants of the SMS can be achieved through various ways such as retiring old and inefficient plants and replacing them entirely with latest designs or by improving of some of the components and operating with the best practices. The following subsections will segregate power generation into thermal power using coal, gas and oil, followed by hydro power plants.

4.1.1.1. Best Technologies in Thermal Power Generation

Increasing the efficiency of the fossil fuel plants is an effective way of reducing GHG emissions. Running a coal or gas-based power generator at a higher efficiency has an indirect correlation with reducing the generator's CO_2 emissions. For 1% increase in the efficiency of the power generation setup there is nearly a 2-3% reduction in its GHG emissions (UNECE, 2013). Best practices if deployed by the SMS can collectively lead to GHG emission reductions.

There has been substantial research and development in coal-based power generation. Cleaner and more energy efficient technologies such as supercritical pulverized coal (SCPC) and ultra-supercritical pulverized coal (USCPC) steam generators are being introduced in the new line of power plants.

---

30 (United States Energy Information Administration, 2016)

31 *(Central Electricity Authority, 2016)*

32 (Ceylon Electricity Board, 2015)

There have also been cases where the country has taken steps to replace or retrofit the existing plants with latest and efficient technologies. China, in 2006, implemented a programme named 'Large Substitute for Small' that advanced the existing technologies in the plants with latest technologies and retrofits such as the SCPC and USCPC generators. Table 29 elaborates on the state of art coal fired plants in the world.

Table 29 State-of-art coal plants[33]

Country	Coal Type	Plant type	Efficiency
Canada Genessee 3	Sub-bituminous coal	Genessee 3 supercritical once-through Benson type, two-pass, sliding pressure	41.4%
Japan Isogo New Unit 1	Bituminous coal	Isogo New Unit 1 supercritical once-through, tower type, sliding pressure	42.0%
Germany Niederaussem K	Lignite	Niederaussem K once-through supercritical tower type	43.7%
Denmark Nordjyllandsværket 3	International steam coals	Nordjyllandsværket 3 supercritical, Benson, tower type, tangential firing	47.0%
South Korea Younghung	International bituminous	Younghung supercritical once-through, tower type, sliding pressure	43.3%

Some of the other advanced technologies for power generation from fossil fuel plants are being developed that also offer higher efficiencies and lower carbon emissions. These include: Combined Cycle Gas Turbines (CCGT), Combined Heat and Power gas turbines (CHP), and Integrated Coal Gasification combined cycle plants (IGCC).

There are many methods for improving efficiency of thermal power plants to bring down the generation cost and maximize the generation levels. With this objective in view, several techniques have already been implemented in various parts of the world and some of them are explained next.

Cogeneration and Trigeneration

Cogeneration or Combined Heat and Power (CHP) is primarily involved in utilizing the excess heat generated in a thermal plant. Trigeneration or combined cooling, heat and power (CCHP) refers to the simultaneous generation of electricity and useful heating and cooling from the heat released during the combustion of fuel. Community heating systems, in cold countries, are usually driven from a power plant's condenser heat. Such cogeneration systems can yield theoretical efficiencies above 95% (Power Grid Corporation of India Limited, 2014). By-product heat at moderate temperatures (100–180°C) can also be used in absorption refrigerators for cooling applications. The heat energy can also be used for running a heat operated chiller for comfort cooling and / or refrigeration applications (e.g., aqua ammonia system).

A typical process of cogeneration is presented in Figure 46[34].

[33] *(Economic Commission for Europe, 2015)*

[34] (Power Grid Corporation of India Limited, 2014)

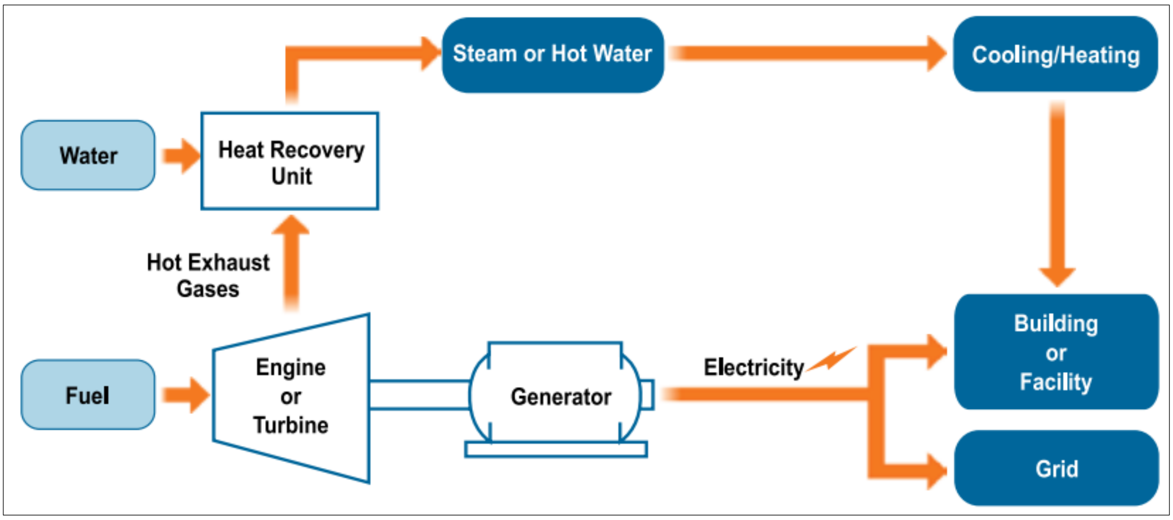


Figure 46 Cogeneration process

Integrated Gasification Combined Cycle (IGCC)

IGCC is an upcoming technology which increases the energy utility of a conventional coal fired power plant. Coal, instead of being combusted as done in conventional pulverized coal fired power plants, is converted into a synthetic gas (or syngas) in an IGCC setup. This high temperature syngas is fed into gas turbines that generate power generation. The heat from high temperature syngas coming out of the gas turbine is further utilized to heat water in order to generate steam, which is used to run steam turbines to generate additional power.

Efficiencies higher than 45% can be achieved in IGCC incorporating the latest 1500°C-class gas turbines with bituminous coals (Power Grid Corporation of India Limited, 2014). Thermal efficiency is the main factor that puts IGCC above the conventional pulverized coal technology (it could go up to 60%). This is a substantial improvement over the 35% efficiency of pulverized coal plants. Furthermore, for each percent increase in thermal efficiency of the plants, there is nearly 2-3% reductions in its GHG emissions. A typical process of IGCC is shown in Figure 47[35].

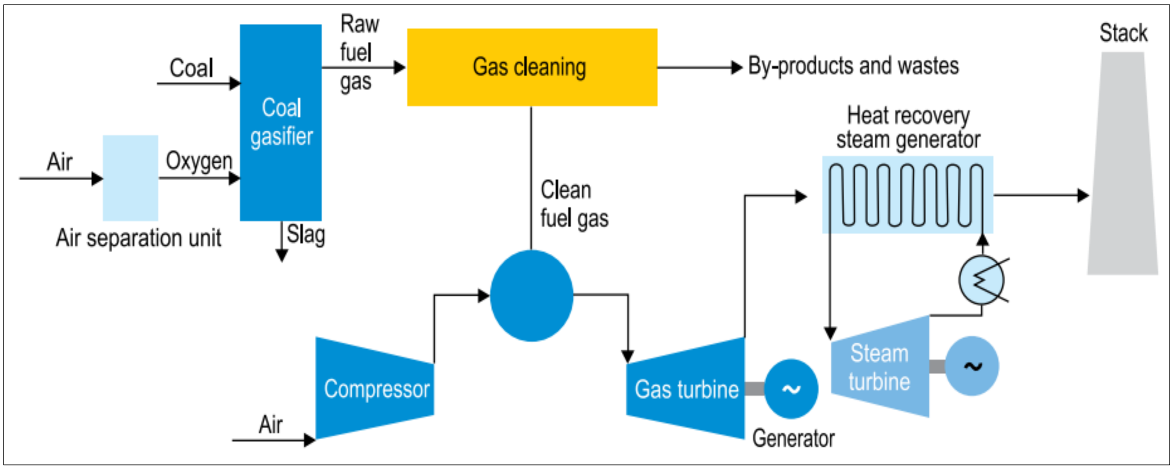


Figure 47 IGCC process

Super Critical Power Plant (SCPP)

Super critical power plants operate above the critical pressure and temperature (221.2 bar, 374.15

[35] (Power Grid Corporation of India Limited, 2014)

°C) of water. Supercritical steam conditions improve the turbine cycle heat rate significantly over subcritical steam conditions. With present supercritical parameters, overall supercritical power plant efficiency of 42% is achievable (Power Grid Corporation of India Limited, 2014). There have been continuous efforts in R&D of this technology over the past 30 years. Advancements in metallurgy and design concepts have made supercritical technology units reliable and highly efficient. Japan and Europe constitute modern super critical technologies for boilers and turbines ranging up to 1,000 MW. Supercritical technology units also offer flexibility of plant operation such as:

- Shorter start up times
- Faster load change flexibility and better temperature control
- Better efficiency even at part load due to variable pressure operation
- High reliability and availability of power plant

Ultra-Super Critical Power Plant

With continuous R&D to increase the efficiency of thermal plants, coal fired power plants have now been progressing to ultra-supercritical (USC) steam conditions. General Electric (GE) Energy has designed the next generation USC steam turbine generator with a rating of 1,000 MW to address the need for higher efficiency coal fired power plants. With inlet steam conditions of 260 bar and 610 °C/621 °C (3762 psi and 1130 °F/1150 °F), the primary objective for the advanced technology USC 1,000 MW steam turbine is high efficiency (Power Grid Corporation of India Limited, 2014). To achieve this higher cycle efficiency, the design utilizes advanced steam turbine technology, system design and a longer last stage bucket design in addition to ultra-supercritical steam conditions.

Advanced Ultra Super Critical Power (USC) Plant

Advanced ultra-supercritical pulverized coal combustion (Advanced USC or A-USC) is a further development of ultra-super critical thermal plants. Use of super-alloys (non-ferrous materials based on nickel) for plant components are required for further raising the pressure and temperature of the steam conditions to those required for A-USC. Though super-alloys have already been established in gas turbine systems, their component sizes in a coal plant are much larger, their combustion situation is different, and pressure stresses are higher as compared to gas turbines. Consequently, new formulations and fabrication methods are necessary.

China, Europe, India, Japan and the United States have taken steps for development of the Advanced USC plants, with demonstration projects planned after 2020. Manufacturers and utilities are working to achieve efficiencies approaching 50% (LHV) and higher by using A-USC steam conditions of 700°C to 760°C at pressures of 30 MPa to 35 MPa. A-USC is expected to deliver a 15% cut in CO_2 emissions compared with super critical technology, bringing CO_2 emissions down to 670 g/kWh (Power Grid Corporation of India Limited, 2014).

Gas Fired Combined Cycle Power Plants

Gas-fired power plants with state-of-the-art gas turbines are highly sophisticated plant and technology concepts offering unmatched excellence in operation, reliability and environmental friendliness. These plants are highly efficient and provide huge resource savings along with reduction in CO_2 emissions. When comparing the efficiency and CO_2 emission levels of gas-based turbines with different types of fossil fuel power plants, gas turbine-based combined cycle power plants are one of the most sustainable, predictable and reliable power generation technology available. It is estimated that CO_2 emissions from state-of-the-art hard coal-fired plants is still 57%

higher than modern gas-fired combined cycle power plants. Gas based CCPPs today achieve efficiencies ranging from 52 to 61% (World Energy Council, 2013).

The best operation and maintenance practices and its corresponding benefits in thermal power plants are presented in Table 30.

Table 30 Best practices in thermal plants[36]

Best practice	Benefit
Specific energy consumption of each equipment is recorded and running and loading preference is given to equipment with less SEC. Root cause analysis is done for the equipment consuming power more than desired and accordingly preventive/ predictive maintenance is planned for rectification of the defect.	• Substantial savings in Auxiliary Power Consumption. • Prevention of equipment from major breakdown. • Maximum capacity utilization of the equipment with lower specific energy consumption
Whenever load schedule is changed, more generation biasing is provided to most efficient unit in terms of response time, ramp rate, heat rate and variable cost to meet the changed schedule and rest load is taken care by other units in merit order.	• Quicker participation in load-frequency control. • Overall heat rate improvement of the generating station. • Stations having low variable cost get maximum schedule and their profitability increases.
Condenser tube cleaning is carried out by high pressure jet or by Congo ball cleaning or by back washing. On-load tube cleaning system is also envisaged which is run on daily basis. APH water washing is carried out in APH hot condition. Normally low-pressure washing is in practice. If differential pressure across APH is quite high, high-pressure washing is carried out.	• Improvement in condenser vacuum • Improvement in turbine efficiency • Improvement in unit heat rate • Improvement in unit generation
Full authority to shift operation executive has been given to take decisions during emergencies in the overall interest of station upholding safety of man and machines as supreme. Shift operation personnel are taking their own decision in case of emergent condition.	• Safety of machine • It prevents further damages
The details of important and critical incidents are being uploaded on LAN for wide circulation and easy reference.	• Easy to search • Knowledge enhancement
To highlight the system deficiency of a particular unit/plant, technical audit is conducted once in every year. System deficiencies are brought into the knowledge of senior officials and a resolution plan is made to resolve the issues.	• Improvement in reliability of the system • Reliable and uninterrupted power generation • Enhancement in safety of man and material
Integrated start-up procedure is developed and followed for safe & smooth start-up of units. Detailed start up procedure of individual equipment is also prepared for ready reference. Dynamic start up curve is developed & followed for taking timely action. Start-up curve is compared	• Comparison of unit start-up with the time period given by the manufacturer curve will help in improving start-up practices and will help in start-up cost optimization and increased generation

[36] (NTPC India, 2018)

Best practice	Benefit
with designed curve and deviation is analysed for improvements. Turbine rolling is done through ATRS keeping desired TSE margin.	
Furnace temperature is measured by using Infrared thermometer/ optical pyrometer/ HVTC for optimization of boiler combustion & efficiency.	• By maintaining design furnace temperature, problems like clinker formation & ash build up will be minimized by taking timely action and ultimately unit forced outage will be avoided.
Boiler tube leakage is major forced outage of boiler. Delay in leakage detection leads to severe secondary damage and generation loss.	• Online tube leak detection system is installed in boiler at various locations that helps in detecting boiler tube leakage at earliest. It sends sound signal in unit control room that is confirmed by unit operating personnel
Use of contact-less type temperature sensors that are installed in high energy drains valve to detect passing through valves and values are displayed in control room for taking action plan for any deviation in temperature.	• It will help in early detection of valve passing and prevent erosion of valve seat. Early action will lead to improvement in heat rate.
Steam dumping is done during unit start-up to achieve quick chemical parameters for turbine rolling and subsequently load raising by maintaining low silica level in boiler water.	• This practice helps in maintaining parameter quickly for turbine rolling and quick unit loading during unit start-up.
HR & APC are calculated and displayed online in control room through packages like TLA, PADO and PI server application for continuous monitoring and improvement.	• Improvement in HR & APC will help in improving merit order rating and also earning carbon credits that can be traded.
During the Gas Turbine shutdown, Air Curtains (Plastic) are provided at Air Intake filter house by fixing them inside of the bird screen. These protective curtains can be easily fixed and removed to save time.	• Prevent dust ingress • Ensure higher life of Air Intake Filters • Less choking of filters • Reduced cost
Infrared Thermography is regularly carried when HRSG is in operation and all the leakage points mapped which have occurred to cracks in the plate or expansion bellows. These leakage points are attended in the next opportunity shutdown.	• Timely identification of leakages • Reduced heat loss and better heat transfer inside HRSG • By timely welding/repairing of duct/bellows, major cracks can be prevented
After ensuring reliability of these pumps, now only one CWP, CEP, HPBFP and LPBFP are run in case of half module operation.	• Reduced APC • Reduced running hours of Pumps • Reduce wear and tear • Enhanced life of equipment

The areas with potential for energy efficiency improvements in thermal power plants are presented in Table 31.

Table 31 Potential areas for energy efficiency improvement in thermal plants[37]

Potential areas	Description of process
Air & flue gas cycle	• Optimizing excess air ratio: It reduces FD fan & ID fan loading. • Replacement of oversized FD and PA fan: Many thermal power plants have oversized fan causing huge difference between design & operating point leads to lower efficiency. Hence, fan efficiency can be improved by replacing with correct size of fan. If replacement is not possible, use of HT VFD for PA & ID fan can be the solution. • Attending the air & flue gas leakages: Leakages in air & flue gas path increases fan loading. Use of thermo vision monitoring can be adopted to identify leakages in flue gas path. Air pre-heater performance is a crucial factor in leakage contribution. If APH leakage exceeds design value, then it requires corrective action.
Steam, feed water and condensate cycle	• BFP scoop operation in three-element mode instead of DP mode: In three-element mode, throttling losses across FRS valve lead to reduction in BFP power. • Optimization of level set point in LP & HP heater: Heater drip level affects TTD & DCA of heater, which finally affect feed water O/L temp. Hence, it requires setting of drip level set point correctly. • Replacement of BFP cartridge: BFP draws more current If cartridge is worn out, causing short circuit of feed water flow inside the pump. It affects pump performance. Hence, cartridge replacement is necessary. • Attending passing recirculation valve of BFP: BFP power consumption increases due to passing of R/C valve. It requires corrective action. • Installation of HT VFD for CEP: CEP capacity is underutilized and there is pressure loss occurs across Deaerator level control valve. There is large scope of energy saving which can be accomplished by use of HT VFD for CEP or impeller trimming.
Fuel & ash cycle	• Optimized ball loading in Ball tube mill: Excessive ball loading increases mill power. Hence, ball loading is to be optimized depending upon coal fineness report. • Use of Wash Coal or Blending with A-grade coal: F-grade coal has high ash content. Overall performance can be improved by using Wash coal or blending of F-grade coal with A- grade coal instead of only using F-grade coal. • Avoiding idle running of conveyors & crusher in CHP • Use of Dry bottoms in ash handling instead of Wet bottoms: Dry system uses no water and results in lower coal usage which in turn produces reduced emissions. • Optimize mill maintenance: Mill corrective/preventive maintenance is to be optimized depending on parameters like running hours, mill fineness, bottom ash unburnt particle, degree of reject pipe chocking etc.
Electrical & lighting system	• Optimizing voltage level of distribution transformer: It is found that operating voltage level is on higher side than required cause insulation failure. It is required to maintain the voltage level up to an optimum level. • Use of Auto star/delta converter for under loaded motor

[37] (Awale, 2020)

Potential areas	Description of process
	• Lighting: Use of LEDs and replacement of mercury vapor lamp &metal Halide lamp with LED lights. Use of timer for area lighting is the methods can be used.
ECW & ACW system	• Isolating ECW supply of standby auxiliaries: Many times, standby coolers are kept charged from ECW side. Also, standby equipment's auxiliaries like lube oil system kept running for reliability. We can isolate standby cooler from ECW system & switch of standby auxiliaries, doing trade-off between return & reliability. • Improving condenser performance by condenser tube cleaning & use of highly efficient debris filter: Tube cleaning by bullet shot method increases condenser performance. Condenser tube cleaning is necessary which is to be carried out in overhaul. Also, highly advanced debris filter contributes condenser performance. • Application of special coating on CW pump impeller: It improves pump impeller profile condition thus increasing pump performance.
Compressed air system	• Optimizing discharge air pressure by tuning loading/unloading cycle: It is helpful in reducing specific power consumption. • Use of heat of compression air dryer instead of electrically heated air dryer: Heat of compression type air dryer uses heat generated in compression cycle for regeneration of desiccant, thus the heat of air can be utilized, and this will reduce overall specific power consumption of compressor. • Use of screw compressor instead reciprocating compressor: Specific power consumption of screw compressor is less than reciprocating air compressor, which will lead to reduction of auxiliary power consumption.
HVAC system	• Cooling tower performance improvement • Installing absorption refrigeration system instead of vapor compression system • Use of wind turbo ventilators instead of conventional motor driven exhauster

4.1.1.2. Best Technologies in Hydropower Generation

Pumped Storage Hydropower

Hydropower is a renewable source of power generation. Scientifically, hydroelectric power generation relies on the law of conservation of energy where kinetic energy that resulted from the movement of the mass of water from the reservoir is converted into electricity, the quantum of which depends on multiple systemic variables viz: plant efficiency, volumetric water flow through the turbine and the head of the water from the water surface to the turbine.

The pumped storage set-up is presented in Figure 48[38].

[38] (Ajibola, Ajala, Akanmu, & Balogun, 2018)

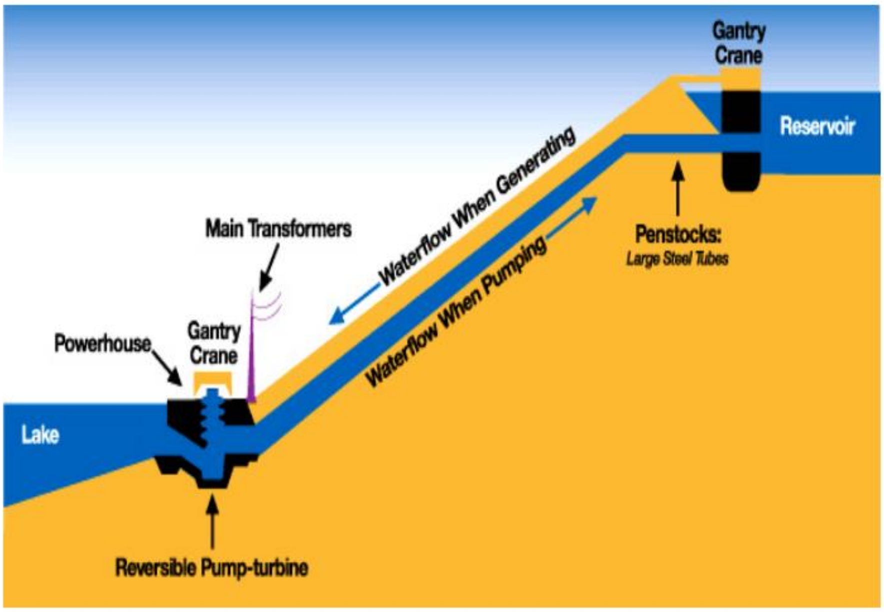


Figure 48 Pumped storage hydro setup

Among the SMS Nepal, Afghanistan and Bhutan are highly dependent on hydropower for their power generations. Pumped hydro storage is being practiced in USA and other developed nations. The operating principle of a pumped storage hydro power plant is very basic wherein two reservoirs at different altitudes are required (one above the turbine the other below it). Energy is created by the down flow when the water is released from the upper reservoir, which is directed through high-pressure shafts linked to turbines. The turbines power the generators to create electricity. The pumping of water from lower reservoir to upper reservoir takes place during off-peak hours of the demand cycle, meaning that the plant can use inexpensive surplus power to pump water and then reclaim the stored energy to match higher demand during peak periods. To achieve this, water is pumped back to the upper reservoir by linking a pump shaft to the turbine shaft using a motor to drive the pump. The excess electricity generated from the hydropower plant is used to power the pumps. However, the gains of the process can be obtained from the efficacy and the efficiency derivable from the recurrent process (Ajibola, Ajala, Akanmu, & Balogun, 2018).

Pump storage generation offers a critical back-up facility during periods of excessive demand on the national grid system. There have been R&D activities being carried out which have directed towards the development of reverse-engineered conventional pumps that can be used as hydraulic turbines. Table 32 presents the best maintenance practices in hydro power plants.

Table 32 Best maintenance practices in hydropower[39]

Area	Practice
Water Intake, Water Conduit System and Associated Equipment	• Periodic physical inspection of water conductor system from inside as well as outside to know its condition, silt deposition, rusting/erosion of conduit system is very much essential to find out various changes due to ageing factor, stresses developed due to water hammer etc. • Purification and frequent testing of hydraulic system oil should be carried out as per recommendations of the manufacturers. • Cavitation & erosion at top portion due to rushing of air during fill up • Inspection schedule for the durability of anticorrosive paints used

[39] (Central Electricity Authority, 2020)

Area	Practice
	• Replacement schedule for various vulnerable parts such as bends, open conduits etc. • Due to humidity, open conduit deteriorates from outside. As such inspection & cleaning to be carried out at regular intervals. • Anticorrosive-painting schedules should be followed. • Timely Operation & Maintenance of the cranes & hoists • Healthiness of control & protection for isolating gates/valves & for cranes/hoists • Maintenance of trash-rack/intake gate filter • Maintenance of communication systems, availability of power supply, equipment for emergency operations, approach roads etc.
Turbine & its Auxiliaries	• Regular inspection of runners of turbines should be carried out and record to that effect should be invariably maintained. Best efficiency microprocessor based digital PID speed governors provide fast response should be used. • Periodical maintenance of speed governors along with all associated mechanical, electrical, electronic component should be carried out. • The control circuit should be neatly dressed in identification marks. • The electronic components and cards should be carefully maintained at appropriate temperature level to achieve desired performance. • Periodic calibration and testing of transducers, meters etc. • Polishing of the various under water parts of the turbines once in a year to minimize the white pitting • Inspection & testing of the runners from experts to decide residual life so as to initiate action for procurement of runners for replacement • Inspection of labyrinth seals in case of reaction turbines • Painting of runner housing with anticorrosive tar-based paints • Applying anti-erosion coating to the runner • Checking of brake jet operation in power stations having Pelton turbines once in three months • Purification of hydraulic oils by centrifugal, electrostatic liquid cleaner • Periodic maintenance of the servo valves and motors after carrying out inspection of the pistons & housings of the servo valves and motors for their worn-out parts; replacement of the leaking seals • Survey of the component failure & procurement of the same and maintain minimum inventory
Generator & its Auxiliaries	• Proper cooling system is to be maintained to limit rise in stator winding temperatures and consequently increase the life of stator winding. • Inspection of the stator winding is also required to be carried out to verify its firmness in stator core slots and healthiness of overhang portion with firm end winding caps & end spacers, slot wedges checked for healthiness. • Periodic checking of the foundations and tightness of the bolts; filling the foundations with epoxy • Vibration check should be performed periodically & in case of any misalignment historical data should be consulted for guidance on

Area	Practice
	realignment, looseness, unbalanced electrical components, increase in bearing gaps, coupling misalignment, uneven stator-rotor air gap etc. • Periodic cleaning or replacement of the generator air coolers and bearing oil coolers to improve performance of the generator • Primary and secondary testing of the protection system for its healthiness and correct operation • Inspection of the CTs, PTs and bus bars for overheating, temperature rise • Inspection of circuits for protection & control circuits • Mock trials of the firefighting system along with evacuation system; checking weight loss of the CO_2 cylinders and replenish as per recommendations of OEM.
Transformer & Switchyard	• Continuous monitoring of oil & winding temperatures • Periodic oil filtration • Oil testing for various tests and Dissolved Gas Analysis • Tan-delta & insulation resistance etc. as per schedule • Cleaning and replacement of radiator fins oil cooler • Testing protection system for healthiness • Mock trials of checking, maintenance and inspection for Firefighting system, CO_2 & MulsiFyre system • Tests for operation time of the breaker • Operation & testing of isolator opening & closing • Checking of control circuit & healthiness of operating system of the breaker; periodic cleaning of transformer bushings & insulator strings • Switchyard are to be kept neat & tidy. Minimum area surrounding the yard to be free from growth of scrubs and bushes to avoid any bush fire damaging the equipment.
Emergency D. G. Set	• Regular maintenance of the emergency set; checking of control & protection system; running of DG set at regular intervals.
Other P. H. Equipment	• Periodic maintenance of unit auxiliary, station auxiliary & station service transformer • Checking healthiness of station batteries & battery chargers; the two charges should be rotated once in a week. • Regular inspection of cable ducts to ensure proper ventilation / heat dissipation; checking the healthiness of pressure relief valve, if provided.

