West Bengal State Energy Plan and Action Plan

Final Draft

2019

Contents

List of Abbreviation

AB	Aerial bundled
AMI	Advanced metering infrastructure
API	Application programming interfaces
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
AT&C	Aggregate Technical and Commercial
ATF	Aviation turbine fuel
BAU	Business-As-Usual
BCM	Billion cubic metre
BEE	Bureau of Energy Efficiency
GEF	Global Environment Facility
BEMS	Building energy management system
BENFISH	West Bengal State Fishermen's Cooperative Federation Limited
BGBS	Bengal Global Business Summit
BGS	Balanced Growth Scenario
BPL	Below Poverty Line
BRT	Bus Rapid Transit System
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
CBM	Coal Based Methane
CCHP	Combined Cooling, Heat and Power
CCS	Carbon Capture and Storage
CEA	Central Electricity Authority
CESC	Calcutta Electricity Supply Corporation
CFB	Circulating Fluidized Bed Combustion
CFL	Compact Fluorescent Lamp
CGD	City gas distribution
CNG	Compressed Natural Gas
COCO	Company Operated Company Owned
CPI	Consumer Price Index
CPWD	Central Public Works Department
CREDAI	Confederation of Real Estate Developers Association of India
CSIR	Council of Scientific & Industrial Research
CIMFR	Central Institute of Mining and Fuel Research
CSOs	Civil society organizations
CSR	Corporate Social Responsibility
CTC	Calcutta Tramways Company
CTL	Coal to liquid
CUF	Capacity Utilization Factor
DA	Distribution Automation
DC	Designated consumers
DCS	District cooling system
DIPP	Department of Industrial Policy & Promotion
DISCOM	Distribution Company
DMS	Distribution Management Systems
DoP	Department of Power and Non-Conventional Energy Sources
DPL	Durgapur Projects Limited
DPR	Detailed Project Report
DRS	Demand Response System
DST	Decision Support Tool
DT	Distribution Transformer
DVC	Damodar Valley Coporation
EAP	Energy Action Plan
ECBC	Energy Conservation Building Code
ECBC-C	Energy Conservation Building Code - Commercial

ECBC-R	Energy Conservation Building Code - Residential
EE	Energy Efficiency
EEPS	Energy Efficient Pump Set
EESL	Energy Efficiency Services Limited
EMS	Energy Management Systems
ERP	Enterprise Resource Planning
ESCO	Energy Service Company
ESPs	Electrostatic Precipitators
ESS	Energy Security Scenario
EU	European Union
EV	Electric vehicles
EWeLiNE	Erstellung innovativer Wetter- und Leistungsprognosemodelle für die Netzintegration wetterabhängiger Energieträger
FAME	Faster Adoption and Manufacture of (Hybrid and) Electric Vehicle
FBC	Fluidized Bed Combustion
FCBTK	Fixed Chimney Bull Trench Kilns
FE	Final Energy
FGDs	Flue-Gas Desulfurization
GAIL	Gas Authority of India Limited
GAMS	General Algebraic Modeling System
GCGSC	Greater Calcutta Gas Supply Corporation
GCV	Gross Calorific Value
GHG	Green House Gas
GIFT	Gujarat International Finance Tec-City
GIS	Geographic Information Systems
GIZ	Gesellschaft für Internationale Zusammenarbeit GmbH
IGEN	Indo-German Energy Programme
GOBAR-DHAN	Galvanizing Organic Bio-Agro Resources Dhan
GoI	Government of India
GoWB	Government of West Bengal
GPS	Global Positioning System
GRIHA	Green Rating for Integrated Habitat Assesment
GRTSPV	Grid Connected Solar Photovoltaic
GSDP	Gross State Domestic Product
GVA	Gross Value Added
GW	Giga Watt
HDI	Human Development Index
HDPE	High Density Poly Ethylene
HIDCO	Housing Infrastructure Development Corporation
HT	High-Tension
HVAC	Heating Ventilation and Air Conditioning
HVDS	High Voltage Distribution System
IC&E	Industries, Commerce and Enterprises
ICT	Information and communications technology
IESS	India Energy Security Scenario
IGCC	Integrated Gasification Combined Cycle
IGEA	Investment Grade Energy Audit
IIASA	International Institute for Applied Systems Analysis
IIP	Index of Industrial Production
IPCL	India Power Corporation Limited
IPDS	Integrated Power Development Scheme
IWAI	Inland Water Authority of India
IWT	Inland water transportation
KV	Kilo-Volt
KW	Kilo-Watt
LCOE	Levelized Cost of Electricity