4.1.2. Power Distribution Sector

As can be seen in chapter 2, the SAARC Nations have distribution losses much greater than the global standards. The generated electricity does not reach the consumer entirely and these losses in the distribution network put burden on the existing capacity on generation side and increased tariff on consumer side.

Table 33 maps the potential of few measures for improving energy efficiency along with their impact on losses. The table provides a two-dimensional view, such that along with depicting the applicability of each measure on different voltage levels, it also shows the effectiveness for loss reduction when the measure is applied. This combination of these two dimensions allows to make an estimation of the potential, e.g., measures of low effectiveness but of high applicability would rank low on potential.

Table 33 Mapping of energy efficiency measures against their effectiveness[40]

			Applicability		Effectiveness			
			Distribution Networks		Technical Losses			Non Technical Losses
					Variable		Fixed	
			LV	MV	Marginal	Reactive		
Component replacement	EE Transformers		+++	+++	++		+++	
	Increase Line Cap.	Increase Diameter	+	+	+++	++		
		HTS		+	+++	++		
	Increase Voltage level			+	+++	+++		
Feed-in Control	DG	VRES	++	++	+			
		Contrl. (m-chp)	++	++	++			
	DR		+++	+++	+++			++
	Energy Storage		+	+	+++			
Grid Management	Network Mgmt	Trafo Switching	++	++	+	+	+++	
		Network reconf.		++	++	++		
	CVR		+	+	++			
	Voltage Optim.	Reactive comp. devices	++	++		++		
		Smart Trafos		++		+++		
		DER Volt. control	++	++		+++		
	Balancing 3ph loading		+++		++			

Smart Metering and Demand Side Management

One of the common approaches, followed by loss making utilities to become financially sustainable, is implementation of smart metering and demand side management in their infrastructure. Management of peak load is a key factor for efficient distribution of power. The solution is to reduce demand through demand-side management and implement variable pricing models for peak and off-peak hours (TOU/TOD), which can be achieved through Smart Grid (digital metering). Smart Grid is the way forward in electricity distribution systems, it delivers electricity to consumers using two-way digital technologies & ICT for efficient management of consumer end usage of electricity. In addition, it also incorporates efficient use of the grid to identify and correct supply-demand imbalances instantaneously (Power Grid Corporation of India Limited, 2014). Some of the key enabling intelligent technologies which are building blocks of the Smart Grid are given as under.

[40] (Tractebel Engineering and Ecofy, 2015)

Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure (AMI) is system that measures, collects, transfers and analyses energy usage and communicates with metering devices either on request or on a schedule. It helps in reducing the AT&C losses and facilitates in demand side management & demand response, load disconnection / re-connection, outage management, power quality management etc.

The energy consumption data from distribution transformer (DT) and customers is shared with the control centre at a defined time, which could be audited to regulate theft & pilferages or further assessed for automatic billing. AMI meters can also be used to gather various signals for demand response, load dis/re-connection, operation of critical & non-critical loads. Alerts can also be sent from control centres to customers and vice-versa. Implementing AMI infrastructure can help in percentage reduction in losses due to theft from meter to reach up to 100%.

Demand Side Integration

Demand side integration is an effective measure to manage the demand of electricity during peak hours of the day. This can be done by maintaining an ecosystem with the use of smart meters and load management software. The use of demand side integration can help a DISCO in improving the power quality, reducing the peak load and load curtailment.

Outage Management System (OMS)

Outage management systems are the set of software, which assist the power distribution utility by alerting them in case of any outage in the system. They also record the history of outages throughout the operations and provide real-time insight into the systems. OMS systems also provide customer assistance by alerting them about outages and status of repairs. OMS systems usually work in combination with GIS (geographic information systems), customer information systems and call handling systems such as IVR.

Energy Efficient Transformers

Inefficient transformers installed in power systems are responsible for both variable and fixed losses in the system and their replacement is easier than changing cables or lines. Although energy efficient transformers are expensive, their deployment presents a good loss reduction potential and affects almost all factors of losses. A typical transformer has about 20-25 years of lifetime before it becomes inefficient and causes high power losses. After this tenure, they should be replaced with an efficient transformer in order to curb power losses. The replacement strategy for a transformer is dependent on the state of the population, characterized by the age, size and type of transformers.

Improving Power Factor using Automatic Power Factor Controller

Power factor can be improved by adding power factor correction capacitors in the distribution system. Some of the key advantages of PF improvement are stated below:

- Reactive component of the network is reduced and so is the total current in the system from the source end.
- I^2R power losses are reduced in the system because of reduction in current.
- Voltage level at the load end is increased.

- kVA loading on the source generators, as also on the transformers and lines up to the capacitors, reduces giving capacity relief. A high-power factor can help in utilizing the full capacity of your electrical system.

Increasing Line Capacity

Variable losses can be reduced by increasing the cross-sectional area of cables. Typically, doubling cable rating leads to a reduction of losses by a factor of four. However, once a cable is installed, it becomes expensive to make alterations to the cable, since civil works cost element of replacing a cable outweighs any loss reduction benefits. The key opportunity to reduce losses therefore exists at the time that the cable is initially installed or replaced. An alternative approach is to make use of high-temperature superconductors[41] (HTS) which present no resistance when they are cooled down at -180°C and can carry five times the current of a conventional cable system with the same outer dimensions. The losses from this system are due to the energy needed to operate the cooling mechanism.

Implementation of IT Application in Metering, Billing and Collection Activities (AMR/HHD/e-mail, SMS based intimation)

Fully automated metering, billing and collection systems like AMR or semi-automated systems like handheld devices for meter reading help to minimize meter reading error, billing time and increase collection efficiency leading to less commercial losses. Customer engagement and relationship management through modern communication mediums like email and SMS create enhanced customer service.

Implementation of IT Application in Network Management Activities

IT Packages like Distribution management system (DMS), outage management system (OMS) or SCADA system helps the operation team to be updated with real time network situation and performance. These are essential requirements for distribution utilities to monitor network, plan activities, mobilize workforce in time to reduce network failure or down time. It also helps utilities to build a comprehensive zero information leakage operational system to meet and exceed customer satisfaction and optimize cost and time. IT applications like these help operation team to identify any loss or leakage in the system through automatic and fast system and helps to reduce losses.

Strengthening of Energy Accounting Infrastructure - Feeder Metering, DT Metering & 100% Consumer Metering

To reduce losses, the first step is to identify loss level. Energy accounting is the fundamental measurement process to identify electricity losses in a distribution system. For implementation of proper energy accounting, measurement and recording of energy consumption is required at different levels of network. Starting from 100% metering at consumer end to DTs, feeders should be covered to identify any technical and commercial losses across the network. Meter data management system (MDMS) is a central database of meter readings and a layer of meter data analytics on top of this MDMS can be of great help to identify loss of electricity at different levels.

Replacement of Defective Meters and Electromechanical Meters

There are different generations of electric meters, starting from electromechanical to modern day

[41] *The indicative cost for high temperature superconductor is around USD 50 per kiloamp metre.*

smart meters. The purpose of meters has been changed from merely recording only energy consumption to storing other useful information like electric parameters and communicating them back to central remote database. Old electro-mechanical meters are maintenance heavy and not suitable to be a part of automatic metering infrastructure. All defective meters and electro-mechanical meters if replaced by modern digital meters or by smart meters, will help to increase transparency over the meter data and smooth operation for a DISCO.

Management Information System (MIS) Based Periodic Reporting of Unit-wise Business Parameters

Identification and monitoring of key business parameters are required to gauge the health of the utility. Further, to get a true picture, correct recording of data is utmost important. A robust MIS can help to record correct data and report the business parameters including loss figures on a regular frequency.

Consumer Communication on Loss Reduction

Proper communication of the plans to the consumers in general is crucial in order to increase public participation and contribution towards the heath of a utility. Public outreach programmes or communication programme through media ads, posters, and videos can help in disseminating information related to penalties in case of theft/meter tampering among the consumers.

Customer Feedback Programmes

Initiatives linked to consumer analysis and feedback indirectly help in loss reduction through faster collection of data/feedback about possible problems in the network. Initiatives like setting up of Interactive Voice Response System (IVRS), Toll Free numbers for consumer complaints, mobile alerts through SMS etc. are some of the examples of customer feedback programmes. Consumer Analysis Tool (CAT) are used to monitor the metering, billing and collection of consumers to identify revenue leakages.

Case Study of Brazil: Various initiatives undertaken by DISCOMs

On a basis of a study conducted by joint collaboration of the US Agency of International Development (USAID), the International Copper Association, and AES Eletropaulo, an electricity distribution company in the region of Sao Paulo in 2006. On careful examination of the causes leading to losses in the system, it was discovered that the losses were basically due to degraded network entailing to electricity theft, higher distribution losses and completely zilch collection efficiency. A substantial number of technical and nontechnical loss initiatives were adopted that can be summarized as follows:

Technical Loss Reduction

- Upgradation of existing distribution system and service infrastructure of the concerned area,
- Installation of twisted and bi-coaxial cables with new connections,
- Replacement of the twelve conventional overloaded transformers with more efficient and reliable transformers.

Nontechnical Loss Reduction

- Waiving off of initial upfront fee for new consumers;
- Setting up of price capped low-income tariff for economically weaker section;
- Assisting consumers to prove their eligibility to receive the low-income tariff;
- Capping the billed consumption until consumers of the section had been regularized;
- 100% metering in the area for all categories of consumers;
- Installing electronic meters for proper recording of energy consumption and controlling electricity theft
- Conducting awareness drives wherein the consumers were provided with benefits like efficient light among others.

Impact

Financial analysis of the results from the perspectives of the company and the consumer provided a measure of the overall impact of the project. The main takeaways of the project were regularization of consumers, successful implementation of energy efficiency measures and creation of new physical infrastructure in the pilot area. The key benefits achieved were:

- Substantially improved revenues due to improved collection efficiency virtually going up from 0% earlier to 68% after regularization;
- Reduction in average electricity consumption within the pilot area to the tune of 40%;
- Reduction in costs to company due to timely payment of electricity dues;
- Reduction in expenditure incurred on account of power purchase;
- Conversion of consumers to metered and paying customers which enabled the utility to collect the low-income subsidy component of the tariff from the Government.

Case Study of Iran: Various initiatives undertaken by DISCOMs

The Electricity Distribution Sector of Iran was facing a tough time with high electricity distribution losses during early 2011. It was observed that the technical losses were primarily due to poorly designed transformers, transmission and distribution lines and presence of large area under low voltage network. Further nontechnical losses were identified majorly due to electricity theft, non-payment of bills by customers, errors in accounting and record- keeping.

The activities implemented for reduction of technical and nontechnical losses have been summarized below:

Technical Loss Reduction Initiatives

- Removal of low voltage network: High Tension line was extended nearer to the consumer premises.
- Utilization of pad-mounted transformers: Higher KVA transformers were replaced with lower value pad mounted transformers (Transformer locked in a steel cabinet and placed over a concrete pad)
- Installation of shunt capacitor banks: For Power Factor Correction and reduction of reactive power present in the system.

Nontechnical Loss Reduction Initiatives

- Implementation of AMI system: Installation of smart meters for recording of real time data.
- Implementation of automatic reading of meters: For capturing consumption details and reducing the cost of the billing system.
- Load Management: Ability to turn on and off meters from data management centre.

Case Study of Oman: Various initiatives undertaken by DISCOMs

A pilot loss distribution strengthening project was undertaken by Mazoon Electricity Company (MZEC) which was further extended to the other distribution utilities of the Country. The project aimed entire value chain of distribution sector for reduction of losses and achieving efficiency gains. The loss reduction programme was envisaged across the following aspects:

- Augmentation of existing substation capacity
- Creation of additional sub- station to cater to future demand in long term
- Network reconfiguration and load balancing

The activities implemented for reduction of technical and nontechnical loss under this programme are summarized as follows:

- Adding of new transmission lines with appropriate size conductors to reduce system overloading
- Installing EHV network (Extra High Voltage Networks)
- Revising design specifications/material considerations and loading guidelines for procurement of distribution transformer
- Developing operational guidelines for improved management of distribution transformers
- Conducting low-loss distribution transformer research
- Installing of smart meters at consumer level for real time monitoring and timely meter reading;
- 100% Metering at all levels i.e., at the feeder level as well as the consumer level
- Engaging the community by holding various community meetings and workshops in order to create awareness among people and curbing theft of electricity.

4.1.3. Policy and Governance

Technical Standards for Conductors and Transformers

A very effective measure that leads to an overall improvement in efficiency is setting mandatory standards on a country level. In such cases, the national regulatory design should allow a higher CAPEX allowance to grid operators as savings in OPEX will over-compensate them in the long run.

Financial Incentives

In general, financial incentives to increase efficiency can be of various forms, e.g., grants, loans or tax breaks. They can also be set via lower interest rates for energy-efficient investments. To further motivate and simplify investments, specific energy-efficiency budgets can be set up. Given that the transmission and distribution networks are regulated industries, the most appropriate way to deliver financial incentives would seem to be via the existing regulations. Another option regulator can use is setting individual targets of network losses for the grid operators which can be a mechanism that financially penalises or rewards deviations from the target. This can be a strong incentive for the grid operators to improve operational performance while leaving them free space to decide on the most effective measures.

Obligation or Certificate Schemes

With obligations or certificates for energy efficiency and energy savings, the grid operators are given specific shares of losses (and savings) that they have to meet, just like the option of financial incentives. In many schemes, there is also the option to trade certificates to meet the obligation. In case of not conforming to the obligation, penalties (financial or not) can be set to promote actions to meet the obligation which is a key difference to financial incentives.

Voluntary Agreements

Regulators can start by setting voluntary agreements with grid operators which would comprise non-binding guidelines e.g., for a maximum share of grid losses in power transmission and distribution. It can acquire the market participants’ attention on the issue and provide alignments on grid operation.

Loss Level Based Tariff Design:

Different consumer categories or different areas contribute different proportions to the overall loss level of the utility. Therefore, the tariff design for these consumer categories should also depend on their respective loss levels and in turn, on the cost of supply to the respective consumer category or respective area.

Introduction of Private Participation - DF Initiatives/ Privatization:

The emerging trend of countries privatizing a part of their distribution business, while retaining the ownership of assets, has proved successful in reducing losses and infusing much-needed capital in reviving ageing infrastructure. This electricity distribution franchisee (DF) model is structured such that the DF receives power supply from the state DISCO at designated input points and pays an annual rate for this energy input. The DF has to achieve a minimum reduction in transmission & distribution (T&D) losses and increase collection efficiency. It is then permitted to keep the revenue collected from consumers.

4.2. Comparison of Efficiency with Similar Country

SAARC Countries are well endowed with natural resources including estimated hydro power, coal reserves, natural gas reserves complimented with large renewable potential of Wind, Solar as well as Biomass. Despite all these factors, the SMS still face acute shortage of electric power leading to frequent black outs. The energy efficiency of power systems in SAARC Nations can be improved by improving operating practices, retrofits to existing systems and by incorporating new technological advancements.

Improving the efficiencies of existing generation and distribution setups of the SMS can help them reap benefits in terms of increased generation of existing capacity, reduction in GHG emissions, reduction in energy import and many others.

4.2.1. Generation

The generation setup of the SMS mostly comprises of coal based thermal plants, gas based thermal plants, hydel power generation and IC driven engines. A comparative analysis of the generation efficiencies will elaborate on the energy saving potentials of the Member States.

4.2.1.1. Coal Based Thermal Plants

There has been a lot of R&D done on coal based thermal plants over the years. With efficiencies as high as 47% of a coal-based plant, the SAARC Nations are behind the best available technology internationally (As discussed in the above sections, Denmark Nordjyllandsværket 3 supercritical, Benson, tower type, tangential firing power plant has reported an efficiency of 47%).

Amongst the SAARC Nations, India, Pakistan and Sri Lanka are the main users of coal to feed their thermal powered plants. According to GE Global Power Plant Efficiency Analysis 2015, it was observed that the overall world average for coal fired thermal power plant was 34% for the year 2015. The average of India was 27% for the same year as compared to USA and Japan which ranged at 37%. Sri Lanka's average thermal power plant efficiency came out be 31%, more than India as well (Ceylon Electricity Board, 2019). Even though India has technologically advanced power plants than Sri Lanka, the average efficiency is less because Sri Lanka only has one coal fired plant installed as opposed to numerous in India. Figure 49[42] elaborates on the variance in plant efficiencies.

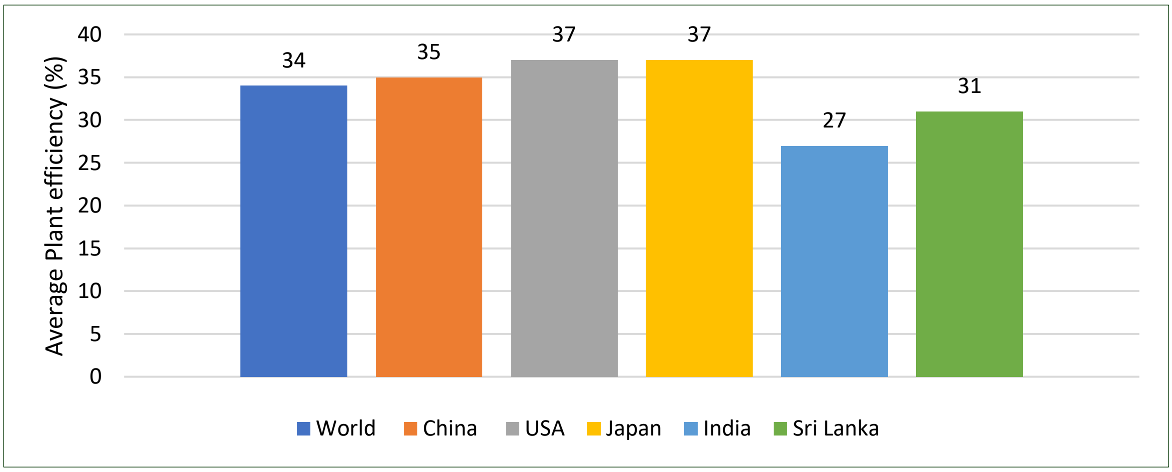


Figure 49 Average plant efficiency of coal based thermal power plant

[42] (General Electric, 2015)

4.2.1.2. Gas Based Thermal Power Plants

Gas based thermal power plants have efficiencies much higher than coal based thermal power plants, with highest efficiencies going as high as 50% in combine cycle gas plants.

Amongst the SAARC Nations, Bangladesh's generating system is dominated by gas-fired power plants. Most of the generation is either gas-fired open cycle combustion turbines or gas-fired reciprocating engines. These types of power plants report efficiency in the range of 30% (open cycle) to 42% (reciprocating engine), whereas the combined cycle technology, exceeding an efficiency of 50% when fired on natural gas, is well established. Moreover, Pakistan, Sri Lanka and India are now seeing an increased use of gas based thermal power plants in their generation mix.

The average power plant efficiency of gas based thermal power generators is around 39% (General Electric, 2015). The average of India, according to the same report, was 45%. According to Sri Lanka's long-term expansion Plan, the efficiency of its gas-based turbines is still 27% (Ceylon Electricity Board, 2019). It can be inferred that Sri Lanka's gas based thermal power generators are way behind in achieving energy efficiency in their generation. Further, the highest efficiency gas-based plants belonging in Japan and USA with efficiency of 48%. Figure 50[43] elaborates on the variance in gas power plant efficiencies.

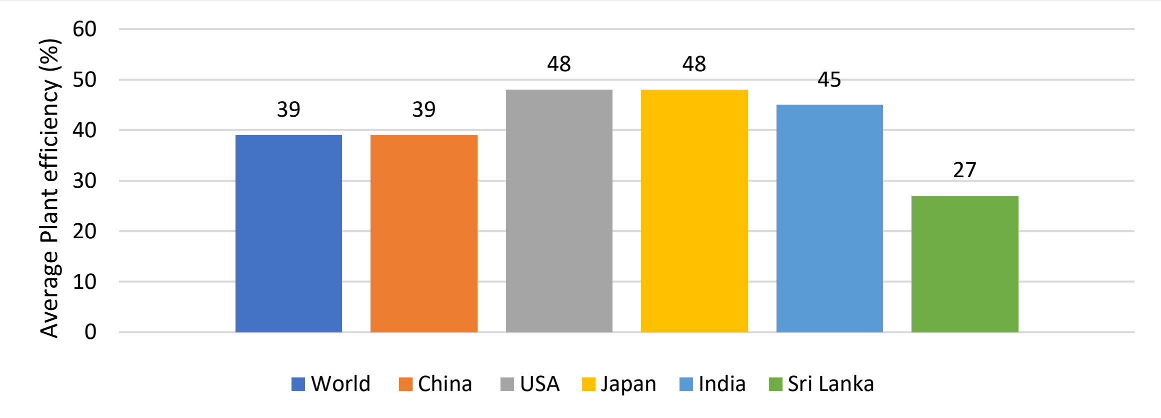


Figure 50 Average plant efficiency of gas based thermal power plant

4.2.1.3. Hydro Power Generation

Both Bhutan and Nepal exclusively are predominated by hydro power in their generation mix. As discussed in the above sections, hydro power has best practices which can be followed to get maximum efficiency from the installed capacity. Moreover, Afghanistan - which is mostly import oriented for its electricity needs - generates a certain amount of electricity from its domestically installed hydro power stations. Major hydro power-based generation are available in India, Pakistan and Sri Lanka as well.

Both Nepal and Bhutan export electricity and are incorporating energy efficiency measures in their generation sector. Opportunities do exist in hydropower plants to improve their efficiency, in particular in the old power stations, with technology interventions and operating practices.

4.2.1.4. Diesel Engines

Maldives Islands exclusively use diesel engines for their power generation. In these island power supply systems, diesel engines generating power operate at part-load conditions most of the time, hence their operating efficiency is poor. In addition, poor maintenance has led to inefficiencies in

[43] (General Electric, 2015)

some of the remote islands. Other than Maldives, there are various regions in the SMS which operate on captive power generators, which is mostly diesel-based generators.

Better O&M practices of these diesel engines are essential to maintain the performance of diesel generators at the end use. Poorly maintained generators emit vastly larger amounts of soot and other pollutants, making the case of regular O&M procedures even stronger. An improvement of nearly 7% can be observed in diesel engines which up take regular O&M practices.

4.2.2. Distribution

Distribution losses of the SAARC Nations are discussed in depth in the previous sections. The SAARC nations have very contrasting profiles in their distribution infrastructure. The SMS like Afghanistan with T&D loss ranging from 40% to 42% whereas Bangladesh and Sri Lanka with T&D losses nearing 8%.

A comparison of distribution losses in India and Pakistan with advanced countries is shown in the Figure 51[44]. It is apparent that the distribution losses in India and Pakistan are very high compared to other developed countries including a neighbouring country, China.

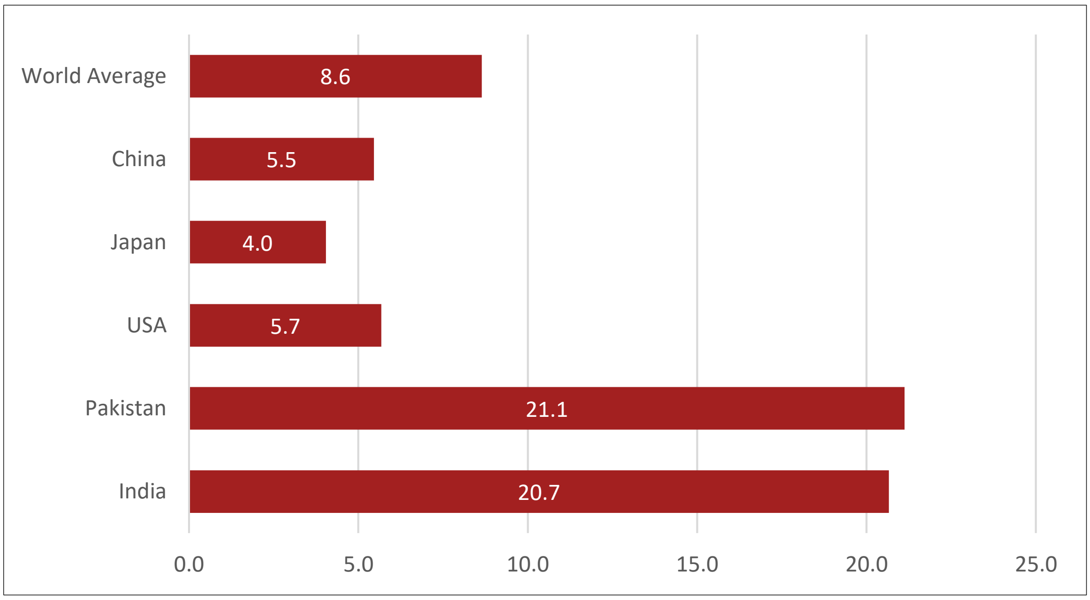


Figure 51 Comparison of distribution loss for India and Pakistan with developed countries

4.3. Efforts in Hand

4.3.1. Afghanistan

Afghanistan is highly dependent on donor agencies such as World Bank, USAID, ADB, etc. for upgrading its power sector. There are various ongoing sector assessment studies, roadmaps and strategies being developed by these agencies in cooperation with the Government of Afghanistan. Some of the key pipelined projects are (UNECE, 2016):

- CASA 1000: 1,300 MW from the Northern neighbours to Pakistan through Afghanistan, 300 MW will be used in the country.
- Aynak copper mine: Chinese company (MCC) will exploit the coal mine in North Hindukush and build coal power plant - projected capacity is 400 MW

[44] (Central Electricity Authority, 2020; NTDC, 2021)

- Mazaar Gas Plant: 50 MW gas power plant supported by IFC/WB
- TAPI: Turkmenistan, Afghanistan, Pakistan and India Gas pipeline
- TUTAP: Turkmenistan, Uzbekistan, Tajikistan, Afghanistan and Pakistan – Interconnection
- TAP 500: Turkmenistan, Afghanistan and Pakistan 500 kV TL project

Afghanistan has also rehabilitated its largest hydro power plant Naghlu hydropower plant through a Russian company, contracted to do the work on the Naghlu Hydropower Rehabilitation Project (NHRP) under DABS' supervision. The rehabilitation of this plant has increased the reliability and efficiency of power generation by these plants.

Afghanistan is geographically blessed with solar power. There are nearly 300 days where there is bright sun and solar energy can be reaped. However, due to lack of resources large scale solar is unlikely in the country. Table 34 presents some of the upcoming solar power plants in the country.

Table 34 Upcoming solar projects in Afghanistan

Name	Capacity (MW)	Year of Commissioning
Kabul	10	2019
Nagarhar	100	2020
Kandahar Phase 1	10	2020
Daikundi	10	2021
Baghdara	240	2022
Sarubi 2	180	2023
Paktita	10	2024
Kandahar Phase 2	20	2025

Government of Afghanistan has laid the foundation for energy efficiency in the country with the Afghanistan Energy Efficiency Policy. The policy document captures Afghanistan's targets and action plans for achieving energy efficiency to reduce costs and GHG emissions. Though the document has a section on energy efficiency in generation and distribution, due to lack of data and high reliance on imports to meet its electricity demands, it has referred to a future scenario where the Best Available Technology (BAT) maybe used to achieve energy efficiency.

Afghanistan's' Energy Efficiency Policy 2014

The Ministry of Energy and Water (MEW), as one of the key ministries to plan and direct the development of energy sector in Afghanistan, prepared the Afghanistan Energy Efficiency Policy (AEEP) which aims to provide direction to the energy efficiency activities in the country. Some of the features of this policy are:

- The objective of the policy is to adopt an integrated approach to harness all resources on the supply side while applying good demand side management practices in all energy consuming sectors.
- The policy sets targets for reducing losses in extraction, generation, transmission & distribution and end use and promotes identification and adoption of energy efficiency opportunities across all sectors of the economy through awareness creation and capacity building
- It seeks leadership from the public sector to adopt energy efficiency practices by setting measurable targets across a range of activities and operations.
- It advocates for the government to provide resources for business leadership to enable them to embrace and lead energy efficiency objectives.
- The policy encourages households and small to medium enterprises businesses to reduce costs by improving access to energy efficiency projects through technology and financing.
- It seeks to strengthen consumer awareness in order to empower them to make informed choices for energy efficient purchasing.
- It supports setting up minimum and acceptable standards across a range of options – minimum energy performance scheme for appliances, energy efficiency rating schemes for buildings, minimum renewable energy integration targets for new developments - with the help of legislations.
- Policy acknowledges the need to create knowledge base and standards to support development of high quality of energy technologies and modern energy efficiency industry
- It encourages use of renewable energy as generation and demand side management as well as fuel diversification option
- It uses existing partnership platforms with other countries to exchange energy efficiency ideas, projects, finance and innovation
- It lays the foundation for setting up "basket-funds" for EE projects which would evolve into a dedicated EE financing institution in TERM 2 of the policy implementation.
- It recognizes the importance of institutional strengthening and possible reorganization, including setting up of new institution for strategizing, planning, budgeting and coordinating the implementation.

4.3.2. Bangladesh

Bangladesh Power development board (BPDB) is the predominant entity in Bangladesh's power sector. BPDB prepared generation expansion plan to add about 17,304 MW from 2019 to 2023 with the aim to provide quality and reliable electricity to all the people across the country for desired economic growth and social development.

Bangladesh has The Sustainable and Renewable Energy Development Authority Act, 2012, which aims to reduce global warming, environmental hazard risk and to ensure energy security by reducing dependency on fossil fuel through the use and expansion of Renewable Energy. The Authority also aims at preventing energy waste in residential, commercial & industrial sectors by saving and conserving energy as well as ensuring its efficient use. The working of SREDA is divided between 5 wings and one of the wings is Energy Efficiency and Conservation wing, which looks after energy audit and preparation of methodology of same. Also, BPDB has conducted various studies to increase the efficiency in power sector of Bangladesh.

Bangladesh is now pioneer in adopting more efficient technologies of power generation. One of that is adoption of combined cycle power plants in the future generation mix. Some of the examples are 583 MW Meghnaghat Combined Cycle Gas-Fired Power Plant in Meghnaghat and upgradation of the 150 MW Sylhet single cycle power plant to 225 MW by adoption of combined cycle technology.

Bangladesh's Power System Master Plan projects the long-term planning in power sector (Figure 52), and is updated every 5 years. For the year 2021, the plan has targeted to reach generation capacity of 24,000 MW from 2016-2021 (Bangladesh Power Development Board, 2019).

Bangladesh has targeted 17 GW expansion in its generation capacity from 2019 till 2023 as well. Under this plan, the coal (indigenous or imported), imported power from neighbouring countries, the limited domestic gas, nuclear power, LNG and renewables are in focus.

Bangladesh's primary fuel to satiate its country's appetite for electricity has been gas till now, the GoB has now taken strategic decision to diversify its portfolio. Government is keen and undertaken various steps in energy efficiency and conservation programme for reduction of the growing power demand. Bangladesh has a lot of bilateral and multilateral organizations contributing in its energy efficiency power infrastructure.

Bangladesh's power sector as of 2019 has 50 projects of capacity 15,151 MW under construction stage, 15 projects of capacity 4,159 MW in the signing process and 9 projects of capacity 1,510 MW in tendering process.

Bangladesh has also focused to increase its share of renewable energy from 2.73% in its generation mix. BPDB has taken systematic steps for implementation, planning & development of renewable energy sector. There are multiple ongoing projects of solar PV, wind power and solid waste to energy in Bangladesh.

Bangladesh's BPDB has implemented global best practices in its distribution infrastructure to reduce system losses. There is incorporation of IT in the distribution services provided by the utility. Some of the key services adopted/being adopted by BPDB in its operation are:

- Computerized billing and remote billing system
- Easy Bill pays
- One stop service
- Online applications
- Prepaid metering
- Supervisory Control and Data Acquisition (SCADA) System
- Demand Side Management

BPDB is increasing its network in Bangladesh based on demand. For the year 2018-19, there was an increase of ~247 km distribution lines with nearly 244,306 new connections being given. Bangladesh has targeted 497 km of new distribution lines being setup by 2021. Further, there are 9 distribution projects under progress and lined up for completion by 2022.

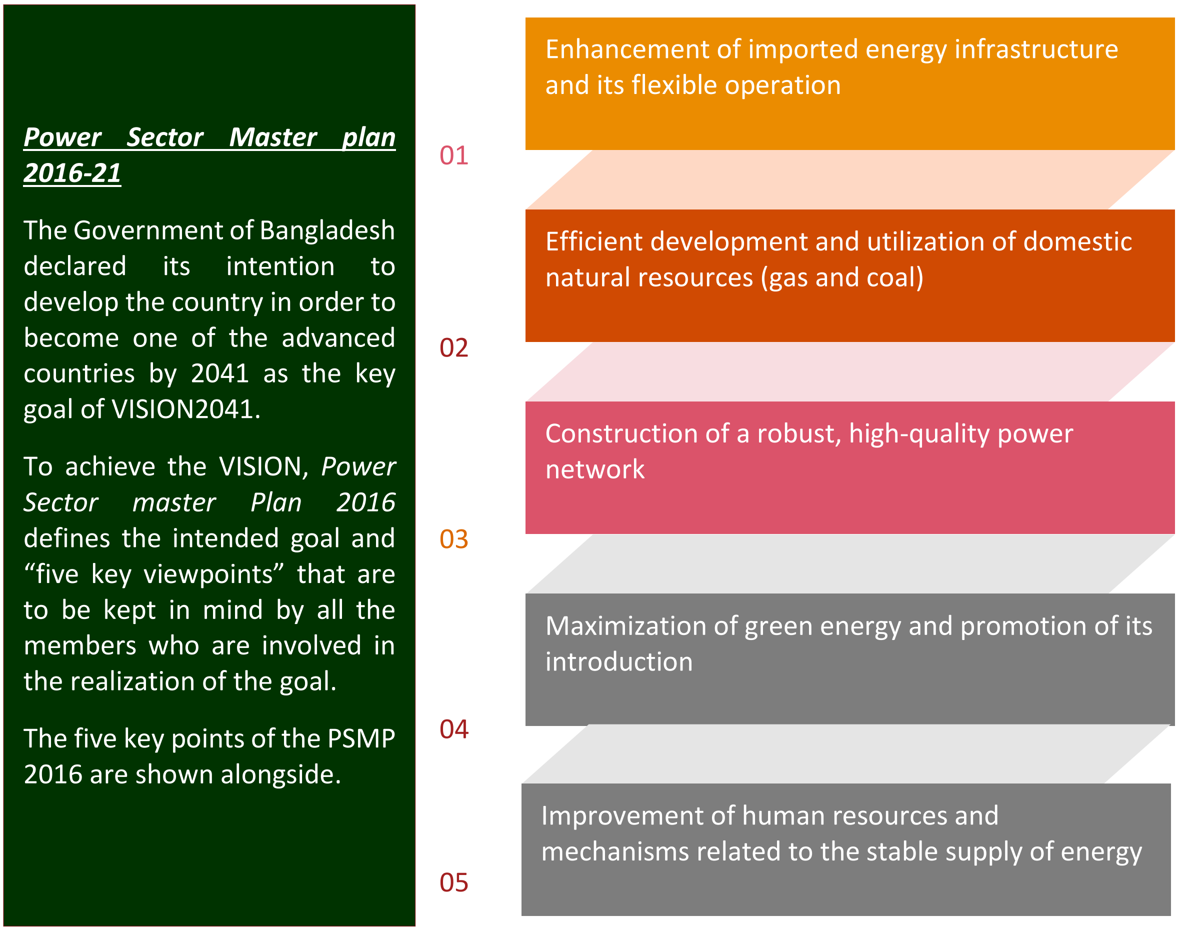


Figure 52 Bangladesh's power system master plan

4.3.3. Bhutan

Bhutan is primarily dependent on hydropower to feed its growing power appetite. There have been several energy efficiency and expansion initiatives undertaken by the government of Bhutan. Bhutan Power Corporation Limited reported a total sale of 2,328.44 GWh for year 2018 as compared to 2,185.75 GWh in the previous year reflecting an increase of about 6.5% over the year (Bhutan Power Corporation Limited, 2019). The Transmission and Distribution (T&D) losses of BPC were at limits comparable within the region. Of the total energy of 6,919.03 GWh received by the system during the year, 6,766.36 GWh was utilized. This translates into energy loss for the year 2018 to 2.21% as compared to 2.00% in the previous year. Bhutan is expected to add 3,658 MW of hydro power generating stations by 2027. Besides new hydro capacities, solar and wind power installed capacities are expected to reach 5 MW each by 2025, as per the target of the Alternative Renewable Policy 2013.

Since cost of electricity is not high in Bhutan, the motivation to implement high costing energy efficiency measures in the power sector is considerably less. The government of Bhutan is still undertaking steps for energy efficiency to increase capacity of its existing hydel setups, as it is one of their main sources of foreign exchange.

BPC has constantly undertaken measures to upgrade its existing infrastructure to ensure reliability of power. For example, in 2018, BPC undertook the upgradation of 220/66 kV Singhigaon substation from air insulated switchgear (AIS) to gas insulated switchgear (GIS), commissioned 10

MVA 132/33 kV transformer at Kilikhar substation to meet the increasing power demand of Kilikhar including the Bondeyma Industrial Estate, etc.

In order to improve power reliability and most importantly to meet the increasing load demand, distribution planning and system expansion works are carried out across the country as and when needed. Some of the new projects in progress as of 2018 were the supply and construction of 33/11 kV, 2x2.5 MVA substation at Denchi, Pemagatshel, and conversion of 33 kV AIS to GIS at 33/11 kV Changangkha Substation, Thimphu.

BPC has initiated the establishment of the Distribution Management System (DMS) for real-time network viewing for quick decisions to optimize resources and managing demands. The work is in advanced stage of completion as of 2018, and once established and operationalized, it will reduce the duration of outages, improve the speed and accuracy of outage predictions.

BPC has a R&D Lab within the IT Division to support and explore opportunities for ICT, assess new technologies and formulates corporate ICT strategy and long-term ICT planning. This R&D Lab aspires to produce ICT tools and in-house innovations for BPC that could bring huge cost saving and system improvement.

BPC has completed the Rural Electrification works under the electricity for all programme initiated by the Royal Government of Bhutan. Under the On-Grid Rural Electrification (RE) of Off-Grid households in the country, 1,429 Off-Grid households in 15 dzongkhags will be connected to On-Grid through the loan savings from Rural Electrification Project (Phase 2) under JICA financing and RGoB as counterpart financer. These works are under advanced stage of implementation.

4.3.4. India

India is seeing ever-increasing electrification in the country with favourable investments and policy support by the government. There are various schemes such as the Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY), Ujjwal DISCOM Assurance Yojana (UDAY) and Integrated Power Development Schemes (IPDS) which have further served to benefit the power sector of the country. Further, India has also been ranked 6th in the world in terms of investments made in clean energy (Central Electricity Authority, 2019).

Central Electricity Authority of India is the apex regulatory body of power sector in the country. CEA has incorporated global best practices which are being followed in the power sector and provides consultancies and serves as a reference to other developing nations.

India’s national electricity plan guides the country towards reaching its generation targets. There is emphasis on energy efficiency in the targets. As per the National Electricity Plan, there are plans for capacity addition in the country, primarily through coal based thermal plants, as well as retirement of 22,716 MW (5,927 MW old and inefficient units and 16,789 MW - completing 25 years by 2022 & without FGD space) of coal-based capacity during 2017-22.

The share of renewable is targeted to reach 20.1% in the generation mix, with capacity addition of up to 175 GW (Central Electricity Authority, 2018).

India’s generation and distribution expansion are guided by the National Electricity Plan given by the CEA. Further, the country has also successfully been able to undertake rural electrification in its regions.

India has taken significant steps to improve energy efficiency, which have helped India avoid an additional 15% of annual energy demand and 300 million tonnes of CO_2 emissions over the period

2000-18 (IEA, 2020). With continued progress towards achieving its NDC targets, India has set a benchmark for many developing nations in terms of incorporating EE in its power infrastructure.

The Government of India has set up Bureau of Energy Efficiency (BEE) on 1st March 2002 under the provision of the Energy Conservation Act, 2001. The mission of Bureau of Energy Efficiency is to assist in developing policies and strategies with a thrust on self-regulation and market principles with the primary objective of reducing energy intensity of the Indian economy within the overall framework of the Energy Conservation Act, 2001. This will be achieved with active participation of all stakeholders, resulting into accelerated and sustained adoption of energy efficiency in all sectors. BEE has initiated various energy efficiency initiatives for power sector like:

- **Demand Side Management (DSM)**: The capacity building and other support is essential for the DISCOMs to implement DSM in their respective areas. In this context, Bureau of Energy Efficiency has launched a programme for capacity building of DISCOMs. This will help in capacity building of DISCOMs and development of various mechanisms to promote DSM in their respective states. During financial years 2012-17, BEE had selected 34 DISCOMs for their capacity building and providing necessary support for the implementation of DSM related activities. During second phase, remaining 28 DISCOMs are included under this programme.
- **PAT Scheme**: PAT is a regulatory instrument to reduce specific energy consumption in energy intensive industries, with an associated market-based mechanism to enhance the cost effectiveness through certification of excess energy saving which can be traded. The energy intensive industries including the thermal power plants are the major players in this entire scheme of PAT. It refers to the calculation of Specific Energy Consumption (SEC) in the baseline year and projected SEC in the target year covering different forms of net energy going into the boundary of the designated consumers' plant and the products leaving it over a particular cycle. BEE has notified power generation and DISCOMs as designated consumers for mandatory energy audit and M&V. Till date, a total of 3 PAT cycles are completed and 2 are in execution phase.

4.3.5. Maldives

Maldives state electric company (STELCO) has a major role in Maldives electricity generation and distribution. STELCO currently has diesel generators-based generation units across the island. As of 2018, STELCO has 35 community run diesel-based powerhouses with basic infrastructure.

STELCO has plans to deploy more solar energy projects in its infrastructure. They have tested hybrid battery solar diesel systems at their power houses, which they plan to replicate at all the existing diesel-based powerhouses. After the fifth power development project, STELCO aims to establish a unified grid for Maldives. Some initial groundwork has been done in order to achieve the same. Some of the key planned projects of STELCO are:

- Industrial village HV substation
- Fifth Power Development Project phase 2
- Development of distribution Network in HulHumale Phase 2 (Substations, DB's HV and LV cables, SCADA systems and HV substation)
- Male distribution network upgrade and automation
- Gulhifalhu new powerhouse (16 MW) and distribution network
- ERP systems to improve efficiency within the company

Unified Grid

STELCO Greater Male' Interconnection phase 1 will be completed by mid-2020. Under this project, 3 substations will be established in Male', Hulhumale' and Hulhule. The prime power fed to this grid will be from newly established Fifth Power Development Project at Male' Power Plant. Completion of this high voltage grid will also enable STELCO to add more renewable energy into the grid.

Additional 50MW's will be installed in Hulhumale' to increase the power generation capacity.

Furthermore, Greater Male' Grid Connection Phase 2 is designed to utilize the connectivity of Greater Male' Region all the way to Thilafushi with the establishment of a 200 MW Power Plant in Thilafushi for long term power security of the region.

The company regards the Fifth Power Project as an important milestone in the development of the country's power sector. The Fifth Power Project is the largest power project conducted in Maldives.

The USD 79 million project initiated by STELCO in Hulhumale' is contracted to Dongfang Electric International Corporation. STELCO aims to assure electricity coverage for the next 10 to 20 years, upon completion of the project. The project is funded by a loan arranged from the Exim Bank of China.

4.3.6. Nepal

Nepal electricity authority (NEA) – established in August 1985 under NEA Act 1984, wholly Government of Nepal undertaking – is responsible for generation, transmission and distribution of electricity throughout Nepal. NEA has successfully brought down its system losses over the years with implementation of best practices and latest technologies in its system infrastructure.

Nepal is predominated by hydel power generation making cost of generation of electricity not high. The motivation to implement high costing energy efficiency measures in the power sector is considerably less in the country. The government of Nepal is still undertaking steps for energy efficiency to increase generation of its existing hydel setups to feed its every growing population.

NEA has started adopting modern digital technology into its system to enhance its operational efficiency and reduce energy theft. The implementation of Smart Grid and Smart Metering system will increase efficiency and reduce losses. Smart Meter installation within Ratnapark and Maharajgunj distribution centres will be accomplished in FY 2020-21.

NEA is in the process of utilizing the global best practices followed in different countries. Major initiatives include implementation of Enterprise Resource Planning (ERP), Geographical Mapping

(GIS Mapping), Smart Metering, Substation Automation and expansion of IT infrastructure in the years to come.

NEA has prepared an IT Road map for its systematic implementation in all its business functions, in line with the Government of Nepal's vision of "Digital Nepal".

Addition of two new power plants, namely Upper Trishuli 3A (60 MW) and Kulekhani III (14 MW), to NEA's system contributed in the increased generation. NEA's hydropower plants including small power stations generated a total of 3,021 GWh of electricity in FY 2019-20, an increase by 18.57% over the generation of 2,548 GWh in FY 2018-19 (Nepal Electricity Authority, 2019).

Nepal has various hydro generation projects lined up under its Engineering Services Directorate, some of these projects are Dudhkoshi Storage Hydroelectric Project, Upper Arun Hydroelectric Project, Upper Modi Hydroelectric Project and Uttarganga Storage Hydroelectric Project.

The White Paper 2074 issued by Ministry of Energy, Water Resources and Irrigation (MOEWRI) has set up a roadmap for the next decade in the energy sector. It will continue to be a master document to NEA for its future action plans in power sector development of Nepal.

The Government of Nepal has articulated a clear strategic direction for the electricity sector in the White Paper. The key sector goals include: (a) to reach 5,000 MW installed capacity in 5 years and 15,000 MW installed capacity in 10 years, (b) to expand access to electricity and clean cooking to 100 percent of the population in 5 years, and (c) to increase the per capita consumption of electricity to 1,500 kWh in 10 years.

- In the short term, minimize load shedding through reduction of system losses, demand-side management and consumer education, increased power imports, and efficient system dispatch; initiate power sector reforms through establishment of the Electricity Regulatory Commission (ERC); preparation of the restructuring plan for the vertically integrated utility NEA; and preparation and implementation of the financial viability plan of NEA.
- In the medium term, reach supply-demand balance through investments in new generation, prioritization of large peaking and storage hydropower projects, expansion of T&D, energy access and export, and cross-border transmission lines; deepen power sector reforms through full operationalization of the ERC, establishment of a power trading mechanism, introduction of competitive power purchase mechanisms, integrated system planning, and separation of NEA's generation, transmission, and distribution business.
- In the long term, achieve sound regulatory framework, competent sector institutions and competitive, efficient power market through continued sector reform, sustainable investments in generation, transmission, and distribution infrastructure, grid and off-grid access, and integration into the South Asian regional power market.

4.3.7. Pakistan

National Electric Power Regulatory Authority (NEPRA) is the sole regulator of power sector in Pakistan. NEPRA's regulatory regime involves provision of safe, reliable, efficient and affordable electric power to the electricity consumers in Pakistan. In NEPRA's state of Industry report 2019, it has captured in detail Pakistan's power sector performance and plans.

Some of the measures implemented in Pakistan are:

- National Energy Efficiency and Conservation Act, 2016 was introduced for institutional development to improve energy efficiency, specifically mandating the creation of the National Energy Efficiency and Conservation Authority (NEECA, transformed from former National Energy Conservation Centre - ENERCON); the Authority Fund; and the National Energy Efficiency and Conservation Board. As per this act, energy audits will be conducted by certified energy auditors of different designated consumers, but no proper measures were taken by the authority to force these designated consumers to implement energy efficiency measures.
- Pakistan is currently deploying Advanced Metering Infrastructure (AMI) in two of its distribution companies, LESCO and IESCO. The Asian Development Bank (ADB) has committed to 80% of the cost for this project.
- National Energy Efficiency and Conservation Authority (NEECA), a subsidiary under the Ministry of Energy (Power Division) Pakistan, is carrying out energy audits of gas based captive power plants (CPP's) all across Pakistan.
- NEECA and PEECA (Punjab Energy Efficiency and Conservation Authority) in Pakistan offer trainings and guidance to promote energy efficiency and conservation in the power sector. NEECA and PEECA come under the Ministry of Energy of Pakistan.
- Pakistan's NEEPA Act has laid out path for preparation and launch of National Certification Scheme for Energy Auditors/ Managers as per NEEPA Act. The NEEPA Act also has provision for Detailed Energy Audits of (Grids/ Power plants/ Industries).
- NEPRA receives an Indicative Generation Capacity Expansion Plan (ICGEP) from Pakistan's National Transmission and Dispatch Company (NTDC) every year for review. NTDC is obligated under Planning Code of Grid Code of Pakistan for preparation of IGCEP for review and approval of NEPRA. For the reporting year 2018- 19, NTDC submitted IGCEP 2018-2040 to NEPRA.

Strategic Plan 2020-23 (NEECA)

NEECA aim to achieve the goal of 3 MTOE energy saving by 2023 through its strategic plan for different energy intensive sectors. It states that Pakistan has the potential to save up to 10-15% (10-12 MTOE) of primary energy supply through energy efficiency and conservation.

To achieve this goal, the Plan will be implemented in three phases.

- **First phase** will be the 'institutionalization of the energy efficiency and conservation at the national and provincial levels.
- **Second phase** will be the 'operationalization' of policy & actions
- **Third phase** will be the 'implementation' of action plans.

Due to high energy share of 5 major sectors of **Power**, Industrial, Buildings, Transport and Agriculture, they are prioritized for strategic plan on energy efficiency and conservation in Pakistan.

For power sector, a goal of achieving total saving up to 0.4 MTOE through the intervention of various EE programmes which includes transformer and LT capacitor programmes, carrying out heat rate assessments, and enforcement of mandatory energy audits.