LED	Light Emitting Diode
LNG	Liquefied Natural Gas
LOBS	Lube Oil Base Stocks
LPG	Liquefied Petroleum Gas
M&V	Monitoring and Verification
MBBL	Model Building Bye-Laws
MDMS	Meter Data Management Systems
MGNREGA	Mahatma Gandhi National Rural Employment Gurantee Act
MIS	Management Information System
MJ	Million Units
MMSCM	Million metric standard cubic meter
MNRE	Ministry of New and Renewable Energy (MNRE)
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MSME	Micro, Small and Medium enterprise
MT	Metric Tonne
MtCO2	Metric Tonne of CO_2 equivalent
MTOE	Million Tonne of Oil Equivalent
MW	Megawatt
NCV	Net Calorific Value
NOX	Nitrogen Oxides
OMCs	Oil marketing companies
OMS	Outage Management Systems
OPEX	Operation Expenditure
P&RD	Panchayat and Rural Development
PAT	Perform Achieve Trade
PCS	Public Charging Stations
PLF	Plant load factor
PMKSY	Pradhan Mantri Krishi Sinchai Yojana
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped natural gas
PNNL	Pacific Northwest National Laboratory
POSOCO	Power System Operation Corporation Limited
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RES	Reference Energy System
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RLDCs	Regional Load Despatch Centre
RO-RO	Roll On-Roll Off
SAPCC	State Action Plan for Climate Change
SCADA	Supervisory Control and Data Acquisition Systems
SDA	State Designated Agency
SEC	Specific Energy Consumption
SEEDN	Strengthening and Extension of Electricity Distribution Network
SGST	State Good and Services Tax
SIDBI	Small Industries Development Bank of India
SLDC	Regional Load Despatch Centre
SOX	Sulphur Oxides
SVSKP	Swami Vivekananda Swanirbhar Karmasansthan Prakalpa
T&D	Transmission and Distribution
TCF	Trillion Cubic Foot
TOE	Tonnes of Oil Equivalent
TPA	Third Party Assessor
TSO	Transmission system operators
UD&MA	Urban Development & Municipal Affairs
ULB	Urban Local Body
VFD	Variable frequency drive

VRM	Vertical Roller Mills
WAM	Wide Area Measurement
WAMS	Wide Area Monitoring Systems
VFD	Variable frequency drive
VRM	Vertical Roller Mills
WAM	Wide Area Measurement
WBIDC	West Bengal Industrial Development Corporation
WBPDCL	West Bengal Power Development Corporation Limited
WBREDA	West Bengal Renewable Energy Development Agency
WBSEDCL	West Bengal State Electricity Distribution Company Limited
WBSETCL	West Bengal State Electricity Transmission Company Limited

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Executive Summary

West Bengal is the fourth largest economy of India and one of the fastest growing Indian states with GSDP growing at a CAGR of 12% from 2012 to 2018. The population of the State is also expected to increase by 46% between 2015 and 2040 to reach 13.3 crore by 2040. This twin effect of population growth coupled with a healthy economic growth is expected to increase energy consumption by 2.5 times between 2015 and 2040 under the business-as-usual (BAU) scenario. Moreover, a combined effect of continuing the BAU scenario coupled with a change in market dynamics of the energy sector is expected to lead to the following implications that can potentially disrupt the growth path that the State is envisaging:

1. **Increase in emissions due to increased dependency on fossil fuel:** Carbon Emissions of the state is expected to increase three folds from 118 Million Tonnes of CO_2 in 2015 to 344 Million Tonnes of CO_2 in 2040. This will be primarily due to dependence of the state on consumption of oil and coal – share of oil and coal in primary energy supply will increase from 82% in 2015 to 91% in 2040. Since the state has no oil reserves, increased dependence on oil also poses a threat to the energy security of the state.

2. **Increased penetration of EVs:** Transport sector contributed to 76% of oil demand in 2015 in the state and this is expected to increase to 85% by 2040. Transformation from traditional oil driven vehicles to electric vehicles (EVs) in transport sector, provides a potential of reducing the dependence on oil.