In phase 3 of the programme following ECMs are proposed for power sector:

- Installation of Heat Recovery Systems (HRS) from exhaust flue gases and High-Pressure Cogeneration (HPC) in 50 Sugar mills. (Funds Required Pak Rs.9 million)
- Deployment of smart metering technology. (Funds Required Pak Rs.100 million)
- Upgrading and expanding the Grid to minimize line losses in the electricity sector. (Funds Required Pak Rs.500 million)
- To operationalize small and digital feeders for load management. (Funds Required Pak Rs.500 million)
- Replacement of old transformers with small smart and digital transformers (Funds Required Pak Rs.700 million)

4.3.8. Sri Lanka

The Sri Lankan economy continues its growth momentum driven by the improved physical infrastructure including electricity. In year 2018, usage of electricity was recorded a growth of 4.9% when compared to the previous financial year (Ceylon Electricity Board, 2020).

The Ministry of Power and Energy of Sri Lanka is very ambitious towards implementing smart meters in its distribution systems. It has directed CEB and LECO to explore the possibilities of up scaling the existing electricity grid to a Smarter Grid and of introducing electronic smart meters. (A successful pilot study has already been conducted which shall translate into a full-scale deployment).

Sri Lanka Sustainable Energy Authority is working with Accredited Energy Auditors and energy managers to provide technical assistance and capacity building of Sri Lanka’s power sector professionals.

Sri Lanka’s CEB has incorporated the best practices and the latest technologies which are being used internationally in its infrastructure. CEB installed a new system control centre equipped with an Alstom SCADA / EMS system in Pelawatta during the year 2018. This system can monitor remotely 63 grid substations and 15 power plants in Sri Lanka. This is a laying stone for the technical advancement for Sri Lanka's IT in power sector.

Study on 'Integration of Renewable Based Generation into Sri Lankan Grid 2020-2030' was also conducted during the year 2019-20 with the objective of investigating the main challenges faced in renewable energy-based generation and determining the optimum level of renewable energy generation.

The Greater Colombo Transmission and Distribution Loss Reduction Project (CEB) is in implementation wherein the aim is to strengthen the transmission and distribution network in Greater Colombo area in order to improve the reliability, reduce system losses and cater growing electricity demand due to mega development activities planned in the Colombo City.

Green Power Development & Energy Efficiency Improvement Investment Programme (Tranche 2) is an ongoing project supported by the ADB across the Mannar–Nadukuda Transmission Line The project will finance investments in (i) transmission infrastructure enhancement; (ii) efficiency improvement of medium voltage network; and (iii) demand-side management improvement for energy efficiency including development of an innovative smart grid and metering pilot subproject.

Sri Lanka has a series of ongoing projects such as Mannar Wind Power Project, Broadlands Hydropower Project, Moragolla Hydropower Project, Uma Oya Hydropower Project, National Transmission & Distribution Network Development and Efficiency Improvement Project, all of which had commenced in the previous years and are phases of implementation.

Sri Lanka is taking steps to incorporate nuclear power generation in its generation mix. International Atomic Energy Agency (IAEA) has agreed to provide assistance to develop a national strategy for the introduction of nuclear power in Sri Lanka by establishing a roadmap for the nuclear power programme.

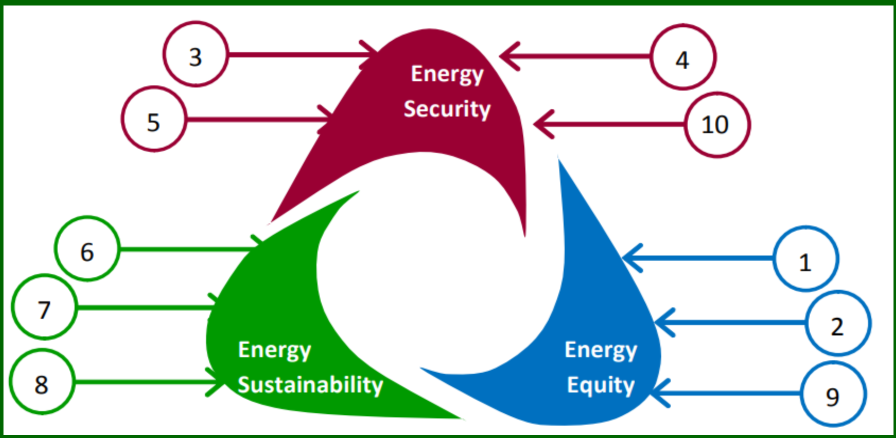
CEB has also undertaken studies and initial steps to assess the impact of pre-paid metering systems in Sri Lanka. Pre-paid metering systems in Sri Lanka.

The Sri Lankan Government gave out the **National Energy Policy and Strategies** of Sri Lanka. This policy document aims at ensuring convenient and affordable energy services available for equitable development of Sri Lanka using clean, safe, sustainable, reliable and economically feasible energy supply. This policy document has three sections:

1. The National Energy Policy, *stating the ten pillars of the policy framework*
2. Implementing Strategies, *describing the specific strategies to implement the policy*
3. The Results Delivery Framework, *elaborating the specific actions, milestones and the institutions responsible*

The national energy policy is founded on ten pillars, rooted in the broad areas impacting the society, economy and the environment. They are:

1. Assuring Energy Security
2. Providing Access to Energy Services
3. Providing Energy Services at the Optimum Cost to the National Economy
4. Improving Energy Efficiency and Conservation
5. Enhancing Self Reliance
6. Caring for the Environment
7. Enhancing the Share of Renewable Energy
8. Strengthening Good Governance in the Energy Sector
9. Securing Land for Future Energy Infrastructure
10. Providing Opportunities for Innovation and Entrepreneurship



4.4. Recommendations for Energy Efficiency Improvements in the SAARC Nations

In the SAARC Nations, on the supply side of the power systems, the key energy efficiency issues are:

- The relatively lower efficiency and reliability of thermal power plants mainly in countries like India, Pakistan, Bangladesh and Sri Lanka.
- The significantly high losses in electricity transmission and delivery systems in countries like Afghanistan, India and Pakistan.
- Absence of regulatory policies for implementation of energy efficiency in power utilities in countries like Afghanistan, Bhutan, Nepal and Maldives.

There is scope for significant improvement in efficiency of coal fired thermal power plants by 3-6% and in countries like Sri Lanka and Bangladesh efficiency of gas/oil fired single cycle power generators can be improved by 15 – 20% by installation of heat recovery steam generator (HRSG). Similarly, losses in transmission and distribution can be minimized by various technical improvements and nontechnical reforms that are presented in subsequent sections.

4.4.1. Technical Improvements in Generation Sector

In the SAARC Countries, there are different types of generation sources like hydro, thermal plants using coal, oil and gas, renewables. In the study, we are mainly analysing the losses and remedial measures which the countries can adopt for minimizing these losses and make the power system more efficient. The detailed analysis of improvement for each SAARC Nation will be provided in succeeding country specific sections. Some of the key improvements, which can be made in the power sectors of all SAARC nations are presented below.

Proper Monitoring of Critical Parameters

All the power stations operating on conventional sources of energy have some critical parameters, which should be monitored for efficient and safe operation. Thus, in absence of total automation and online controls, the operator's skills are critical for efficient operation of the plants. Often, the operators are semi-skilled or do not have enough capacity to undertake efficient operations of these plants. At times, due to cumbersome schedule and overloading of officials, required attention is not given to these critical parameters. There are tools to maintain the power plant at parameters for best efficiency. These tools are called Performance Analysis, Diagnosis and Optimization System (PADO) software. Some of the developed and tested PADO software are as follows:

1. ELTRIX Plant Performance Management (PPM)

This tool is one of the best performance management and optimization applications available. The main application of this tool is in various power generation utilities including thermal, gas, combined cycle, co-generation and hydro generation plants. This software provides the recommendation to the operator by computing the values of key performance indicators as per the real time plant conditions (Kalkitech, 2020).

2. STEAG PADO

This system continuously collects and validate real time plant parameters like current, temperature, pressure and flow of different water and steam cycle. It then computes the average value obtained by system in 5 minutes through an internal Ebsilon software, which is previously trained to provide the best recommendations with respect to current running status of plant. The modules of SRx PADO tool are shown in Figure 53[45].

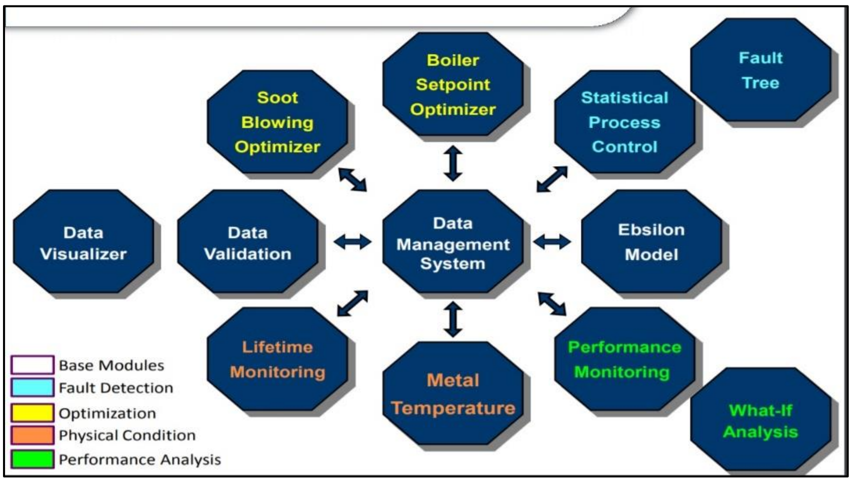


Figure 53 Modules of PADO system

[45] (Steag, 2020)

3. Enerlytics for Gas-Based Generation Plant

Enerlytics is a real time performance monitoring tool developed mainly for gas and oil-based turbine units for proper monitoring of performance and efficiency. It uses its own in-built data library for analysing the current condition to the ideal conditions for which the turbine was designed (Uniper, 2020).

Renovation and Modernization of Equipment

An effective and economical way to improve the efficiency of existing power stations is to renovate and modernize (R&M) the inefficient equipment with the new and efficient technology. Due to shortage of funds and poor financial condition of utilities, it becomes very difficult to directly switch to new technologies and scrap the existing plants. Like in case of India & Pakistan, they are using the same subcritical thermal power plant technology with an efficiency rage of 30-35% for the past 40 years, although there is breakthrough of ultra and super ultra-critical power plants which have an efficiency range of 40-45%. Similarly, in Bangladesh and Sri Lanka utilities are still using single cycle gas turbine power plants in place of combine cycle power plants, which can improve the efficiency by 15-20% of the GT system. Some of the R&M methods to improve the plant efficiency are presented below.

1. Variable Frequency Drive for Motors

Variable Frequency Drive (VFD) is used to make an AC motor rotate at variable speed (among other parameters). Fans and pumps in power utilities are designed to be capable of meeting the maximum demand of the system in which they are installed (Natural Resources Canada, 2020). However, quite often the actual demand could vary and be much less than the designed capacity. These conditions are accommodated by adding outlet dampers to fans or throttling valves to pumps. These are effective and simple controls, but severely affect the efficiency of the system. Using a VFD to control the fan or pump is a more efficient means of flow control than simple valves or inlet or outlet dampers. The power input to fans and pumps varies with the cube of the speed, so even seemingly small changes in speed can greatly impact the power required by the load. Primary benefits of VFDs are:

- VFD saves electricity in under loaded equipment by preventing throttling losses in the pumps.
- VFD prevent overloading and heating of motor by regulating the starting power required by the equipment.
- VFD helps extending equipment life and consequently reduces the maintenance cost.

2. Replacement of Old Motors with Energy Efficient Motor

Motors are the prime movers in any power generation plant for running various auxiliaries. Electric motors are known as the “workhorses” of industry. They are used in driving a broad range of applications such as pumps, compressors, fans or blowers, conveyors and other auxiliary machines. The use of inferior standard efficiency motors is dominant in power sectors of the SAARC Nations. Moreover, these motors have been in use for many years, and thus experience downtime and undergo repairs more frequently. This further reduces their efficiency. These substandard motors consume more energy and entail a high energy cost. Therefore, improvement in motor efficiency must be a part of any comprehensive energy conservation effort. There have been breakthroughs in increasing the efficiency of motors to a large extent like use of copper rotor technology for induction motor among others. Figure 54[46] shows efficiency variation for different motor classes.

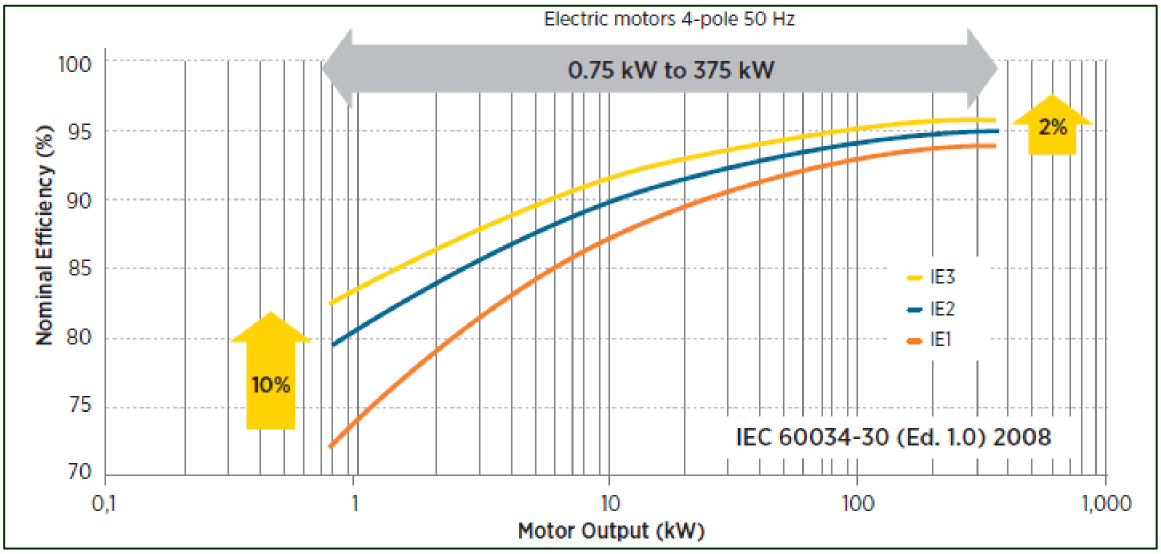


Figure 54 Efficiency for different class of motors

3. Installation of Heat Recovery Steam Boiler in Single Cycle Gas/Oil Turbine

In countries like Bangladesh, which has majority of generation by single cycle gas turbines based thermal power plant, HRSG can be installed, which can provide electricity from the steam generated after recovering heat from flue gas of Gas turbine. A schematic diagram of single shaft combined cycle is shown Figure 55[47]. A typical combined cycle power plant increases the efficiency of system by 15-20% and can reduce cost of generation of electricity produced by the plant.

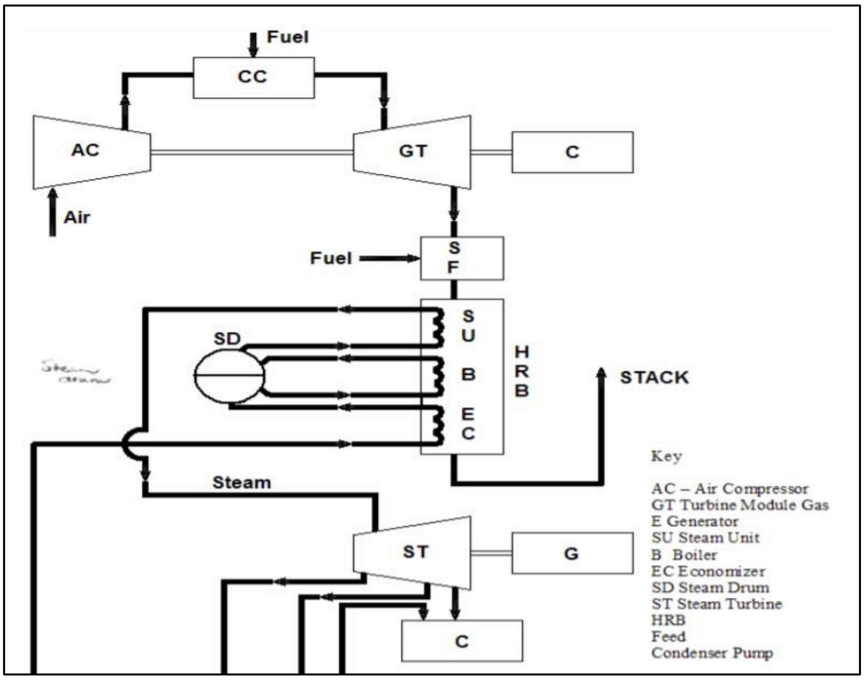


Figure 55 A schematic diagram for a single shaft combined cycle

[46] (US Department of Energy, 2014)
[47] *(Kiameh, 2002)*

4. Upgrade of Turbine Blades and Vanes for Gas Turbine

Continuous research and development by the OEM of gas turbine resulted in improved guide blades and vanes, which can be retrofitted in the old gas turbine to increase its efficiency. Many of the OEM companies such as Siemens and General Electric have developed aerodynamic blades and vanes for retrofitting them in old gas turbine. This helps in increasing their power generation and decrease maintenance cost.

Case Study of Siemens

Siemens has developed innovative 3D optimized turbine blades and vanes that are characterized by an aerodynamic blade and vane design with optimal efficiency as well as a capability for retrofitting during service life. This generation of turbine stages 3 and 4 blades and vanes has a new, optimized aerodynamic air foil designed with enhanced material, coatings, an improved cooling air path and a reduction of parasitic losses (Siemens, 2020). Siemens innovative 3D optimized turbine blades and vanes for stages 3 and 4 can include the following benefits:

Increased gas turbine power up to 2.5 MW*)	Increased gas turbine efficiency up to 0.5 percentage point*)	Reduced life cycle costs	Compatible with the Siemens 41,000 equivalent operating hours (EOH) maintenance concept upgrade

5. Installation of O_2 Analysers at Various Stages of Boiler

Monitoring the oxygen level is very important for efficient operation of boiler and reducing the dry gas losses in the boiler. Normally oxygen analysis is only done at air preheater inlet to check the excess oxygen level in boiler. A complete O_2 analysis is necessary for checking the boiler leakages in the whole fuel gas path. Due to ageing of boiler, there are various leakages of external air into the boiler, which cools the fuel gas and increases the draft and loading of ID fan. This further decreases overall boiler heat and increases the fuel consumption.

6. Soot Optimization System

The soot formation in coal/lignite boiler is removed by blowing steam extracted from the intermediate stage of turbine (J. Pekar, 2008). The soot removal takes a considerable amount of steam, which can generate extra power in turbine if not wasted in soot blowing. The general practice in plant is to do periodical soot blowing of different parts of furnace irrespective of need of blowing at that location. To optimise the soot blowing process, there are various tools, made by Siemens, GE, STEAG etc., available depending upon the requirement of the client and type of fuel used. They alert the operator in case of degradation of efficiency of particular heat exchanger and the operator can operate soot blowing only when needed.

7. Optimization of Ash Handling System

Ash handing is one of the major critical areas for energy optimization in the coal fired thermal power plant. The Ash conveying should be done with minimum leakages of ash and compressed air. The major conveying of ash is done as dry ash and frequent leakages of line causes energy and monetary losses. It should also be considered to utilize ash as much as possible for land filling, brick and cement manufacturing etc. Also, dense phase pneumatic conveying system for dry ash conveying should be retrofitted wherever it is not available.

8. Installation of Pumped Storage Facility for Hydro Power Plant

The utility can consider pump storage type design for future expansion of hydropower plants. These type of plants helps in stabilizing the demand of power in the grid and can provide required head for running the plant at its designed efficiency level. Figure 56[48] shows the category of pumps storage in hydropower plant.

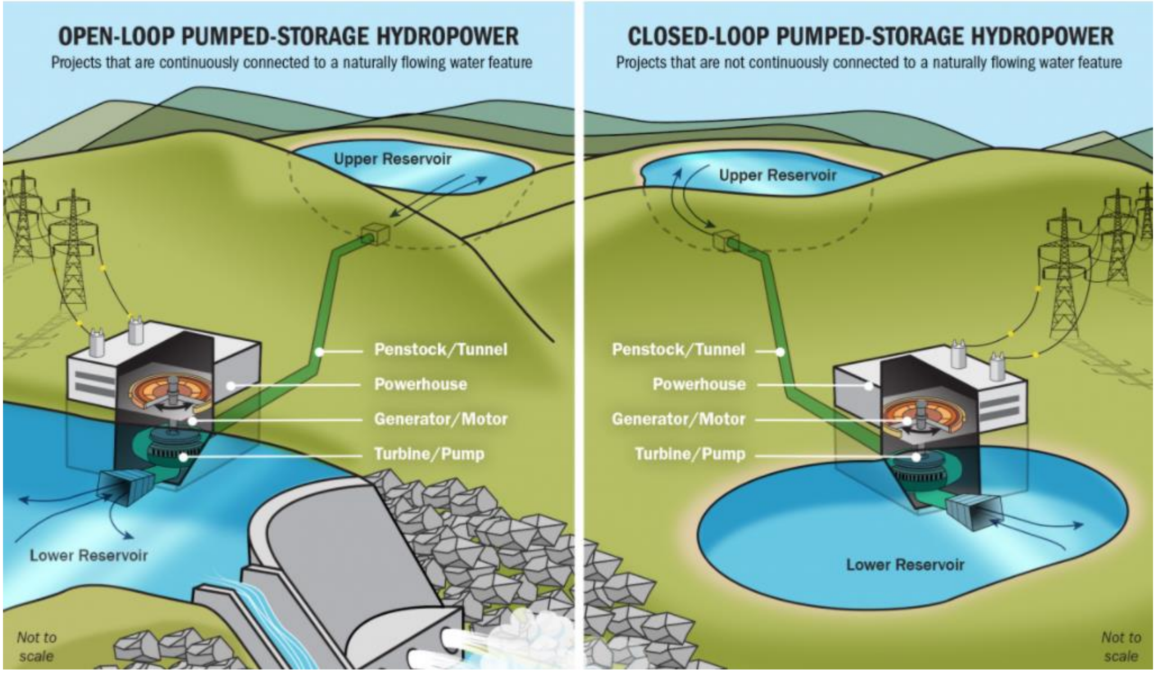


Figure 56 Type of pump storage hydropower plant

Proper Maintenance and Operation Practices

Proper maintenance and operational practices are major factors governing efficiency of any generation plant. Having a good operation and maintenance practice provides quick saving without any investment by the utilities.
Some of the major steps, which should be adopted by the utilities for better O&M practices are:

- The utility should form a central team to monitor performance and efficiency of each unit and there should be targets assigned to each plant head for loss reduction and cost-effective energy saving techniques.
- Most of the plants have morning meeting of officials from different department of plant. The daily agenda should include discussion on the past day performance of the plant and analysis should be presented for any losses, which can be curtailed in the future.
- The various elements like root cause analyses of failure of equipment, equipment spare budget, maintenance time spent on particular equipment among other maintenance related KPIs should be analysed weekly by the plant officials.
- Plant management should use their own expertise or should hire an external consultant to prepare their plant specific standard operating manuals and standard maintenance practices document for each process and equipment. The same should be followed for each operation and maintenance related process in the plant.

[48] (US Department of Energy, 2020)

Training of Operators and Maintenance Officials

Training of operational and maintenance staff in energy conservation and efficiency improvement of power plant plays a vital role in energy saving for the utility. The training provided to plant officials should have the following objectives:

- Awareness about the best operational and maintenance practices followed globally for their respective plants
- Knowledge of gaps in the performance of plants and measures to reduce the same
- Overview of recent developments and innovations in the process and equipment, which when implemented can optimize their plant performance and reliability
- Motivating trainees to create an energy savings culture in their organisation and identify conservation opportunities and goals that sustain energy efficiency over the long term
- Preparation of small proposal of energy savings based upon the suggestions of trainees

The training sessions covering above topics can be conducted by in-house experts, which can leverage their experience and expertise to train operators and engineers in adopting energy efficiency in their daily practice. There are international certifications which can be made mandatory for any individual to work in utilities:

- Association of Energy Engineers certifications on
  - Certified Energy Manager
  - Certified Power Quality Professional
  - Certified Demand Side Manager
  - Energy Efficiency Practitioner
  - Distributed Generation Certified Professional
- Boiler Operator Engineer (BOE) in India
- BEE Certified Energy Manager in India

Alternatively, all the SAARC Countries can standardize the required qualifications and certifications required to operate and manage the power utilities.

4.4.2. Technical Improvement in Distribution Sector

Aggregate Technical and Commercial (AT&C) losses and Transmission and Distribution (T&D) losses are referred in power sector as the yardsticks for measuring performance of distribution utilities. There is variation in presenting the performance of distribution system in the SAARC Nations. The measures for curtailing nontechnical losses in power distribution network will be discussed separately for each country. Some countries present aggregate technical and commercial losses and some countries like Maldives and Bhutan have no data pertaining to commercial losses in the system.

As discusses in Chapter 2 of this report, there are mainly two types of losses in distribution system – Technical and Nontechnical losses. Below are some improvements, which can be adopted for reducing the technical losses in the system:

1. **Preventing Transformer Losses**: The utility should consider procuring most efficient transformer present in the local market or if feasible available at comparable rates globally. Also, the transformer sizing should be decided keeping 20% margin of the peak demand in that

area. Regular oil change and preventive maintenance should be done for increasing the life and decreasing the maintenance cost.

2. **Installation of Smart Meters**: The utility should consider installing only smart meters where new meters need to be installed. Also, action plan should be formed to replace old meters with smart meters in a phased manner. The newly installed smart meters should be precured from a reputed vender for performance guarantee of the equipment and compatibility with the software used by the DISCO for billing and demand management should be ensured as well. Also, submetering of feeders should be adopted with installation of smart meters for better energy accounting. This measure will help in identifying major commercial loss areas in the distribution network and action plan to curtail these losses can be formed accordingly.

   The benefits of smart meters for reducing technical and commercial losses are:

   - Eliminates manual monthly meter readings
   - Monitors the electric system in real time
   - Encourages more efficient use of power resources through TOU/TOD metering
   - Provides responsive data for balancing electric loads while reducing blackouts
   - Enables dynamic pricing
   - Helps to optimize the profit with existing resources

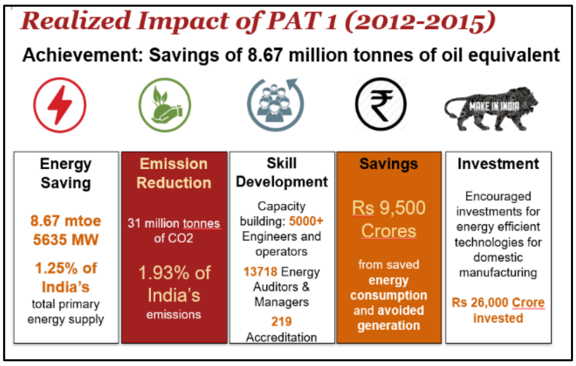
3. **Preventing Line Losses**: Increasing the voltage level in distribution networks reduces the current required to distribute the same amount of power, increases current capacity of the grid and reduces substantial voltage drops and line losses.

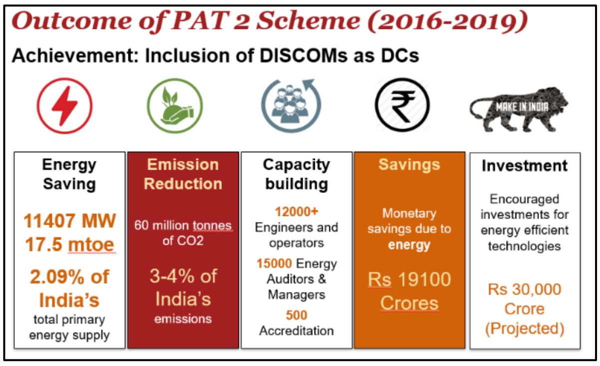
4. **Redesigning Distribution Network**: Fixed losses can be reduced without replacing equipment by reducing the number of energized transformers in the system. This can be achieved by eliminating transformation steps which could be achieved by direct coupling of higher voltage levels to lower ones without the use of intermediate transformers. The distribution network should be designed to minimize the LV lines and stepping down the voltage around the load centre only.

4.4.3. Nontechnical Improvements in Generation and Distribution Sectors

There are various reforms, which can be adopted by the SAARC Countries to improve their efficiency levels in power sector. One such major step adopted by India is introduction of PAT scheme first in power generation sector and now extended to power distribution sector as well.

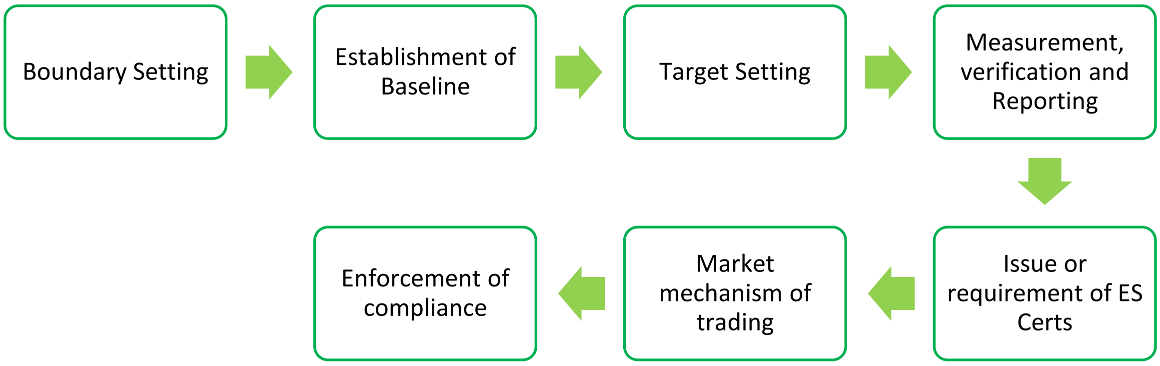
Perform Achieve Trade (PAT) is a regulatory instrument to reduce specific energy consumption in energy intensive industries, with an associated market-based mechanism to enhance the cost effectiveness through certification of excess energy saving which can be traded. The energy





intensive industries include the thermal power plants and DISCOMs. PAT is based on calculation of Specific Energy Consumption (SEC) in the baseline year and projected SEC in the target year. At the end of PAT cycle, a Measurement and Verification (M&V) audit is conducted by Accredited Energy Auditors to access the energy saving achieved in the PAT cycle. Based on the total energy saved and the set target, the designated consumer (DC) is either issued ESCerts (energy saving certificated) are issued or is penalised if targets are not met and has to buy ESCerts from trading market.

The design of PAT scheme can be understood along the lines of the following broad topics:



4.5. Afghanistan

Afghanistan faces many technical and nontechnical issues, which causes various losses in power sector. The improvements in power sector are divided into technical and nontechnical measures for both generation and distribution sector. The generation sector selected for improvement is hydro power plants as they account for nearly 85% of total domestic generation.

4.5.1. Technical Improvements

As Afghanistan imports as much as ~80% of total power requirement and only small amount of power is generated domestically. Also, major electricity generation of Afghanistan is by hydropower generation, which have an efficiency range of 80-85%. So, there is limited opportunity of technical improvements in power generation. However, some key improvements that can be done in hydropower generation plants of Afghanistan are:

- Turbine's rehabilitation: The water turbine of hydropower plants of Afghanistan can be rehabilitated with more efficient turbine design. This new design is usually investigated by hydraulic studies with more sophisticated CFD calculations. The original OEM of the power plant can suggest compatible turbine, which will increase the electricity generation by 30% (Bernard, 2020) of the original rated capacity at a given head. Overall increase in the efficiency can be in range of 2-5% of the present efficiency.
- Actions to reduce friction in the water conveyance systems: Redesigning the existing water conveyance system can be capital intensive measure. So, regular cleaning and removal of sediments, algae and unwanted plantations should be done.
- Maintaining head of reservoir: The head in reservoir should be maintained close to design level of dam. So that during power generation maximum efficiency from the turbine can be achieved with less inherent losses of the turbine system. As Afghanistan imports electricity from neighbouring countries, proper planning should be done to import more electricity during period of low reservoir head.

- Proper maintenance practice: The auxiliary consumption from various equipment in hydropower plant can be optimized by maintaining proper maintenance schedule. There must be proper monitoring of performance of each equipment and in case of any deterioration in performance is observed, the same should be rectified.
- The line losses should be curtailed by more effective expansion planning of distribution network. As Afghanistan has a developing network, it should adopt strategies to adopt energy efficient equipment and forecast network requirement based on geography and plan capacity augmentation accordingly.
- Submetering of feeders should be adopted with installation of smart meters for better energy accounting. This measure will help in identifying major commercial loss areas in the distribution network and action plan to curtail these losses can be formed accordingly.
- Strict vigilance: The main share in T&D losses in Afghanistan is of unmetered connections and thefts. The lines are overloaded due to illegal hooking on the lines. Setting up vigilance squads to check and prevent pilferage of energy and severe penalties should be imposed on those tampering the meter seals etc.
- Smart meters: There are security issues in Afghanistan, which prevent officials of DISCOs to visit sites to collect meter readings or check for any tempering of meters. This can be mitigated by installing smart meters for new consumers. As Afghanistan is still expanding its distribution network, it can implement smart meters more easily with less investment cost.

4.5.2. Nontechnical Reforms

There are various nontechnical reforms, which Afghanistan can adopt for loss reduction in power generation and distribution sector:

- **Target Setting for Loss Reduction:** The government should form regulations for compulsory loss reduction for DISCOs and GENCOs. There should be proper monitoring of targets achieved by the utilities and applicable incentives or penalty should be applied for achieving or failing to meet the targets respectively.
- **Energy Audit**: The government should implement framework for mandatory energy audit of power generation and distribution utilities at a defined period of time. An agency should be formed to overlook the recommendations of that audits and measures taken by the utilities in implementing the recommendations. There should be a regulation to bind the utility to decrease the losses and in case the utilities are not able to achieve the goal, penalties should be imposed.
- **Standardization for Procurement**: The government should only allow use of highly efficient equipment in power sector. There should be performance and energy efficient clause in the tenders, which will resist the inflow of inefficient products in the distribution and generation utilities.
- **Security and Power to Vigilance Officials**: There should be strict laws, which provide security to DISCOs officials conducting field vigilance in their respective jurisdictions. There should be more power to impose penalty and disconnection of connections in case of any misconduct is found.
- **Privatization of Utilities**: Afghanistan has a vast hydropower resource which is still untapped due to limited involvement of private players in development and operation of generation sector. The involvement of private companies will enhance the domestic generation and

reduce the dependency of import of power from neighbouring countries. Also, rising T&D losses in DISCOs can be prevented by privatization of DISCOs. The starting pilot programme of privatization can be done at city level and can be increased further depending upon the success of pilot programme.

4.5.3. Cost Benefit Analysis of Recommended Improvements

There are various recommendations for power generation and distribution sector of Afghanistan as mentioned in the earlier sections. In Table 35, various energy conservation measures, which can be adopted for Afghanistan, are computed along with indicative cost and estimated annual saving in terms of energy savings and monetary benefit. The annual monetary saving is calculated on the basis of average supply cost of power in Afghanistan. Also, due to unavailability of reliable grid emission factor of Afghanistan, the GHG reduction potential is not computed. A total of 59.8 GWh of electricity saving can be achieved in hydro power plants with a monetary value of USD 3.7 million. The cost of implementation of measures is USD 22.5 million for generation sector with an average payback of 6.1 years. In distribution sector the target achievable saving is of 929 GWh with a monetary value of USD 57.6 million. The cost of implementation of these measures is USD 106 million with an effective payback of 1.8 years. The total cost of implementation of energy efficiency measure for Afghanistan is USD 129.1 million**.**

Table 35 Cost benefit analysis for Afghanistan

S. No.	Energy Saving Measures	Annual Energy Saving Potential		Cost of Recommendation (Million USD)	Payback Period (Years)
		(GWh)	(Million USD)		
Generation					
1	Refurbishment of turbine of hydropower plant	32.6	2.0	11.1	5.5
2	Proper maintenance of unit	21.8	1.3	11.3	8.4
3	Awareness of officials and policy formation for Energy Efficiency in generating station	5.4	0.3	0.1	0.2
	Total	**59.8**	**3.7**	**22.5**	**6.1**
Distribution					
1	Installation of smart meters for consumers	216.9	13.4	50.4	3.7
2	Replacement of existing old transformers with energy efficient transformers	185.9	11.5	22.6	2.0
3	Development of distribution lines from existing 11 kV to 33 kV	309.9	19.2	30.4	1.6
4	Deployment of manpower for strict vigilance	185.9	11.5	3.1	0.3
5	Awareness of officials and policy formation for Energy Efficiency in distribution sector	31.0	1.9	0.1	0.0
	Total	**929.6**	**57.6**	**106.6**	**1.8**
	Grand Total	**989.4**	**61.3**	**129.1**	**2.1**

4.5.4. Sustainability of Recommended Improvements

The energy efficiency measures recommend for Afghanistan are based on proven technologies implemented by different countries globally. The recommendations in hydropower and distribution sectors of Afghanistan are based on the country's economic scenario and ease of implementation.

4.6. Bangladesh

4.6.1. Technical Improvements

Bangladesh faces many technical and nontechnical issues that cause various losses in power sector. The large dependency on gas-based power plants and financial loss of utilities has caused huge losses in power sector. Some of the measures to reduce the losses in power sector are presented below:

- **Cogeneration Power Plants**: Bangladesh has around 537 MW simple cycle powerplants, which can be retrofitted with a heat recovery steam generator (HRSG), which will utilize exhaust gas from turbine to again generate power through steam turbine. Around 60% more generation can be achieved by installing HRSG system in the existing simple cycle gas turbines.
- **Installation of Monitoring Tools**: Efficiency of a power plant should be near the design value set by the manufacturer, which can be achieved by running the plant near to the design value prescribed for different load conditions. In Bangladesh thermal power plants, the critical parameters are not maintained causing loss in efficiency. There are various performance monitoring tools for analysing and diagnosis of losses that also provide suggestions to improve the critical parameters of plant.
- **Installation of Energy Efficient Equipment**: Bangladesh power utilities need to replace old inefficient motors, pumps and other auxiliary equipment with more energy efficient equipment. The oversized motors should be downsized or VFD can be installed on the respective motors to reduce the net auxiliary consumption by 3-4%.
- **Proper Maintenance and Operational Practices**: The auxiliary consumption from various equipment in power plant can be optimized by maintaining proper maintenance schedule. There must be proper monitoring of performance of each equipment and in case of any deterioration in performance is observed, the same should be rectified. Improvement in operational practices will extend the life of plant and also reduce expense of maintenance.
- **Awareness and Development of Officials in Energy Efficiency**: The main drivers of energy efficient practice in a utility are its own officials and supporting staff. More emphasis on power generation, rather than efficient power generation causes losses in the plant. Proper awareness sessions should be scheduled for officials on operation and efficiency.

The T&D losses in Bangladesh can be reduced by implementing following measures:

- **Installation of Smart Prepayment Metering System**: Smart prepaid meters can be beneficial in reducing net commercial losses of distribution network. The smart meters will cut the power supply in case of low balance.
- **Implementation of SCADA System**: SCADA system for distribution network helps the DISCO in monitoring the performance in the system. A smart distribution network will help operator to cut the supply in case of overloading of lines and can prevent the losses in transformers and LV lines.

- **Substation Automation System**: Automation of substation can be an effective measure to reduce overloading of feeders. In case of Bangladesh, the agricultural and domestic dominant feeders are overloaded due to hooking and under capacity of lines. The automation in feeders will detect the overloading and alarm the operator for either cutting supply of feeder or field checking for possible reasons of overloading.
- **Underground Distribution System**: Bangladesh should implement underground cabling of distribution lines in a phased manner. It should be started with areas having high T&D losses like sub urban areas of city and tier 3 cities. It is effective way to reduce net technical and commercial losses. The undergrounding of lines is a capital-intensive programme, but it is beneficial in the long run.
- **HVDS Network**: Bangladesh can expand its HVDS network in rural and sub urban cities, where transformers are located at a distance from the load centre. Plan should be formed to reduce the share of LV lines and stepping down of voltage should be done near load centre only.

4.6.2. Nontechnical Reforms

There are various nontechnical reforms, which Bangladesh can adopt for loss reduction in power generation and distribution sector:

- **Renovation of Old Plants:** The government should form policies for feasibility studies of old thermal power plants running on oil and gas. The policies should clearly establish baselines on energy efficiency and the power plants and the utilities, which are below that efficiency level should opt for complete renovation and implementation of best technologies available in market to make their plants more efficient and reduce cost of generation.
- **The Sustainable and Renewable Energy Development Authority:** The necessary amendment should be done in The Sustainable and Renewable Energy Development Authority Act, to provide power to agency in implementing penalties to the utilities and forming policy to only procure energy efficient equipment in their utilities. The agency should conduct regular training programmes for officials in energy efficiency and load reduction techniques adopted globally.
- **Energy Audit**: The Sustainable and Renewable Energy Development Authority has laid the regulations for energy audit in the country, but it should implement framework to bind the utilities for mandatory energy audits. The agency should oversee the recommendations of the audit and, measures taken by the utilities in implementing the recommendations.
- **Target for Load Reduction**: The utilities should be provided load reduction targets depending upon the economic and geographical condition of DISCOs. The DISCOs should be provided incentives in tariff revision in case they have achieved their load reduction targets.

4.6.3. Cost Benefit Analysis of Recommended Improvements

In Table 36 various energy conservation measures, recommended for adoption in Bangladesh, have been computed along with indicative cost and estimated annual savings in energy. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for Bangladesh is taken as 0.67 tCO_2/MWh (Department of Environment), the total GHG reduction potential is 8.48 million tCO_2 annually. A total of 5,231 GWh of electricity saving can be achieved in power generation with a monetary value of USD 376.7 Million. The cost of implementation of measures is USD 285.4 million for generation sector with an average payback of 1 year. In distribution sector the target achievable saving is of 7,419 GWh with a monetary value of USD 535 Million. The cost of implementation of these measures is USD 690 million with an effective payback of 1.3 years. The total cost of implementation of energy efficiency measure for Bangladesh is USD 975 Million.

Table 36 Cost benefit analysis for Bangladesh

S. No.	Energy Saving Measures	Annual Energy Saving Potential		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (Million tCO2)
		(GWh)	(Million USD)			
Generation						
1	Installation of HRSG system in simple cycle power plant	4,759.0	342.6	256.8	0.7	3.2
2	Installation of monitoring tool for power plant	323.1	23.3	3.4	0.1	0.2
3	Replacement of existing old inefficient equipment with efficient and process improvements	143.0	10.3	24.6	2.4	0.1
4	Awareness of officials and policy formation for energy Efficiency in generating station	6.6	0.5	0.7	1.5	0.004
	Sub Total of Generation	**5,231.6**	**376.7**	**285.4**	**1.0**	**3.5**
Distribution						
1	Installation of smart meters for existing consumers	2,374.2	170.9	127.9	0.7	1.6
2	Development of distribution lines from existing 11 kV to 33 kV	2,411.3	173.6	473.4	2.7	1.6
3	Replacement of existing old transformers with energy efficient transformers	2,225.8	160.3	77.9688	0.5	1.5
4	Automation of feeders	371.0	26.7	10.5	0.4	0.2
5	Awareness of officials and policy formation for energy Efficiency in distribution sector	37.1	2.7	0.56	0.2	0.02
	Sub Total of Distribution	**7,419.4**	**534.2**	**690.4**	**1.3**	**5.0**
	Grand Total	**12,651.1**	**910.9**	**975.8**	**1.1**	**8.48**

4.6.4. Sustainability of Recommended Improvements

Energy efficiency measures for power sector in Bangladesh are based on consultation with stakeholders and various past studies conducted over past 5 years. The recommendations provided have proven energy savings in many countries across the globe. In addition, these measures have scope of continuous improvements in future. The replicability of the recommendations in public and private sector is substantially high.

4.7. Bhutan

Bhutan has majority of power generation by hydro power plants and it is a net exporter of electricity to neighbouring countries. There are various measures, which can be implemented in Bhutan to increase its generation capacity and reduce the net losses in the system.

4.7.1. Technical Improvements

Some key improvements that should be initiated in hydropower generation plants of Bhutan are:

- **Turbines Maintenance and Replacement**: The water turbine of hydropower plants is major area of losses in the hydro power generation. The sediment supply and transport in the Himalayas is quite significant and is considered to be highest in the world (Choden, 2009). Due to heavy silt in water, turbine is eroded and causes lower efficiency of total system. The efficiency of turbine can be improved by periodic inspection and maintenance of turbine. Also, in case a replacement is necessary, original OEM of the power plant can suggest compatible turbine, which can increase the electricity generation by 30% of the original rated capacity at a given head (Bernard, 2020). Overall increase in the efficiency can be in range of 2-5% above the present efficiency.
- **Actions to Reduce Friction in the Water Conveyance Systems**: There should be regular cleaning and removal of sediments, algae and unwanted plantations.
- **Pump Storage in Power Plant**: The head in reservoir should be maintained close to design level of dam. So that during power generation maximum efficiency from the turbine can be achieved with less inherent losses of the turbine system. Bhutan generation utilities can opt for pump storage type power plant for their upcoming and existing plants. It will help in restoring the optimum head in the reservoir and the plant will generate power at maximum efficiency.

The T&D losses in Bhutan were 10.93% for FY 2018-19 (Bhutan Power Corporation Limited, 2019). The losses in Bhutan can be improved by implementing following measures:

- **Upgrade of Distribution Network**: The distribution network in Bhutan should be upgraded with advance SCADA system in substations. This will help BPC in monitoring line and feeder loading/losses and take preventive measures to reduce losses.
- **Transformer Replacement**: Bhutan has no clear standards for selection of transformers for the distribution network. As a result, there may be many inefficient/oversized/undersized transformers working in the distribution network. The existing transformers in Bhutan can be replaced by more efficient transformers for reducing the T&D losses in the distribution system. In addition, proper maintenance and connections should be done to prevent losses in the transformer system.
- **HVDS System to Preventing Line Losses**: Bhutan, being a hilly terrain, needs long distribution line to supply power to consumers at different areas. This has resulted in long lines that should be redesigned and HVDS should be implemented to reduce losses in the long lines of the network and the transformers should be located near the load centres.

4.7.2. Nontechnical Reforms

There are various nontechnical reforms, which Bhutan can adopt for loss reduction in power generation and distribution sectors:

- **Feasibility for Pump Storage Power Plants:** The government should emphasis more on pump storage type hydropower stations for future projects. This will provide more flexibility for power generation and will reduce the losses incurred in plant due to low head in dry seasons.
- **Energy Audit**: Bhutan has no clear guidelines for utilities to conduct energy audits. The government should implement framework for mandatory energy audits of power generation and distribution utility at a defined period of time. An agency/department should be formed to overlook the implementation of audit recommendations by the utilities and its M&V. This could be started on voluntary basis and made mandatory after first or second phase.

4.7.3. Cost Benefit Analysis of Recommended Improvements

There are various recommendations for power generation and distribution sectors of Bhutan as mentioned in previous sections. In Table 37 various energy conservation measures along with indicative cost and estimated annual savings have been tabulated. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for Bhutan is considered as 0.1 tCO_2/MWh (the average factor for run-off river and small reservoir hydro plant), the total GHG reduction potential is 0.057 million tCO_2 annually. A total of 504 GWh of electricity saving can be achieved in power generation with a monetary value of USD 17.1 million. The cost of implementation of measures is USD 58.2 million for generation sector with an average payback of 3 years. In distribution sector the target achievable saving is of 67.2 GWh with a monetary value of USD 2.3 million. The cost of implementation of these measures is USD 3.7 million with an effective payback of 2 years. The total cost of implementation of energy efficiency measure for Bhutan is USD 61.8 million.

Table 37 Cost benefit analysis for Bhutan

S. No.	Energy Saving Measures	Annual Energy Saving Potential		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (Million tCO2)
		(GWh)	(Million USD)			
Generation						
1	Proper maintenance of turbine and related auxiliaries	275.1	9.4	58.2	6.2	0.03
2	Reduction of friction in the water conveyance systems	183.4	6.2	3.4	0.1	0.02
3	Awareness of officials and policy formation for energy Efficiency in generating station	45.9	1.6	0.03	0.02	0.005
	Sub Total of Generation	**504.4**	**17.1**	**58.2**	**3.4**	**0.05**
Distribution						
1	Replacement of existing old transformers with energy efficient transformers	33.6	1.1	1.4	1.2	0.003
2	Development of distribution lines from existing 11 kV to 33 kV	33.6	1.1	2.3	2.0	0.003
	Sub Total of Distribution	**67.2**	**2.3**	**3.7**	**2.0**	**0.01**
	Grand Total	**571.6**	**19.4**	**61.8**	**3.2**	**0.057**

4.7.4. Sustainability of Recommended Improvements

Bhutan being a net exporter of electricity can easily implement energy efficiency measures suggested in the above section. The measures have a sustainable future, as once these measures are adopted, they can easily serve Bhutan long-term.

4.8. India

India's power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil, hydro and nuclear power to viable unconventional sources such as wind, solar, and agricultural and domestic waste. Electricity demand in the country has increased rapidly and is expected to rise further in the years to come. In order to meet the increasing demand for electricity in the country, massive addition to the installed generating capacity is required.

4.8.1. Technical Improvements

There are various technical improvements, which can be done in generation sector to improve the energy efficiency and reduce the losses:

- **Proper Use of Monitoring Tools**: In India, NTPC and many state utilities have installed online performance monitoring tools for monitoring the deterioration in performance on a real time basis. Many OEMs like BHEL, L&T and others provide these tools as a part of total BTG package. But it is observed that operators pay less importance to that system after few years of its commissioning. The utilities should motivate their officials to use the system and based upon the recommendations by the system, necessary measures should be performed by the system operator.
- **Improvement in Auxiliary Power Consumption**: Indian coal fired power plants have an average auxiliary power consumption in the range of 8-15% depending upon the size and technology used in the plant. There should be improvement of 2-3% in some of the generating stations by replacing existing motors with energy efficient motors, preventing oversizing of equipment and use of VFD system where downsizing of equipment is not be possible.
- **Process Improvement**: Most of the generating stations in India have a standard operating practice in place for different processes in the power plant but due to lack of awareness and training these SOPs are not followed by the operators. Various process in the plant like start up, shut down, ramping up of load, maintaining the firing of fuel among others should be done by following proper steps as suggested by OEM.
- **Turbines Maintenance and Replacement**: The water turbine of hydropower plants is major area of losses in the hydro power generation. Due to heavy silt in water turbine is eroded and causes loss in efficiency of total system. The efficiency of turbine can be improved by periodic inspection and maintenance of turbine. Overall increase in the efficiency can be in range of 2-5% of the present efficiency.
- **Proper Maintenance and Operation Practices**: The auxiliary consumption from various equipment in power plant can be optimized by maintaining proper maintenance schedule. There must be proper monitoring of performance of each equipment and in case of any deterioration in performance is observed, the same should be rectified. Improvement in operational practices will extend the life of plant and also reduce expense on maintenance. Also, proper overhauling schedule should be followed by the maintenance team of plant.

- **Awareness and Development of Officials in Energy Efficiency**: The main drivers of energy efficient practice in a utility are its own officials and supporting staff. More emphasis on power generation, rather than efficient power generation causes losses in plant. Proper sessions should be scheduled for officials on operation practices and efficiency.

The average AT&C losses in India are around 20.7%. The losses in India can be improved by implementing following measures:

- **Substation Automation System**: In India only, few utilities have automatic substations and all other utilities still rely on manual control of substations. Automation of substation can be an effective measure to reduce overloading of feeders. The automation in feeders will detect the overloading and alarm the operator for either cutting supply of feeder or field checking for possible reasons of overloading.
- **Underground Distribution System**: An effective way to reduce net technical and commercial losses in India is by undergrounding the distribution lines. The undergrounding of lines is a capital-intensive programme, but it is beneficial in long-term. It reduces hooking on lines and can also be effective to reduce effect of weather on distribution network. In smart city project of India, all the electricity distribution lines are undergrounded, which will minimise line losses.
- **Promotion of Net Metering System**: Net metering can be helpful in reducing losses due to domestic and agricultural consumers, it allows the consumer to sell excess generation from renewable source of energy like wind and solar in their fields and homes. As government subsidise the tariff for these consumers, it can be helpful to reduce subsidy burden and sell electricity to more profitable consumers like commercial and Industrial. Also, due to net metering, there are less chances of tampering in meters.
- **Transformer Replacement**: The existing transformers in many utilities in India are overloaded and inefficient, which can be replaced by more efficient transformers for reducing the T&D losses in the distribution system. Also, proper maintenance and connections should be done to prevent losses in the transformer system.

4.8.2. Nontechnical Reforms

There are various nontechnical reforms, which India can adopt for loss reduction in power generation and distribution sector:

- **Monitoring of PAT Data**: India has PAT scheme, which mandates energy audits of designated consumers like power generation and distribution companies. Presently, utilities themselves procure services of various empanelled agencies to conduct M&V and energy audits. The government should change this practice by hiring its own agencies and conducting energy audits of utilities. This will help government to access more accurate data and evaluate actual losses in the utilities.
- **More Effective Policy for Commercial Losses**: The government of India has formed various policies to reduce the commercial losses of DISCOMs but at actual field level there are various issues like security of vigilance team, political interference and others; which prevent utilities in imposing fines and disconnecting the connections of defaulters. These issues should be addressed in the revised policy guidelines by the government.
- **Standardization for Procurement**: The government should only allow highly efficient equipment to be used in power sector. There should be performance and energy efficiency related clauses in the tenders, which can resist the inflow of inefficient products in the distribution and generation utilities.

- **Fuel Shortage:** Gas based, and imported coal based thermal plants faces issues of shortage or expensive fuel prices causing them to either shut down their operation or run of bare minimum load. Due to expensive imported coal price, some plants need to run on Indian coal, which is of high ash content causing deterioration of overall efficiency of the plant.

4.8.3. Cost Benefit Analysis of Recommended Improvements

The various recommendations for power generation and distribution sectors of India as mentioned in above sections have been summarised in Table 38, along with indicative cost and estimated annual saving potential. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for India is taken as 0.82 tCO_2/MWh (Central Electricity Authority, 2018), the total GHG reduction potential is 97.4 million tCO_2 annually. A total of 11,137 GWh of electricity saving can be achieved in power generation with a monetary value of USD 467 million. The cost of implementation of measures is USD 1,367 million for generation sector with an average payback of 3 year. In distribution sector, the target achievable saving is of 107,667 GWh with a monetary value of USD 4,522 million. The cost of implementation of these measures is USD 17,766 million with an effective payback of 4 years. The total cost of implementation of energy efficiency measure for India is USD 19,133 Million.

Table 38 Cost benefit analysis for India

S. No.	Energy Saving Measures	Annual Energy Saving Potential		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2)
		(GWh)	(Million USD)			
Generation						
1	Replacement of existing old inefficient equipment with efficient and process improvement	4,348.0	182.6	315.9	1.7	3.6
2	Training of officials and redevelopment of monitoring tool for gas and coal based thermal power plant	207.4	8.7	22.4	2.6	0.2
3	Awareness of officials and policy formation for Energy Efficiency in generating station	2,535.1	106.5	0.8	0.0	2.1
4	Proper maintenance of turbine and related auxiliaries of hydro power plant	4,046.8	170.0	1,028.2	6.0	3.3
	Sub Total Generation	**11,137.2**	**467.8**	**1,367.4**	**2.9**	**9.1**
Distribution						
1	Programme for under-ground distribution system	23,926.2	1004.9	8232.2	8.2	19.6
2	Development of distribution lines from existing 11 kV to 33 kV	35,889.3	1507.3	2837.0	1.9	29.4

S. No.	Energy Saving Measures	Annual Energy Saving Potential		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2)
		(GWh)	(Million USD)			
3	Replacement of old transformers with energy efficient transformers	41,870.8	1758.6	6696.585	3.8	34.3
4	Awareness of officials and policy formation for Energy Efficiency in distribution sector	5,981.5	251.2	0.42	0	4.9
	Sub Total Distribution	**107,667.8**	**4522.0**	**17,766.2**	**3.9**	**88.3**
	Grand Total	**118,805.1**	**4,989.8**	**19,133.6**	**3.8**	**97.4**

4.8.4. Sustainability of Recommended Improvements

The measures suggested for India are very specific and based on the studies and reports done by various agencies in India. The measures suggested are already implemented by some utilities in India, with proven energy savings. Most of the technological improvements suggested are available domestically and in case of any update in technology, it can be easily implemented on the existing system.

4.9. Maldives

The Republic of Maldives is a small island nation located in the Indian Ocean southwest of Sri Lanka. It consists of some 26 major atolls and 1,190 tiny islands. Of these islands, only 33 have an area greater than one square kilometre. The total land area is less than 300 square kilometres. Due to the mentioned geographical conditions, Maldives mainly relies on diesel-based IC engines for power generations. It does not have a centralized grid except for Male region and all the power distribution network is unique for each island.

4.9.1. Technical Improvements

There are various technical improvements, which can be done in generation sector to improve the energy efficiency and reduce the losses:

- **Flue Gas Heat Recovery System for Air-conditioning (FGHR-AC)**: FGHR-AC process is designed to recover waste heat from exiting flue gas to produce air conditioning effect. Flue gas is drawn from the exhaust gases from generator, using a slip stream fan and passes over the gas to water heat exchanger (GWh) to heat the water. The hot water serves as an input to the Vapour Absorption Machine (VAM) driving Li-Br cycle.
- **Exhaust Gas Recirculation (EGR)**: EGR system recirculates the exhaust gas back in the engine, which contains unburnt fuel and carbon, reduces the combustion temperature, hence bringing down NOx. While doing so, PM increases, which is then controlled outside the engine using a filter. It is an easy-to-use system with low initial cost. The EGR system has potential of reducing SOC by 5-8% (ICF and Shakti Foundation, 2017).
- **Variable Geometry Turbocharger (VGT) with Intercooler**: The VGT turbochargers can be used in generators to maintain the aspect ratio with the change in speed and load of the generators. As most of the power network in Maldives are independent network, sudden change in load

condition is quite common. The VGT can help in increasing torque availability at low speeds and hence improve fuel economy (Adam J.Feneley, 2017).

- **Micro-processor-based Engine Control**: This system can be used to improve the efficiency of DG engine due to better fuel control and easy variation of engine load with load fluctuation.
- Ensure steady load conditions on the DG set, and provide cold, dust free air at intake.
- Consider fuel oil additives in case they benefit fuel oil properties for DG set usage.

The T&D losses in Maldives are around 8%. The losses in Maldives can be improved by implementing following measures:

- **Underground Cabling**: An effective way to reduce net technical and commercial losses in Maldives is by undergrounding the distribution lines. It reduces hooking on lines and can also be effective to reduce effect of whether on distribution network.
- **Replacement of Transformers with Compact Transformers**: Electric transformer power loss typically contributes to about 40% of the total transmission and distribution loss in small distribution networks like in Maldives. The existing transformers in Male are overloaded and inefficient, which can be replaced by more efficient transformers for reducing the T&D losses in the distribution system. In addition, proper maintenance and connections should be done to prevent losses in the transformer system.
- **Changing 11 kV lines with 33 kV lines**: Maldives faces the problem of overloaded distribution lines in Male area. The overloading of lines can be prevented by replacing existing 11 kV lines with 33 kV lines, which will reduce the line losses and increase line capacity.
- **Installation of Smart Prepayment Metering System**: Smart prepaid meters can be beneficial in reducing net commercial losses of distribution network. The smart meters will only work when the meters have sufficient balance thus improving collection efficiency.

4.9.2. Nontechnical Reforms

There are various nontechnical reforms, which Maldives can adopt for loss reduction in power generation and distribution sector:

- **Standardization of Specific Oil Consumption for DG set**: Many countries have standardized the SPC of generators depending upon the size of generator. Like in India, Bureau of Indian Standards (BIS) is the authorised institution to set quality, safety, and performance standards for equipment and appliances. Vide IS 10001, BIS has notified mandatory maximum energy consumption limit in terms of SFC for diesel generators up to 19 kW capacities. As per this notification, it is illegal to manufacture and sell a diesel generator set of up to 19 kW for which SFC exceeds the BIS specified limits. Similarly, Maldives can implement these standards which will enable only energy efficient DG sets be available in the market. IS 10001 has prescribed SFC limit for diesel generator ranging from 19 kW to 500 kW (ICF and Shakti Foundation, 2017) as presented in Table 39.

Table 39 SFC limit of generator set ranging from 19 kW to 500 kW

Rated engine speed (rev/min)	SFC (max) (gm/kWh)	
	Direct injection	Indirect injection
Up to 1000	276	303
Above 1000 up to 2000	252	277
Above 2000	309	340

- **Energy Audit**: The government should implement framework for mandatory energy audits of power generation and distribution utility at a defined period of time. An agency that can overlook the recommendations of the audits and actions taken by the utilities should be formed. There should be a regulation to bind the utility in decreasing the losses and in case the utilities are not able to achieve the goal, penalties should be imposed on them.
- **Prioritize Use of Renewables**: Maldives mostly rely on DG sets for supplying power to consumers, which is one of the costliest and polluting source of power generation. Diesel import leads to foreign exchange loss to the government. The government should form policies to motivate use of renewables to reduce the dependency on DG sets.

4.9.3. Cost Benefit Analysis of Recommended Improvements

In Table 40 various energy conservation measures have been tabulated along with indicative cost and estimated annual savings. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for Maldives is taken as 0.74 tCO_2/MWh (Government of Japan, 2019), the total GHG reduction potential is 0.047 million tCO_2 annually. A total of 48 GWh of electricity saving can be achieved in power generation with a monetary value of USD 16.9 million. The cost of implementation of measures is USD 22.1 million for generation sector with an average payback of 1.3 years. In distribution sector the target achievable saving is of 14.8 GWh with a monetary value of USD 5.2 million. The cost of implementation of these measures is USD 7.3 million with an effective payback of 1.3 years. The total cost of implementation of energy efficiency measure for Maldives is USD 29.3 million.

Table 40 Cost benefit analysis for Maldives's power sector

S. No.	Energy Saving Measures	Annual Energy Saving		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2
		(GWh)	(Million USD)			
Generation						
1	Installation of flue gas recovery system	24.1	8.5	10.0	1.2	0.02
2	Installation of Variable Geometry Turbocharger (VGT) with intercooler	20.1	7.0	12.0	1.7	0.01
3	Awareness of officials and policy formation for Energy Efficiency in generating station	4.0	1.4	0.1	0.0	0.003
	Sub Total Generation	**48.2**	**16.9**	**22.1**	**1.3**	**0.04**
Distribution						
1	Programme for underground distribution system	5.2	1.8	4.4	2.4	0.004
2	Replacement of existing old transformers with compact transformers	7.4	2.6	2.8	1.1	0.01
3	Awareness of officials and policy formation for Energy	2.2	0.8	0.084	0.1	0.002

S. No.	Energy Saving Measures	Annual Energy Saving		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2
		(GWh)	(Million USD)			
	Efficiency in distribution sector					
	Sub Total Distribution	**14.8**	**5.2**	**7.3**	**1.4**	**0.01**
	Grand Total	**63.0**	**22.1**	**29.3**	**1.3**	**0.047**

4.9.4. Sustainability of Recommended Improvements

The recommendations provided for power sector in Maldives are sustainable. Many references and experiences of similar countries around the world suggest high energy efficiency potential of these recommended measures.

4.10. Nepal

Nepal has an estimated potential of 42,000 MW of hydropower plant, but it is still power deficit and relies on import of electricity from neighbouring country. Due to various inefficiencies in the power system, gap in demand and supply of power is increasing.

4.10.1. Technical Improvements

There are various technical improvements, which can be done in generation sector to improve the energy efficiency and reduce the losses:

- **Pump Storage in Power Plant**: The head in reservoir should be maintained close to design level of dam. So that during power generation maximum efficiency from the turbine can be achieved with less inherent losses of the turbine system. Nepal generation utilities can opt for pump storage type power plant for their upcoming and existing plants. It will help in restoring the optimum head in the reservoir and the plant will generate power at maximum efficiency.
- **Actions to Reduce Friction in the Water Conveyance Systems**: Redesigning the existing water conveyance system can be capital intensive. So regular cleaning and removal of sediments, algae and unwanted plantations from the water path do make passage smoother and less resistant.
- **Turbines Maintenance and Replacement**: Regular maintenance and inspection of turbines should be done in all the hydropower plant. Overall increase in the efficiency can be in range of 2-5% of the present efficiency through regular maintenance.
- **Proper Maintenance Practice**: The auxiliary consumption from various equipment in hydropower plant can be optimized by maintaining proper maintenance schedule. There must be proper monitoring of performance of each equipment and in case of any deterioration in performance is observed, the same should be rectified.

The average T&D losses in Nepal are approximately 11.28%. The losses in some areas are around 23% e.g., for Janakpuri. The T&D losses in Nepal can be improved by implementing following measures:

- **HVDS System to Prevent Line Losses**: Nepal needs long distribution line to supply power to consumers at different areas. This has resulted in long LV lines. These lines should be redesigned and HVDS should be implemented to reduce losses in long lines of the network and the transformers should be located near the load centres.
- **Smart Meters**: Nepal has implemented smart meters in Kathmandu area, but it needs to replace all the existing manual meters with smart meters, which are tampering proof and will reduce the commercial losses in the system. As it may be observed that Kathmandu has 7.4% T&D losses, as compared to national average T&D losses of 11.28%.
- **Installation of Net Metering System**: Net metering can be helpful in reducing losses as it allows the consumer to generate electricity for own use and sell excess generation to the grid. As government subsidises the tariff for domestic and agricultural consumers, it can be helpful to reduce subsidy burden. Also due to net metering, there are less chances of tampering meters.
- **Strict Vigilance**: The main share in T&D losses in Nepal is because of unmetered connections and theft. The lines are overload due to illegal hooking on the lines. Setting up vigilance squads to check and prevent pilferage of energy, and impose severe penalties can help in this regard.

4.10.2. Nontechnical Reforms

There are various nontechnical reforms, which Nepal can adopt for loss reduction in power generation and distribution sector:

- **Energy Audit**: Nepal has not formed any regulations for utilities, which bind them in conducting energy audits and establishing baseline losses for their utility. The government should implement framework for mandatory energy audits of power generation and distribution utility at a defined period of time. An agency should be formed to look after the audits of utilities and follow up with the implementation of recommendations of such audits.
- **Standardization for Procurement**: Procurement of energy efficient equipment should be encouraged and necessary clauses should be added in the contracts of power projects to ensure that new equipment is as energy efficient as possible.
- **Privatization of Utilities**: Nepal should encourage more private entities in power sector to invest in power generation and distribution sectors. This will allow technological improvement in the power sector and will significantly reduce the losses.

4.10.3. Cost Benefit Analysis of Recommended Improvements

There are various recommendations for the improvement of power generation and distribution sector of Nepal as mentioned in above sections. In Table 41, these recommendations have been summarised along with indicative cost and estimated annual savings. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for Nepal is considered as 0.1 tCO2/MWh (the average factor for run-off river and small reservoir hydro plant), the total GHG reduction potential is 0.032 million tCO_2 annually. A total of 164 GWh of electricity saving can be achieved in power generation with a monetary value of USD 16.4 million. The cost of implementation of measures is USD 46 million for generation sector with an average payback of 3 years. In distribution sector, the target achievable saving is of 158 GWh with a monetary value of USD 16 million. The cost of implementation of these measures is USD 60 million with an effective payback of 4 years. The total cost of implementation of energy efficiency measure for Nepal is USD 106 million.

Table 41 Cost benefit analysis for Nepal

S. No.	Energy Saving Measures	Annual Energy Saving		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2
		(GWh)	(Million USD)			
Generation						
1	Proper maintenance of turbine and related auxiliaries	89.4	8.9	45.9	5.0	0.009
2	Reduction of friction in the water conveyance systems	59.6	6.0			0.006
3	Awareness of officials and policy formation for energy Efficiency in generating station	14.9	1.5	0.03	0.02	0.001
	Sub Total Generation	**163.8**	**16.4**	**45.9**	**3.0**	**0.016**
Distribution						
1	Installation of smart meters for high losses region of NEA	81.9	8.2	32.8	4.04	0.008
2	Development of distribution lines from existing 11kV to 33 kV in areas where load centre is far from substations.	56.7	5.7	27.1	5.0	0.006
3	Awareness of officials and policy formation for EE in distribution sector	18.9	1.9	0.084	0.0	0.002
	Sub Total Distribution	**157.6**	**15.8**	**60.1**	**4.0**	**0.016**
	Grand Total	**321.4**	**32.1**	**106.0**	**3.3**	**0.032**

4.10.4. Sustainability of Recommended Improvements

The energy efficiency measures recommended for Nepal are based on proven technologies implemented by different countries globally. The recommendations in hydropower sector and distribution sector of Nepal are based on the country economic scenario and the measures suggested can be easily implemented in the country.

4.11. Pakistan

Pakistan faces many technical and nontechnical issues that cause various losses in power sector. The improvements in power sector have been divided into technical and nontechnical measures for both generation and distribution sectors.

4.11.1. Technical Improvements

There are various technical improvements, which can be done in generation sector to improve the energy efficiency and reduce the losses:

- **Installation of Monitoring Tools**: Efficiency of a power plant should be near the design value set by the manufacturer, which can be achieved by running the plant near to the design value prescribed for different load conditions. In some of the Pakistan's thermal power plants, the critical parameters are not maintained causing loss in efficiency. There are various performance monitoring tools available for analysing and diagnosis of losses and to provide suggestions to the plant operator to maintain efficiency.

- **Installation of Energy Efficient Equipment**: The auxiliary power consumption (APC) of coal power plant in Pakistan can be as high as 26.73% whereas APC in developed countries for similar plants is in the range of 6.5 to 9.6% (Dileep Kumar, 2017). Pakistan power utilities needs to replace old inefficient motors, pumps and other auxiliary equipment with more energy efficient equipment. The oversized motors should be downsized or VFD can be installed on the respective motors to reduce APC.
- **Proper Maintenance and Operation Practices**: There must be proper monitoring of performance of each equipment, particularly turbines, and in case of any deterioration in performance is observed, the same should be rectified. Improvement in operational practices will extend the life of plant and also reduce expense of maintenance.
- **Awareness and Development of Officials**: The main drivers of energy efficient practice in a utility are its own officials and supporting staff. Awareness sessions for officials should be scheduled for better understanding of energy efficiency and best operational practices.

The T&D losses in Pakistan distribution sector can be improved by implementing following measures (Khan, 2013):

- **Underground Cabling**: An effective way to reduce net technical and commercial losses in Pakistan is by undergrounding the distribution lines. The undergrounding of lines is a capital-intensive programme, but it is beneficial in the long run. It reduces hooking on lines and can also be effective to reduce effect of whether on distribution network.
- **Installation of Smart Prepayment Metering System**: Smart prepaid meters can be beneficial in reducing net commercial losses of distribution network. The smart meters will only work when the meters have sufficient balance thus improving collection efficiency.
- **Identification of the Major Loss:** Pakistan has a large diversity in terms of terrain. The DISCOs should identify the major area of losses and the type of commercial losses encountered by the utility. The losses can be in form of tempered meters, hooking on the lines or corruption at the lower level.
- Reducing the length of LT lines by relocation of distribution sub stations/installations of additional distribution transformers (DTs). The major losses in the distribution lines are in agricultural fields. So, the HVDS system can be adopted and low-capacity distribution transformers can be installed near to load only.
- Proper sizing of distribution transformers based on loading close to its best efficiency point.
- Formation and substitution of DTs with those having lower no load losses such as amorphous core transformers.
- Installation of shunt capacitors for improvement of power factor in the distribution network.

4.11.2. Nontechnical Reforms

Some nontechnical reforms, which Pakistan can adopt for loss reduction in power generation and distribution sectors, are presented below:

- **Energy Accounting of Utilities**: The government should implement framework for mandatory energy accounting of power generation and distribution utilities at a defined period of time.

NEPRA may be mandated to check the loss figures submitted by the utilities and remedial measures adopted by them to curtail the losses.

- **Standardization for Procurement**: Procedures should be developed to ensure that only energy efficient equipment is procured for the new power sector projects.
- **Privatization of Utilities**: Pakistan should encourage more private entities in power sector to invest in power distribution sector. Currently, only a single DISCO is owned by private sector in Pakistan. This will allow technological improvement in the power sector and will significantly reduce the losses.
- **Shift in Power Generation Type**: Government should consider shifting the generation to more efficient and cost-effective power generation technologies like super critical thermal power plants, renewables, pump storage type hydro power plants etc. This will enable more flexibility in operation and will conserve precious natural resources from being wasted in inefficient power plants.

4.11.3. Cost Benefit Analysis of Recommended Improvements

Table 42 presents a summary of the recommendations for the improved performance of power generation and distribution sectors of Pakistan along with indicative cost and estimated annual energy and monetary savings. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for Pakistan is taken as 0.7 tCO_2/MWh (Kentaro Takahashi, 2021), the total GHG reduction potential is 8.2 million tCO_2 annually. A total of 3,518 GWh of electricity saving can be achieved in power generation with a monetary value of USD 211 million. The cost of implementation of measures is USD 346 million for generation sector with an average payback of wo years. In distribution sector the target achievable saving is of 8,156 GWh with a monetary value of USD 489 million. The cost of implementation of these measures is USD 2,136 million with an effective payback of four years. The total cost of implementation of energy efficiency measure for Pakistan is USD 2,481 million.

Table 42 Cost benefit analysis for Pakistan

S. No.	Energy Saving Measures	Annual Energy Saving		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2)
		(GWh)	(Million USD)			
Generation						
1	Installation of monitoring tool for power plant	210.3	12.6	5.3	0.4	0.1
2	Replacement of existing old inefficient equipment with efficient and process improvement	2,416.2	145.0	20.16	0.1	1.7
3	Proper maintenance of turbine and related auxiliaries of hydro power plant	664.0	39.8	320.22	8.0	0.5
4	Awareness of officials and policy formation for energy Efficiency in generating station	227.5	13.6	0.56	0.5	0.2

S. No.	Energy Saving Measures	Annual Energy Saving		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2)
		(GWh)	(Million USD)			
	Sub Total Generation	**3,518**	**211**	**346**	**1.6**	**2.5**
Distribution						
1	Replacement of LV lines with HV lines of 11 kV and 33 kV in high loss DISCOs	2,548.8	152.9	819.7	5.4	1.8
2	Replacement of old meters with smart prepaid meters	2,039.0	122.3	433.8	3.6	1.4
3	Replacement of old transformers with energy efficient transformers	3,058.5	183.5	882.0	4.8	2.1
4	Awareness of officials and policy formation for energy Efficiency in distribution sector	509.8	30.6	0.7	0.1	0.4
	Sub Total Distribution	**8,156.1**	**489.4**	**2,136.2**	**4.4**	**5.7**
	Grand Total	**11,674.0**	**700.4**	**2,481.0**	**3.5**	**8.2**

4.11.4. Sustainability of Recommended Improvements

The measures suggested for Pakistan are based on best practices followed globally to reduce the losses in power sector. There are recommendations for each type of power generation and efforts have been done to consider each and every aspect of the losses and their remedial measures. The measures suggested have a sustainability in the near future and can be upgraded. The replicability of the recommendations in public and private sector is substantially high.

4.12. Sri Lanka

Sri Lanka's current electricity generation portfolio is made up of both grid-connected and off-grid systems. While the grid-connected space is dominated by the CEB, there is also a significant presence of private independent power producers who are well versed in generating electricity through renewables. Off-grid systems on the other hand are few, consisting of mostly diesel or renewable powered setups. The generation in Sri Lanka is predominant by hydro power generation followed by use of coal and oil. Due to seasonal dependency of hydro power plants in Sri Lanka, it faces issue of low efficiency of oil-based power generation and more dependency on costly source of power generation.

4.12.1. Technical Improvements

There are various technical improvements, which can be done in generation sector to improve the energy efficiency and reduce the losses:

- **Cogeneration Power Plants**: Sri Lanka's simple cycle powerplants, can be retrofitted with a heat recovery steam generator (HRSG), which will utilize exhaust gas from turbine to again generate power through steam turbine. Reportedly, 60% more generation can be achieved by installing HRSG system in the existing simple cycle gas turbines.

- **Installation of Monitoring Tools**: Efficiency of a power plant should be near the design value set by the manufacturer, which can be achieved by running the plant near to the design value prescribed for different load condition. In Sri Lanka, the critical parameters of thermal power plants are not maintained causing loss in efficiency. There are various performance monitoring tools for analysing and diagnosis of losses which could support the operator in maintaining the critical parameters of plant.
- **Installation of Energy Efficient Equipment**: Sri Lanka power utilities need to replace old inefficient motors, pumps and other auxiliary equipment with more energy efficient equipment. The oversized motors should be downsized or VFD can be installed on the respective motors to reduce the net auxiliary consumption by 2-3%.
- **Turbines Maintenance and Replacement**: The efficiency of water turbine of hydropower plants can be improved by periodic inspection and maintenance of turbine. Overall increase in the efficiency can be in range of 2-5% above the present efficiency through periodic maintenance.
- **Proper Maintenance and Operation Practices**: The auxiliary consumption from various equipment in power plant can be optimized by maintaining proper maintenance schedule. There must be proper monitoring of performance of each equipment and in case of any deterioration in performance is observed, the same should be rectified. Improvement in operational practices will extend the life of plant and also reduce expense of maintenance.

The T&D losses in Sri Lanka distribution sector can be improved by implementing following measures:

- **Installation of Smart Prepayment Metering System**: Smart prepaid meters can be beneficial in reducing net commercial losses of distribution network. The smart meters will only work when the meters have sufficient balance.
- Replacement of existing inefficient transformers with more efficient transformers.
- Adopting system improvement measures with the implementation of medium voltage development proposals. These proposals include the installation of new primary substations, new distribution substations, feeder cables and feeder pillars and upgrading of substations and cables.
- Fixing of capacitors to feeder pillars in order to reduce the reactive current drawn within the distribution system.
- Improvement of workmanship and introduction of proper materials and tools which reduce most of TL (such as looseness of contacts of joints due to improper installation, loose connections in fuses and joints of service cables at the poles/junction boxes).
- Rehabilitation of LV network of estates with Ariel Bundled Conductors and GI pipes.

4.12.2. Nontechnical Reforms

There are various nontechnical reforms, which Sri Lanka can adopt for loss reduction in power generation and distribution sector:

- **Modernization of Existing Power Plants:** Sri Lanka has many oil-fired turbines running on simple cycle technology. Government should consider renovation and modernization of these existing power plants. There should be clear policy in place either to completely close these inefficient plants or to perform renovation and modernization activity to increase their efficiency.

- **Energy Audit**: The government of Sri Lanka should form policies for energy audit of power generation and distribution utility. The Sri Lanka Sustainable Energy Authority should overlook the recommendations of these audits and also check the savings incurred by utilities by implementing measures suggested to them.

4.12.3. Cost Benefit Analysis for Recommended Improvements

The various recommendations for power generation and distribution sectors of Sri Lanka have been summarised in Table 43. The indicative cost and estimated annual savings resulting from the recommended measures are also included. The annual monetary saving is calculated on the basis of average supply cost of power in the country. The grid emission factor for Sri Lanka is taken as 0.88 tCO_2/MWh (Kentaro Takahashi, 2021), the total GHG reduction potential is 1.6 million tCO_2 annually. The cost of recommended measures is considered based on various references and research done. A total of 1,450 GWh of electricity saving can be achieved in power generation with a monetary value of USD 145 million. The cost of implementation of measures is USD 631 million for generation sector with an average payback of 4 years. In distribution sector, the target achievable saving is of 341 GWh with a monetary value of USD 34 million. The cost of implementation of these measures is USD 153 million with an effective payback of 5 years. The total cost of implementation of energy efficiency measure for Sri Lanka is USD 784 million.

Table 43 Cost benefit analysis for Sri Lanka

S. No.	Energy Saving Measures	Annual Energy Saving		Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2)
		(GWh)	(Million USD)			
Generation						
1	Installation of HRSG system in simple cycle power plant	784	78.4	545.76	7.0	0.7
2	Installation of monitoring tool for power plant	323	32.3	1.456	0.05	0.3
3	Replacement of existing old inefficient equipment with efficient and process improvement	215.22	21.5	2.8518	0.1	0.2
4	Proper maintenance of turbine and related auxiliaries of hydro power plant	95.9	9.6	80.685	8.4	0.08
5	Policy formation for increasing energy efficiency in generating station	32	3.2	0.56	0.2	0.03
	Sub Total for Generation	**1,450**	**145**	**631**	**4.4**	**1.3**
Distribution						
1	Installation of smart prepaid meters for regions where T&D losses are maximum	104	10.4	40.0	3.9	0.09

S. No.	Energy Saving Measures	Annual Energy Saving (GWh)	Annual Energy Saving (Million USD)	Cost (Million USD)	Payback Period (Years)	GHG Reduction Potential (million tCO_2)
2	Replacement of existing LV lines with HV lines	148	14.8	112.3	7.6	0.13
3	Policy formation for decreasing T&D losses in distribution sector	89	8.9	0.63	0.1	0.08
	Sub Total for Distribution	**341**	**34**	**153**	**4.5**	**0.3**
	Grand Total	**1,790**	**179**	**784**	**4.4**	**1.6**

4.12.4. Sustainability of Recommended Improvements

Energy efficiency measures for power sector in Sri Lanka are provided on the basis of various studies conducted over the years in the nation. The recommendations provided have proven energy savings in many countries across the globe. Also, these measures have scope of continuous improvement in future.

5. Conclusion

The study reviewed several programmes, policies for energy efficiency in power generation and distribution. Detailed consultations with public and private sector stakeholders from each of the SAARC member nation were conducted. A comprehensive energy efficiency analysis of the power generation and distribution sector was conducted with reference to generation type. As a major result, for each SAARC Member State, we identified the challenges, benefits and requirements for implementation of energy efficiency measures.

The study suggested a list of recommendations for energy efficiency improvements for each SAARC Member State separately. The recommendations are accompanied by cost benefit analysis. A summary of proposed investment, potential monetary saving and greenhouse gas emission reduction potential for the power generation and distribution is presented in Table 44.

Table 44 Summary of energy efficiency investment, saving and GHG reduction

Country	EE Investment (USUSD million)	Monetary Saving (USUSD million /year)	Payback (Years)	GHG reduction potential (million tCO_2)[49]
Afghanistan	129.1	61.3	2.1	NA
Bangladesh	975.8	910.9	1.1	8.48
Bhutan	61.8	19.4	3.2	0.06
India	19,133.6	4,989.8	3.8	97.42
Maldives	29.3	22.1	1.3	0.05
Nepal	106.0	32.1	3.3	0.03
Pakistan	2,481.0	700.4	3.5	8.20
Sri Lanka	784.0	179	4.4	1.60

The summary of energy efficiency recommendations for each of the SAARC member countries is presented next. The summary table provides the following details:

Type of recommendation	**Technical, Nontechnical, Policy related etc.**
Sector of recommendation	**Thermal (oil/coal/gas), Hydro, Distribution etc.**
Relevance of the recommendation	**Medium, Significant, High, Very High**
Ease of implementation	**Easy, Moderately Easy, Difficult, Slightly Complicated, Complicated**

[49] *The grid GHG emission factor references:*
Afghanistan – Not available
Bhutan and Nepal – Considered as 0.1 tCO_2/MWh, the average factor for run-off river and small reservoir hydro plant.
Bangladesh – 0.67 tCO_2/MWh (Department of Environment)
India – 0.82 tCO_2/MWh (Central Electricity Authority, 2018)
Maldives – 0.74 tCO_2/MWh (Government of Japan, 2019)
Pakistan – 0.7 tCO_2/MWh (Kentaro Takahashi, 2021)
Sri Lanka – 0.88 tCO_2/MWh (Kentaro Takahashi, 2021)

Table 45 Summary of energy efficiency recommendations for Afghanistan

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
Strongly recommended as they provide early payback of investment							
1	Proper maintenance and overhauling of hydropower plant	Technical	Hydro Power Plant	High	High	Moderately Easy	2 - 3
2	Awareness of utility officials regarding energy efficiency and loss reductions	Capacity Building	Generation & Distribution		Significant		1 - 2
3	Deployment of manpower for strict vigilance	Regulatory	Distribution	Very High	High		
Recommended for consideration and adoption							
4	Replacement of old transformers with energy efficient transformers	Technical	Distribution	High	Significant	Moderately Easy	2 - 3
5	Rehabilitation of existing turbine of hydro power plant to increase the generation and efficiency		Hydro Power Plant	Significant	Medium	Slightly Complicated	4 -6
6	Installation of smart meters for existing consumers and submetering at the feeder level		Distribution	Very High	High	Moderately Easy	2 - 3
Recommended but require special attention and additional consideration before adoption							
7	Privatization of utilities for decreasing various losses	Regulatory	Distribution	Significant	High	Complicated	3 - 4
Recommended for strong consideration by the government							
8	Formation of guidelines for energy audits of utilities	Policy	Generation and Distribution	Significant	High	Moderately Easy	2 - 3
9	Policy for providing security and authority to vigilance teams		Distribution	Very High			
10	Policy development for procurement of only energy efficient equipment in power utilities		Generation and Distribution			Moderately Easy	

Table 46 Summary of energy efficiency recommendations for Bangladesh

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
Strongly recommended as they provide early payback of investment							
1	Installation of real time performance monitoring tool in thermal power plant	Technical	Thermal Power (Gas, Coal & Oil)	High	Very High	Moderately Easy	1 - 2
2	Capacity building of utility officials in energy efficiency and loss reductions	Capacity Building	Generation and Distribution		Significant		
3	Installation of smart prepaid meters for regions where T&D losses are maximum	Technical	Distribution		High		2 - 3
Recommended for consideration and adoption							
4	Replacement of old inefficient equipment with energy efficient one	Technical	Thermal Power (Gas, Coal & Oil)	High	Very High	Moderately Easy	3 -4
5	Automation system for substation by implementing SCADA system		Distribution	Significant	Significant	Slightly Complicated	2 -3
6	Installation of capacitor banks			Medium	Medium	Moderately Easy	2 - 5
7	Promotion of net metering system for consumers	Regulatory		Significant	High		3 - 4
Recommended but require special attention and additional consideration before adoption							
8	Installation of HRSG system in simple cycle power plant	Technical	Thermal power (Gas)	Very High	Very High	Slightly Complicated	5 - 7
9	Upgrades in distribution network by introducing underground cabling and HVDS system		Distribution	Medium	Significant	Difficult	3 - 5
Recommended for strong consideration by the government							
10	Redevelopment of guidelines set by SREDA for energy audits	Policy	Generation and Distribution	High	Significant	Easy	2 - 3
11	Revision of tariff structure and provision of offering incentive to utilities in case they achieve T&D loss reduction target	Regulatory		Significant	High	Slightly Complicated	1 - 2
12	Renovation of old inefficient power plants	Policy	Generation	Very High	Very High		3 - 4

Table 47 Summary of energy efficiency recommendations for Bhutan

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
Strongly recommended as they provide early payback of investment							
1	Awareness of utility officials in energy efficiency and loss reductions	Capacity Building	Generation and Distribution	High	Significant	Moderately Easy	1 - 2
Recommended for consideration and adoption							
2	Replacement of inefficient with more efficient transformers	Technical	Distribution	High	Significant	Moderately Easy	2 -4
3	Proper maintenance of turbine and related auxiliaries of hydro power plant		Hydro Power Plant	Significant	High	Moderately Easy	2 -3
4	Upgradation of LV lines to HV lines		Distribution	High	Significant	Moderately Easy	4 -5
Recommended but require special attention and additional consideration before adoption							
5	Installation of pump storage hydropower plants for flexibility in operation	Technical	Hydro power plant	Significant	Medium	Slightly Complicated	5 - 10
Recommended for strong consideration by the government							
6	Formation of guidelines for energy audits of utilities	Policy	Generation and Distribution	Significant	High	Moderately Easy	2 - 3

Table 48 Summary of energy efficiency recommendations for India

<table>
<tr><th>#</th><th>Recommendation</th><th>Type</th><th>Sector</th><th>Relevance</th><th>Saving</th><th>Ease of Implementation</th><th>Timeline (Years)</th></tr>
<tr><td colspan="8">Strongly recommended as they provide early payback of investment</td></tr>
<tr><td>1</td><td>Use of already available standard operational and maintenance practices for thermal plants</td><td rowspan="2">Technical</td><td rowspan="2">Thermal Power (Coal & Gas)</td><td rowspan="3">High</td><td>High</td><td rowspan="3">Moderately Easy</td><td rowspan="3">1 - 2</td></tr>
<tr><td>2</td><td>Use of monitoring tool already installed in some plants and installation of new system in plants where it is not installed yet</td><td>Very High</td></tr>
<tr><td>3</td><td>Awareness of utility officials in energy efficiency and loss reductions</td><td>Capacity Building</td><td>Generation and Distribution</td><td>Significant</td></tr>
<tr><td colspan="8">Recommended for consideration and adoption</td></tr>
<tr><td>4</td><td>Replacement of inefficient with more efficient transformers</td><td rowspan="4">Technical</td><td>Distribution</td><td rowspan="2">High</td><td>High</td><td rowspan="2">Moderately Easy</td><td>2 -3</td></tr>
<tr><td>5</td><td>Replacement of old inefficient equipment with energy efficient one</td><td>Thermal Power (Coal & Gas)</td><td>Very High</td><td>3 -4</td></tr>
<tr><td>6</td><td>Proper maintenance of turbine and related auxiliaries of hydro power plant</td><td>Hydro Power Plant</td><td>Significant</td><td rowspan="2">Significant</td><td>Moderately Easy</td><td>2 -3</td></tr>
<tr><td>7</td><td>Upgrade the distribution system with underground cabling and HVDS system</td><td>Distribution</td><td>High</td><td>Moderately Easy</td><td>4 -5</td></tr>
<tr><td colspan="8">Recommended but require special attention and additional consideration before adoption</td></tr>
<tr><td>8</td><td>Redevelopment of distribution network for better reliability and to reduce losses</td><td>Technical</td><td>Distribution</td><td>Very High</td><td>Significant</td><td>Slightly Complicated</td><td>5 - 7</td></tr>
<tr><td>9</td><td>Promoting net metering for DISCOM consumers</td><td>Regulatory</td><td>Distribution</td><td>Medium</td><td>Medium</td><td>Moderately Easy</td><td>4 - 5</td></tr>
<tr><td colspan="8">Recommended for strong consideration by the government</td></tr>
<tr><td>10</td><td>Policy improvement to effectively monitor PAT data submitted by utilities</td><td>Policy</td><td>Generation and Distribution</td><td>Significant</td><td>High</td><td>Moderately Easy</td><td>2 - 3</td></tr>
<tr><td>11</td><td>Assistance to DISCOMs for improving their financial health</td><td>Regulatory</td><td>Distribution</td><td>High</td><td>Significant</td><td>Difficult</td><td>3 - 4</td></tr>
</table>

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
12	Policy development for more effective load allocation to coal and gas based thermal power plant	Policy	Generation	Very High	High	Difficult	1 - 3
13	Policies for better availability of imported coal to thermal power plant designed for high GCV operation			Significant		Slightly Complicated	2 - 3

Table 49 Summary of energy efficiency recommendations for Maldives

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
Strongly recommended as they provide early payback of investment							
1	Flue Gas Heat Recovery System for Air-conditioning use	Technical	IC Engine	High	High	Slightly Complicated	2 - 3
2	Awareness of utility officials in energy efficiency and loss reductions	Capacity Building	Generation and Distribution		Significant	Moderately Easy	1 - 2
Recommended for consideration and adoption							
3	Installation of Variable Geometry Turbocharger (VGT) with intercooler system for performance improvement of Diesel Generator	Technical	IC Engine	High	Very High	Slightly Complicated	2 - 4
4	Ensure steady load conditions on the DG set	Regulatory	Distribution	Very High	Significant	Moderately Easy	1 -3
5	Replacement of existing transformers with high rated compact transformers	Technical		High			1 -3
6	Upgradation of existing 11 kV lines to 33 kV in Male			Very High	High		4 -5
Recommended but require special attention and additional consideration before adoption							
8	Use of renewables source of energy for generation in islands with less population	Regulatory	Generation	Very High	Very High	Difficult	3 - 5
Recommended for strong consideration by the government							
10	Formation of guidelines for energy audits of utilities	Policy	Generation and Distribution	Significant	High	Moderately Easy	2 - 3
11	Policy development for standardizing specific oil consumptions of Diesel generators		Distribution	Very High			1 - 3

Table 50 Summary of energy efficiency recommendations for Nepal

<table>
<tr><th>#</th><th>Recommendation</th><th>Type</th><th>Sector</th><th>Relevance</th><th>Saving</th><th>Ease of Implementation</th><th>Timeline (Years)</th></tr>
<tr><td colspan="8">Strongly recommended as they provide early payback of investment</td></tr>
<tr><td>1</td><td>Deployment of manpower for strict vigilance</td><td>Regulatory</td><td>Distribution</td><td>Very High</td><td>High</td><td>Moderately Easy</td><td>1 - 2</td></tr>
<tr><td>2</td><td>Capacity building of utility officials in energy efficiency and loss reduction</td><td>Capacity Building</td><td>Generation and Distribution</td><td>High</td><td>Significant</td><td>Moderately Easy</td><td>1 - 2</td></tr>
<tr><td colspan="8">Recommended for consideration and adoption</td></tr>
<tr><td>3</td><td>Promotion of net metering system</td><td>Regulatory</td><td>Distribution</td><td>High</td><td>Significant</td><td>Moderately Easy</td><td>2 -4</td></tr>
<tr><td>4</td><td>Proper maintenance of turbine and related auxiliaries of hydro power plant</td><td rowspan="3">Technical</td><td>Hydro Power Plant</td><td>Significant</td><td rowspan="2">High</td><td>Moderately Easy</td><td>2 -3</td></tr>
<tr><td>5</td><td>Installation of smart meters in high T&D loss areas</td><td>Distribution</td><td>Very High</td><td rowspan="2">Moderately Easy</td><td>1 - 2</td></tr>
<tr><td>6</td><td>Upgradation of LV lines to HV lines</td><td>Distribution</td><td>High</td><td>Significant</td><td>4 -5</td></tr>
<tr><td colspan="8">Recommended but require special attention and additional consideration before adoption</td></tr>
<tr><td>7</td><td>Installation of pump storage hydropower plants for flexibility in operation</td><td>Technical</td><td>Hydro Power Plant</td><td>Significant</td><td>Medium</td><td>Slightly Complicated</td><td>5 - 10</td></tr>
<tr><td colspan="8">Recommended for strong consideration by the government</td></tr>
<tr><td>8</td><td>Formation of guidelines for energy audits of utilities</td><td rowspan="2">Policy</td><td rowspan="2">Generation and Distribution</td><td>Significant</td><td rowspan="2">High</td><td>Moderately Easy</td><td rowspan="2">2 - 3</td></tr>
<tr><td>9</td><td>Policy development for procurement of only energy efficient equipment in power utilities</td><td>Very High</td><td>Slightly Complicated</td></tr>
</table>

Table 51 Summary of energy efficiency recommendations for Pakistan

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
Strongly recommended as they provide early payback of investment							
1	Effective monitoring of critical parameters in power plant by use of various PADO tools	Technical	Thermal Power (Gas, Oil and Coal)	High	Very High	Moderately Easy	2 - 3
2	Capacity building of utility officials in energy efficiency and loss reduction	Capacity Building	Generation and Distribution		Significant		1 - 2
3	Development and adoption of standard O&M practices for thermal power plants	Regulatory	Thermal Power (Gas, Oil and Coal)	Significant	High	Slightly Complicated	2 - 3
Recommended for consideration and adoption							
4	Installation of smart prepaid meters for regions where T&D losses are maximum	Technical	Distribution	High	Significant	Moderately Easy	1 -2
5	Replacement of inefficient with more efficient transformers				High		2 -3
6	Replacement of old inefficient equipment with energy efficient one		Thermal Power (Gas, Oil and Coal)		Very High	Slightly Complicated	3 -4
7	Proper maintenance of turbine and related auxiliaries of hydro power plant		Hydro Power Plant	Significant	Significant	Difficult	2 -3
8	Upgradation of LV lines to HV lines		Distribution	High		Moderately Easy	4 -5
Recommended but require special attention and additional consideration before adoption							
9	Redevelopment of distribution network for better reliability and to reduce losses	Regulatory	Distribution	Medium	Medium	Complicated	4 - 5
Recommended for strong consideration by the government							
10	Redevelopment of guidelines set by National Energy Efficiency and Conservation Authority for energy audits	Policy	Generation and Distribution	Significant	High	Moderately Easy	2 - 3

#	Recommendation	Type	Sector	Relevance	Saving	Ease of Implementation	Timeline (Years)
11	Policy development for procurement of only energy efficient equipment in power utilities			Very High		Slightly Complicated	
12	Policy for development of efficient and latest type generation plants to be installed in future		Generation	High	Very High	Difficult	3 - 5

Table 52 Summary of energy efficiency recommendations for Sri Lanka

<table>
<tr><th>#</th><th>Recommendation</th><th>Type</th><th>Sector</th><th>Relevance</th><th>Saving</th><th>Ease of Implementation</th><th>Timeline (Years)</th></tr>
<tr><td colspan="8">Strongly recommended as they provide early payback of investment</td></tr>
<tr><td>1</td><td>Monitoring of critical parameters in power plant</td><td>Technical</td><td>Thermal Power (Coal & Oil)</td><td rowspan="2">High</td><td>Very High</td><td rowspan="2">Moderately Easy</td><td rowspan="2">1 - 2</td></tr>
<tr><td>2</td><td>Awareness of utility officials about energy efficiency and loss reductions</td><td>Capacity Building</td><td>Generation and Distribution</td><td>Significant</td></tr>
<tr><td>3</td><td>Development and adoption of standard operational and maintenance practices for thermal power plants</td><td>Regulatory</td><td>Thermal Power (Coal & Oil)</td><td rowspan="2">Significant</td><td>High</td><td>Slightly Complicated</td><td>2 - 3</td></tr>
<tr><td>4</td><td>Installation of smart prepaid meters for regions where T&D losses are maximum</td><td>Technical</td><td>Distribution</td><td>Significant</td><td>Moderately Easy</td><td>1 -2</td></tr>
<tr><td colspan="8">Recommended for consideration and adoption</td></tr>
<tr><td>5</td><td>Replacement of old inefficient equipment with energy efficient one</td><td rowspan="3">Technical</td><td>Thermal Power (Coal & Oil)</td><td>High</td><td>Very High</td><td>Slightly Complicated</td><td>3 -4</td></tr>
<tr><td>6</td><td>Proper maintenance of turbine and related auxiliaries of hydro power plant</td><td>Hydro Power Plant</td><td>Significant</td><td rowspan="2">Significant</td><td>Difficult</td><td>2 -3</td></tr>
<tr><td>7</td><td>Upgradation of LV lines to HV lines</td><td>Distribution</td><td>High</td><td>Moderately Easy</td><td>4 -5</td></tr>
<tr><td colspan="8">Recommended but require special attention and additional consideration before adoption</td></tr>
<tr><td>8</td><td>Installation of HRSG system in simple cycle power plant</td><td>Technical</td><td>Thermal Power (Oil)</td><td>Very High</td><td>Very High</td><td>Slightly Complicated</td><td>5 - 7</td></tr>
<tr><td>9</td><td>Redevelopment of distribution network for better reliability and to reduce losses</td><td>Regulatory</td><td>Distribution</td><td>Medium</td><td>Medium</td><td>Moderately Easy</td><td>4 - 5</td></tr>
<tr><td colspan="8">Recommended for strong consideration by the government</td></tr>
<tr><td>10</td><td>Formation of guidelines for energy audits of utilities</td><td rowspan="2">Policy</td><td rowspan="2">Generation and Distribution</td><td>Significant</td><td>High</td><td>Moderately Easy</td><td rowspan="2">2 - 3</td></tr>
<tr><td>11</td><td>Policy development for procurement of only energy efficient equipment in power utilities</td><td>Very High</td><td>High</td><td>Slightly Complicated</td></tr>
</table>

Bibliography

Adam J.Feneley, e. (2017). Variable Geometry Turbocharger Technologies for Exhaust Energy Recovery and Boosting-A Review. *Renewable and Sustainable Energy Reviews*, 959-972.

Ajibola, O. O., Ajala, O. S., Akanmu, J. O., & Balogun, O. J. (2018). Improvement of Hydroelectric Power Generation Using Pumped Storage System. *Nigerian Journal of Technology*.

Asian Development Bank. (2015). *Sector Assessment (Summary): Energy, Energy Supply Improvement Investment Program (RRP Afg 47282-001).* Retrieved from https://www.adb.org/sites/default/files/linked-documents/47282-001-ssa.pdf

Asian Development Bank. (2016). *www.adb.org.* Retrieved from Improving Energy Efficiency in South Asia: https://www.adb.org/publications/improving-energy-efficiency-south-asia

Asian Development Bank. (2017). *adb.org.* Retrieved from Assessment of Sri Lanka's Power Sector: adb.org/documents/assessment-power-sector-reforms-sri-lanka

Asian Development Bank. (2019). *Southwest Transmission Grid Expansion Project.* Retrieved from Asian Development Bank: https://www.adb.org/sites/default/files/linked-documents/51137-001-ssa.pdf

Awale, N. D. (2020). *Energy Conservation Through Energy Efficient Technologies at Thermal Power Plant.*

Bangladesh Power Development Board. (2019). *BPDB Annual Report.* Retrieved from Bangladesh Power Development Board: https://www.bpdb.gov.bd/bpdb_new/resourcefile/annualreports/annualreport_1574325376_Annual_Report_2018-19.pdf

Bernard, M. (2020, August). *Hydro Turbines Rehabilitation*. Retrieved from Encyclopédie de l'énergie: https://www.encyclopedie-energie.org/hydro-turbines-rehabilitation/

Bhutan Electricity Authority. (2019). *Annual Report 2018-19.* Bhutan Electricty Authority.

Bhutan Power Corporation Limited. (2019). *Bhutan Power Corporation Limited Annual Report.* Retrieved from Bhutan Power Corporation: https://www.bpc.bt/wp-content/themes/2020/assets/downloads/BPC-Annual-Report-2018.pdf

Bhutan Power Corporation Limited. (2020). *Electricity Tariff*. Retrieved from Bhutan Power Corporation Limited: https://www.bpc.bt/electricity-tariff/

Bonsor, K. (2020). *How Hydropower Plants Work*. Retrieved from How Stuff Works: https://science.howstuffworks.com/environmental/energy/hydropower-plant1.htm

British Petroleum. (2019). *British Petroleum Statistical Review of World Energy.* BP.

Bureau of Energy Efficiency. (2015). Cogeneration. In *Energy Efficiency in Electrical Utilities.* BEE.

Bureau of Energy Efficiency. (2015). DG Set System. In *Energy Efficiency in Electrical Utilities.* New Delhi: Bureau of Energy Efficiency.

Bureau of Energy Efficiency. (2016). *Best Practices and Strategies for Distribution Loss Reduction, Forum of Regulator, India 2016.* BEE.

Bureau of Energy Efficiency. (2017). *Knowledge Exchange Platform.* Retrieved from Diesel Generator Set System: http://knowledgeplatform.in/wp-content/uploads/2017/03/Chapter-3.9-DG-Set-System.pdf

Bureau of Energy Efficiency. (2020). *DG Set System.* New Delhi: BEE.

Campbell, R. J. (2013). *Increasing the Efficiency of Existing Coal-Fired Power Plants.*

Central Electricity Authority. (2008-2020). *All India Electricity Statistics (2008-2020). General Review.* Retrieved from https://cea.nic.in/?lang=en

Central Electricity Authority. (2016). *Load Generation Balance Report.* New Delhi.

Central Electricity Authority. (2018). *CO2 Baseline Database for the Indian Power Sector (User Guide Ver. 14.0).* New Delhi: Central Electricity Authority. Retrieved from http://www.cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver13.pdf

Central Electricity Authority. (2018). *National Electricity Plan.* Retrieved from Central Electricity Authority: https://cea.nic.in/reports/committee/nep/nep_dec.pdf

Central Electricity Authority. (2019). *Central Electricity Authority Annual Report 2018-19.* New Delhi: Central Electricity Authority. Retrieved from https://cea.nic.in/annualreports.html

Central Electricity Authority. (2020, October). *All India Electricity Statistics (2018-19). General Review 2020.* New Delhi: Central Electricity Authority. Retrieved from http://www.cea.nic.in/reports/monthly/installedcapacity/2020/installed_capacity-04.pdf

Central Electricity Authority. (2020). *Best Practices in Operation & Maintenance of Hydro Power stations.* Retrieved from http://www.cea.nic.in/reports/others/hydro/hetd/best_practises/chapter-6.pdf

Central Electricity Authority. (2020). *Growth of Electricity Sector in India from 1947-2019.* CEA.

Central Electricity Regulatory Commission. (2018, December). *Recommendations on Operating Norms for Thermal Generating Stations for the Tariff Period 2019-24.* Retrieved from Central Electricity Regulatory Commission Web site: http://www.cercind.gov.in/2018/draft_reg/CEA%20Recommendations%20for%20thermal%20generating%20stations%20for%20tariff%20period%202109-24.pdf

Ceylon Electricity Board. (2015). *Long Term Generation Expension Plan.* Colombo.

Ceylon Electricity Board. (2019). *CEB Annual Report 2018.* Ceylon Electricity Board. Retrieved from Ceylon Electricity Board: https://ceb.lk/publication-media/annual-reports/en

Ceylon Electricity Board. (2019). *Long Term Expansion Plan 2020 - 2039*. Retrieved from https://www.ceb.lk/front_img/img_reports/1560836289LTGEP_2020-2039_(Draft).pdf

Ceylon Electricity Board. (2020). *CEB Annual Report 2019.*

Ceylon Electricity Board. (2020). *Statistical Digest 2019.* Retrieved from Ceylon Electricity Board: https://ceb.lk/publication-media/statistical-reports/en

Choden, S. (2009). *Sediment Transport Studies in Punatsangchu River, Bhutan.*

Copper Development Association Inc. (2020). *Introduction to Transformer Losses*. Retrieved from Copper Development Association Inc.: https://www.copper.org/environment/sustainable-energy/transformers/education/trans_losses.html

Department of Environment. (n.d.). *Grid Emission Factor(GEF) of Bangladesh.* Retrieved from Department of Environment: http://www.doe.gov.bd/site/notices/059ddf35-53d3-49a7-8ce6-175320cd59f1/Grid-Emission-Factor(GEF)-of-Bangladesh

Dileep Kumar, e. a. (2017). Impact of Auxiliary Equipments' Consumption on Electricity Generation Cost in Selected Power Plants of Pakistan. *Mehran University Research Journal of Engineering and Technology*, 419-436.

Economic Commission for Europe. (2015). *Baseline Efficiency Analysis of Fossil Fuel Power Plants.* Retrieved from https://www.unece.org/fileadmin/DAM/energy/se/pdfs/CES/ge11/CEP.11.2015.INF.4.e.pdf

Enomoto, Y. (2017). Steam Turbine Retrofitting for the Life Extension of Power Plants. In T. Tanuma, *Advances in Steam Turbines for Modern Power Plants* (pp. 397-436). Woodhead Publishing.

Excellence Enhancement Centre for Indian Power Sector. (2013). Retrieved from Excellence Enhancement Centre for Indian Power Sector: https://www.eecpowerindia.com/codelibrary/ckeditor/ckfinder/userfiles/files/APC-EEC%20workshop.pdf

Finance Division. (2020). *Pakistan Economic Survey 2019-20.* Retrieved from Finance Division, Government of Pakistan: http://www.finance.gov.pk/survey_1920.html

Forbes Marshall. (2020). *What is a Boiler: Introduction to Boilers*. Retrieved from Forbes Marshall: https://www.forbesmarshall.com/Knowledge/SteamPedia/Boilers/What-is-a-Boiler-Introduction-to-Boilers

General Electric. (2015). *www.ge.com.* Retrieved from Global Power Plant Efficiency Analysis: https://www.ge.com/reports/wp-content/themes/ge-reports/ge-power-plant/dist/pdf/GE%20Global%20Power%20Plant%20Efficiency%20Analysis.pdf

Global Transmission. (2019, May 8). *Afghanistan: Embarks on Growth Backed by International Support*. Retrieved from Global Transmission: https://www.globaltransmission.info/archive.php?id=36687

Government of Japan. (2019). *Joint Crediting Mechanism (Japan-Maldives).* Retrieved from www.jcm.go.jp: https://www.jcm.go.jp/mv-jp/methodologies/19/attached_document1#:~:text=Grid%20emission%20factor%20It%20is,to%20achieve%20net%20emission%20reductions.

Government of Sri Lanka. (2018). *Energy Balance of Sri Lanka.* Retrieved from Sri Lanka Sustainable Energy Authority: http://www.energy.gov.lk/images/energy-balance/energy-balance-2017.pdf

H.R.P.Wanniarachchi, & Wijayapala, W. (2012). *Modelling of Distribution Losses in an Urban Environment and Strategies for Distribution Loss Reduction.*

Hafeez, A. (2019). Circular Debt in Power Sector of Pakistan: Impacts, Causes and Solutions. *Power Sector Issues and Solutions in the developing world.*

ICF and Shakti Foundation. (2017). *Diesel Generators: Improving Efficiency and Emmision Performance.* Retrieved from Shakti Sustainable Energy Foundation: https://shaktifoundation.in/wp-content/uploads/2017/06/ICF-2014-Diesel-Generators-Improving-Efficiency-and-Emission-Performance-in-India.pdf

IEA. (2020). *IEA*. Retrieved from IEA India 2020: https://www.iea.org/reports/india-2020

India Brand Equity Foundation. (2020, August 30). *Power Sector in India*. Retrieved from India Brand Equity Foundation: https://www.ibef.org/industry/power-sector-india.aspx

International Atomic Energy Agency. (2019). *Pakistan*. Retrieved from International Atomic Energy Agency: https://cnpp.iaea.org/countryprofiles/Pakistan/Pakistan.htm

J. Pekar, D. P. (2008, August). Soot Blowing Optimization System and Application to Oil-Fired Boiler. *2008 IEEE International Conference on Control Applications* (pp. 85-90). San Antonio: IEEE. Retrieved from https://ieeexplore.ieee.org/document/4629581

K.A.B.Pathirathna. (2013). *Gas Turbine Thermodynamic and Performance Analysis Methods.* Gavle: University of Gavle.

Kalkitech. (2020, August). *Performance Monitoring*. Retrieved from Kalki Communication Technologies Pvt. Ltd.: https://www.kalkitech.com/solutions/plant-performance-optimization/

Kentaro Takahashi, M. L. (2021, February). IGES List of Grid Emission Factors. Hayama, Japan.

Khan, M. A. (2013). Measures for Reducing Transmission and Distribution Losses of Pakistan.

Kiameh, P. (2002). *Power Generation Handbook.* McGraw Hill.

Knoema. (2019). *Bangladesh - Total Recoverable Coal*. Retrieved from Knoema: https://knoema.com/atlas/Bangladesh/topics/Energy/Coal/Total-recoverable-coal

KTH Department of Energy Technology. (2017, February 1). *A GIS Approach to Electrification Planning in Afghanistan.* Retrieved from https://energypedia.info/images/4/4a/ONSSET_analysis_for_Afghanistan_-_New_Delhi_Feb_1st_2017.pdf

Lanka Electricity Company. (2020). *Annual Report 2019.*

Maldives Energy Authority. (2014). *MEA Annual Report*. Retrieved from Maldives Energy Authority: https://www.energy.gov.mv/

Memon, R. (2017). Impact of Auxiliary Equipments' Consumption on Electricity Generation Cost in Selected Power Plants in Pakistan.

Ministry of Energy and Water. (2016, October). *Afghanistan Energy Efficiency Policy.* Ministry of Energy and Water, Islamic Republic of Afghanistan. Retrieved from Ministry of Energy and Water, : https://policy.asiapacificenergy.org/sites/default/files/Afghanistan%20Energy%20Efficiency%20Policy%20%28Draft%202016%29.pdf

Ministry of Environment. (2018). *Island Electricity Data Book.* Retrieved from Ministry of Environment, Climate Change and Technology, Republic of Maldives: https://www.environment.gov.mv/v2/en/download/8106

Ministry of Finance. (n.d.). *Bangladesh Economic Review 2017.* Ministry of Finance, Government of the People's Republic of Bangladesh. Retrieved from www.mof.portal.gov.bd: https://mof.portal.gov.bd/sites/default/files/files/mof.portal.gov.bd/page/e8bc0eaa_463d_4cf9_b3be_26ab70a32a47/Ch-10%20(English-2017)_Final.pdf

Ministry of Planning Development and Reforms, Government of Pakistan. (2020, August). *Monthly Bulletin of Statistics.* Retrieved from Ministry of Planning Development and Reforms, Government of Pakistan: http://www.pbs.gov.pk/sites/default/files//Monthly%20Bulletin%20of%20Statistics%20%20%20August%2C%202019.pdf

Ministry of Power. (2020). *AT & C Loss (Aggregate Technical and Commercial Loss)*. Retrieved from Ujwal DISCOM Assurance Yojana: https://www.uday.gov.in/atc_india.php

Ministry of Power. (2020, August 13). *Power Sector at a Glance All India*. Retrieved from Ministry of Power, Government of India: https://powermin.nic.in/en/content/power-sector-glance-all-india

Ministry of Power. (2020). *PRAAPTI*. Retrieved from Ministry of Power, Government of India: http://praapti.in/

Mujib R. Abid, R. (2013, May). *Governance Issues in Afghanistan.* Retrieved from https://www.files.ethz.ch/isn/167225/2013_05_14_Governance_FINAL.pdf

National Statistical Office. (2020, April). *Energy Statistics 2020.* Retrieved from Ministry of Statistics and Programme Implementation: https://www.mospi.gov.in/reports-publications

Natural Resources Canada. (2020, August). *Application Considerations and Estimated Savings for VFD Drives*. Retrieved from Natural Resources Canada: https://www.nrcan.gc.ca/energy-efficiency/energy-star-canada/about-energy-star-canada/energy-star-announcements/publications/variable-frequency-drives/application-considerations-and-estimated-savings-vfd-drives/15385

Nepal Electricity Authority. (2019). *NEA Annual Report.* Retrieved from www.nea.org.np: https://www.nea.org.np/annual_report

NEPRA. (2015-2020). *State of Industry Reports (2015-2020).* NEPRA. Retrieved from Performance evaluation report: https://nepra.org.pk/publications/Performance%20Reports.php

NEPRA. (2019). *State of Industry Report 2019.* Retrieved from https://nepra.org.pk/publications/State%20of%20Industry%20Reports/State%20of%20Industry%20Report%202019.pdf

NEPRA. (2020). *State of Industry Report 2020.* NEPRA.

NSIA. (2019). *Afghanistan Statistical Yearbook 2019.* National Statistics and Information Authority.

NTDC. (2021). *Power System Statistics 45th Edition.* National Transmission and Dispatch Company Pakistan.

NTPC India. (2017). *Study on Impact of Key Parameters Affecting Turbine Heat Rate.* New Delhi: NTPC.

NTPC India. (2018). *O&M Best Practices in Thermal Power Plant.* Retrieved from www.pmintpc.com: https://www.pmintpc.com/sites/default/files/NTPC%20O%26M%20Best%20Practices%20Booklet.pdf

Pakistan Bureau of Statistics. (2019, August). *Monthly Bulletin of Statistics.* Retrieved from Pakistan Bureau of Statistics, Government of Pakistan: http://www.pbs.gov.pk/sites/default/files//Monthly%20Bulletin%20of%20Statistics%20%20%20August%2C%202019.pdf

Power Cell. (2020). *www.powercell.gov.bd.* Retrieved from http://www.powercell.gov.bd/site/view/powerdiv_achievement_at_glance/-

Power Grid Corporation of India Limited. (2014). *Negawatt Makes a Watt: Energy Efficiency Opportunities in India.* Power Grid Corporation of India Limited. Retrieved from https://www.powergridindia.com/sites/default/files/footer/energy_efficiency/efficiency_book.pdf

Power Today. (2015, September). *Critically Acclaimed*. Retrieved from Power Today: https://www.powertoday.in/cover-story/Critically-Acclaimed/88246

PwC. (2016). *www.forumofregulators.gov.in.* Retrieved from Best Practices and Strategies for Distribution Loss Reduction: http://www.forumofregulators.gov.in/Data/study/11.pdf

Qazi, U., & Jahanzaib, M. (2018). *An Integrated Sectoral Framework for the Development of Sustainable Power Sector in Pakistan.* ELSEVIER.

Rodrigo, A. S., & Gunatillaka, M. (2019). *An Effective Method of Segregation of Losses in Distribution Systems, 2019.*

SAARC Energy Centre. (2017). *Comparative Study on Rural Electrification Policies in SAARC Countries.* SAARC Energy Centre. Retrieved from www.saarcenergy.org: https://www.saarcenergy.org/wp-content/uploads/2017/12/SAARC_RE_POLICIES.pdf

SAARC Energy Centre. (2018, September). *Optimal Power Generation Mix for Sustainable Power Sector in South Asia.* SAARC Energy Centre. Retrieved from https://www.saarcenergy.org/wp-content/uploads/2018/09/SEC-Generation-Mix-Study-Final-Clean-28JUN2016-with-Page-Nos-.pdf

SAARC Energy Centre. (2018). *SAARC Energy Outlook 2030.* SAARC Energy Centre.

Siemens. (2020, August). Retrieved from https://assets.siemens-energy.com/siemens/assets/api/uuid:045b096f648f293975196ff5ed78416ddd9d4a57/si3d-stages-3-and-4-e50001-g520-a338-x-4a00-en-lr-final.pdf

SREDA. (2020, August). *www.sreda.gov.bd*. Retrieved from http://www.sreda.gov.bd/index.php/site/page/e0ce-8bba-29ea-4c3a-531e-5f8d-3b9d-db70-a32a-26ec

Steag. (2013). *Auxiliary Power Measurement, Optimization and Analysis.* Retrieved from https://www.eecpowerindia.com/codelibrary/ckeditor/ckfinder/userfiles/files/APC-EEC%20workshop.pdf

Steag. (2015). *MEA at Dhopur TPP.*

Steag. (2016). *Energy Mapping Report: Bangladesh Thermal Power Plant.* Dhaka: Steag Energy Services.

Steag. (2020). *PADO.* Retrieved from https://www.eecpowerindia.com/codelibrary/ckeditor/ckfinder/userfiles/files/PADO%20Overview_new.pdf

STELCO. (2020). *Our Company*. Retrieved from STELCO: https://www.stelco.com.mv/our-company

The World Bank. (2020). *Electric Power T&D losses*. Retrieved from The World Bank Data, 2020: https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS

The World Bank. (2020). *The World Bank Data*. Retrieved from https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=8S

Timilsina, G. (2018). *How Much Has Nepal Lost in the Last Decade Due to Load Shedding?* Development Economics.

Tractebel Engineering and Ecofy. (2015). *ec.europa.eu.* Retrieved from Identifying Energy Efficiency Improvements and Saving Potential in Energy Networks, Including Assessment of the Value of Demand Response: https://ec.europa.eu/energy/sites/ener/files/documents/GRIDEE_4NT_364174_000_01_TOTALDOC%20-%2018-1-2016.pdf

Ulowa WIki. (2020). *Hydroelectric Power.* Retrieved from https://wiki.uiowa.edu/display/greenergy/Hydroelectric+Power

Umbreen Fatima, A. N. (2019, September). *Cost of Electricity Generation in Pakistan.* Retrieved from Institute of Development and Economic Alternatives: https://ideaspak.org/wp-content/files_mf/1569051386IDEAS_WP2_Final.pdf

UN. (2020). *India Plans to Produce 175 GW of Renewable Energy by 2022*. Retrieved from United Nations | Department of Economic and Social Affairs - Sustainable Development: https://sustainabledevelopment.un.org/partnership/?p=34566#:~:text=The%20Government%20of%20India%20has,GW%20from%20small%20hydro%2Dpower.

UN Statistics Division. (2020). *Electricity, Net Installed Capacity of Electric Power Plants*. Retrieved from UN Data: http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AEC

UNECE. (2013). *Mitigating Climate Change through Investments in Fossil Fuel Technologies.* UNECE.

UNECE. (2016). *Afghanistan Energy Sector.* Retrieved from UNECE: https://www.unece.org/fileadmin/DAM/energy/se/pp/eneff/7th_IFESD_Baku_Oct.2016/ESCAP_Elec_CIS/1_W.Aria_AVG.pdf

Uniper. (2020). *Enerlytics: The New IIoT Platform for Power Generation Plants*. Retrieved from Uniper Energy: https://www.uniper.energy/news/enerlytics-the-new-iiot-platform-for-power-generation-plants/

United States Energy Association. (2019, July). *Overview of Power Sector of Bangladesh.* Retrieved from United States Energy Association: https://usea.org/sites/default/files/event-file/493/overviewofbpdb.pdf

United States Energy Assosociation. (2019). *United States Energy Association: Request for Proposal: Afghanistan Electricity Sector Governance and Management Assessment – Afghanistan, 2019.* USAID.

United States Energy Information Administration. (2016). *Independent Statistics and Analysis.*

US Department of Energy. (2014). *Premium Efficiency Motor Selection And Application Guide.* US Department of Energy. Retrieved from Premium Efficiency Motor Selection and Application Guide: https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf

US Department of Energy. (2020, August). *Pumped Storage Hydropower*. Retrieved from Office of Energy Efficiency & Renewable Energy: https://www.energy.gov/eere/water/pumped-storage-hydropower#:~:text=Pumped%2Dstorage%20hydropower%20(PSH),recharge)%20to%20the%20upper%20reservoir.

WAPDA. (2019, July). *FY 2018-19: WAPDA Provides 31.425 Billion Units Hydel Power to National Grid*. Retrieved from WAPDA: http://www.wapda.gov.pk/index.php/newsmedia/news-views/435-fy2018-19-wapdaprovides31-425

Wood Mackenzie. (2019). *Energy Report 2019.* Wood Mackenzie.

World Economic Outlook Database. (2020). Retrieved from https://www.imf.org

World Energy Council. (2013). *Energy Efficient Solutions for Thermal Power Plants .*

Zohuri, B. (2015). Gas Turbine Working Principles. In B. Zohuri, *Combined Cycle Driven Efficiency for Next Generation Nuclear Power Plants* (pp. 147-171). Springer.

Annexure: Sample questionnaire for stakeholder consultation

A.1. Questionnaire for generation side stakeholders

(A) Background and Objective of Study

Energy efficiency improvement is the fastest mitigation method to meeting the growing energy demands. The power generation and distribution sectors of SAARC Member States are adversely affected by energy inefficiency and reliability issues. There exists ample room for SAARC countries to improve and reap the rewards both in economy, and in terms of climate change. Investigating the opportunities of efficiency improvements in SAARC countries' power sectors and identifying the ways to tap those opportunities are the needs of the hour. Therefore, SAARC Energy Centre (SEC) intends to explore the potential energy efficiency improvements in power generation and distribution sector of SAARC region in the form of a research study.

The overall objective of this research study is to develop a document which serve as a guideline for energy efficiency improvement in the power generation and distribution sectors for the SAARC countries. The study will map present status of power sector and energy efficiency in each member country.

(B) GENERAL

1.	**Name of the Agency**	
2.	**Country**	
3.	**Website**	
4.	**Name of the Head** **Email ID** **Telephone/Mobile**	
5.	**Co-ordinating officers:** **Name** **Position** **Email ID** **Telephone/Mobile**	

(C) General Questions for Generating Stations

S. No.	Particular
1	Your view on power sector energy efficiency scenario and how it is different from rest of the developed countries?
Answer	
2	What are major drawbacks in power sector, which hinder the efficient operation of power stations?
Answer	
3	What are the major findings you observed through various energy efficiency studies conducted, if any?

S. No.	Particular
Answer	
4	How are the critical parameters such as plant load factor, plant overall efficiency, auxiliary consumption etc being monitored for individual plants?
Answer	
5	What are the policy issues and challenges faced by Generation Company (Genco) in incorporating energy efficiency projects?
Answer	
6	How do you think these policy challenges can be addressed and is the government taking/planning any steps/programmes to address these challenges?
Answer	
7	Are there any administrative and governance issues faced by Gencos leading to energy inefficiencies?
Answer	
8	What are the steps taken by agency and government in controlling administrative and governance issues faced by Gencos?
Answer	
9	What is the financial impact of these policy, governance and administrative issues on power generation sector?
Answer	
10	Does the sector face any financial constraints in implementing energy efficiency projects?
Answer	
11	What are the measures by which these financial constraints can be mitigated?
Answer	
12	Are there any social or environmental issues, which prohibit implementation of energy efficiency projects?
Answer	
13	What are the major technical losses in power generation? (Separately for each fuel type – like Hydro, Diesel etc)
Answer	
14	What are the measures taken to curtail the losses? (Separately for each fuel type like Hydro, Diesel etc)
Answer	

S. No.	Particular
15	What are the international best practices related to technical and policy related, which can be applied in the generating stations for increasing the efficiency?
Answer	
16	Can you provide case studies of best practices of power plant operation and efficiency measure across the globe?
Answer	
17	Does agency provide any training to Plant officials related to energy efficiency and operation, also please provide the effect of that training?
Answer	
18	How the staff is trained in energy and operational efficiency?
Answer	
19	What are the guidelines and framework, if any followed for ensuring energy efficiency operation of generating station? (Please guide any details present in public domain)
Answer	
20	Please provide list of performance assessment tools and software used in optimising power plant performance?
Answer	
21	Please provide details of Renovation and Modernisation (R&M) and Life Extension (LE) details of generating stations? (If conducted)
Answer	
22	What is the future plan of expansion plan of generating station and which technology is been considered for generation the future power?
Answer	
23	What are the previous energy efficiency programmes implemented by the agency, if any? Also provide details of energy saving by these programmes?
Answer	
24	Are there any studies conducted in past on energy efficiency in power generation sector?
Answer	

A.2. Questionnaire for distribution side stakeholders

(A) GENERAL

1.	**Name of the Agency**	
2.	**Country**	
3.	**Website**	
4.	**Name of the Head** **Email ID** **Telephone/Mobile**	
5.	**Co-ordinating officers:** **Name** **Position** **Email ID** **Telephone/Mobile**	

(B) GENERAL QUESTIONS FOR DISTRIBUTION

S. No.	Particular
1	Could you describe in brief the institutional structure of power distribution sector?
Answer	
2	What are different types of consumer categories defined by DISCO?
Answer	
3	Are the critical parameters such as T&D loss, AT&C loss, line load, transformer loading etc. being monitored?
Answer	
4	Which government agency monitors these parameters? (Provide Agency Details)
Answer	
Next, we would like to understand what the major losses are particular to power distribution including technical and nontechnical inefficiencies such as policy issues, Market competitiveness, Theft and governance issues, administrative weakness, financial constants and social and environmental issues (First set of questions are of nontechnical losses and next set of questions are for technical losses).	
5	What are the policy issues and challenges faced by DISCO in incorporating energy efficiencies? (Challenges faced by government in promoting energy efficiency)
Answer	
6	What are the policy issues and challenges faced by Government in incorporating energy efficiency measures in DISCO?

S. No.	Particular
Answer	
7	How do you think these policy challenges can be addressed and is the government taking/planning any steps/programmes to address these challenges?
Answer	
8	Are there any administrative and governance issues faced by DISCO leading to energy inefficiencies?
Answer	
9	What are the steps taken by agency and government in controlling administrative and governance issues faced by DISCO?
Answer	
10	What is the financial impact of these policy, governance and administrative issues on DISCO?
Answer	
11	Does the sector face any financial constraints in implementing energy efficiency projects? If yes, what are the measures by which these financial constraints can be mitigated?
Answer	
12	Is there challenge of theft in power distribution? If yes, how is that being tackled?
Answer	
13	Are there any social or environmental issues, which prohibit implementation of energy efficiency projects?
Answer	
14	What are the major distribution losses by the DISCO?
Answer	
15	What are the parameters and factors which are monitored for calculation of net distribution losses?
Answer	
16	Which is the major consumer category where distribution losses are maximum and reason for the same?
Answer	
17	What are the measures which are taken or are planned to curtail the losses?
Answer	

S. No.	Particular
18	What is the strategy of agency in implementation of Smart Grid and Smart Meters technology?
Answer	
19	What is the utility plan for underground cabling for end consumers?
Answer	
20	Are there any energy efficiency/loss mitigation goals set for utilities or any long term/medium term/short term plans to maximise energy efficiency?
Answer	
21	What are the government policies to promote cross border electricity trade to reduce network losses where feasible?
Answer	
22	How the staff is trained in energy and operational efficiency?
Answer	
23	Please provide list of performance assessment tools and software used for loss reduction?
Answer	
24	What is the plan of overhauling of transformers and other electrical equipment?
Answer	
25	What is the future plan of expansion and renovation of existing infrastructure of distribution network?
Answer	
26	What are the previous energy efficiency programmes implemented by the agency? Also provide details of energy saving by these programmes?
Answer	
27	Are there any studies conducted in past on energy efficiency in power distribution sector? (Please provide the report of the same)
Answer	

SAARC ENERGY CENTRE ISLAMABAD

Office: 697, St. No. 43, E-11/4, NPF, Islamabad, Pakistan.