3. **Energy Efficiency as a focus in near future:** Over 95% of power generated in the state is from thermal power plants. Hence, cutting down on wasteful power consumption in demand sectors by adopting energy efficiency measures can reduce power requirement, thereby leading to reduced emission. Adoption of Energy Conservation Building Code (ECBC) in this regard for buildings sector and actively pursuing energy efficiency in industries can thus contribute to reducing emissions as well as increase resource efficiency.

   In case of industries, energy costs can account for up to 20% of total cost of production, depending on the specific sub-sector. Adoption of energy efficiency can help reduce this cost, which in effect can help increase cost competitiveness of the industrial sector of the State. Additionally, adoption of energy efficiency can reduce the financial burden on MSMEs, which have limited access to finance and operate with low working capital.

4. **Optimal utilization of existing power generation units:** Plant load factor (PLF) of existing thermal power plants in the state is currently less than 60% which leads to sub-optimal utilization of the power generation asset. Since output of plant is low, auxiliary consumption accounts for around 10% of the total energy consumption of plant and is independent of plant PLF. By increasing PLF, proportion of auxiliary consumption would reduce and expenditure of new power generation assets can be avoided, which can have a positive effect on the power generation costs.

5. **Coal is and remains a major source of energy with inefficiencies in conversion process:** While the expected share of coal in the state's primary energy supply in 2040 stands at 65%, the share decreases to around 40% in the final energy level thereby indicating inefficiencies in energy conversion processes and providing scope for further decreasing emissions. This is exemplified by the high T&D losses of the state (24% in 2015) – the state ranks 3rd in the nation in terms of T&D losses. Also, presently the state's thermal power generation plants are based on sub-critical technology which has a low efficiency of 37%.

6. **Poor financial health of DISCOMs:** As discussed above, optimal utilization of power generating assets and reduction in T&D loss coupled with increased electricity demand through EVs can potentially reduce power costs as well as increase power sales for DISCOMs. The twin effect of cost reduction and sales expansion can potentially improve the financial health of DISCOMs.
7. **National focus on solar power:** Even though the state has a potential of 6.2 GW of solar power generation capacity, it is estimated to have 3.7 GW of solar power generation capacity by 2040. Scaling up solar power generation can potentially reduce the dependence on thermal power plant, thereby reducing emissions as well as enhance energy security for the state. However, addition of infirm solar power would require implementation of advanced forecasting techniques and development of storage sources to ensure grid stability.
8. **Extensive gas reserves in the state:** The state has 66 billion cubic metre (BCM) of Coal Bed Methane (CBM) reserves and is expected to have 25 BCM of shale gas potential as well. The economical extraction of this gas reserve can contribute to energy security of the state and considerably reduce emissions by replacing the use of coal in the industrial sector and biomass in the residential cooking sector. However, this would require substantial involvement of the State to enable transformation in consumption pattern as well as attract market players to setup gas extraction and transportation infrastructure.
9. **Newer coal reserves in the state:** Allocation of Asia's largest coal block with 2.1 billion tonnes of proven reserve - Deocha Pachami coal mines provides an opportunity of ensuring energy security for the state and can potentially remove the need for coal imports for power generation in the state. However, heavy overburden in the block is leading to technical issues in extraction which needs to be addressed. Furthermore, efficient use of extracted coal is essential to prevent further increase in emissions.
10. **New investment opportunities in energy sector:** Development of the state market in energy efficient technologies, new age technology like EV, Smart Metering etc. and adoption of new regulations like ECBC can potentially open up new investment areas and subsequently provide opportunities for job creation in the state.

As discussed above, the changes made in either energy supply or demand has a corresponding implication on the energy scenario and on the socio-economic and environmental aspects of one or more sectors. Hence, it implies that energy planning requires involvement across sectors and departments and a paradigm shift from the conventional approach towards integrated approach to ensure sustainable growth of the state in the coming years. In this context of energy planning, the Department of Power and New Energy Sources (DoP & NES), Government of West Bengal and IGEN Access Program of GIZ has undertaken this initiative to develop State Energy Plan followed by State Energy Action Plan (EAP) for the state of West Bengal.

In order to understand the effect of the multifarious environmental, technical and economic factors on the future outlook of the energy sector of the state and facilitate development of the Energy Action Plan, an energy system modelling exercise has been carried out. Energy systems modelling uses mathematical optimization to provide the ideal energy system under technical-engineering constraints and political-societal considerations. As an alternate to the BAU scenario, a set of two scenarios has been considered as future pathways for the energy sector in the state viz. Balanced Growth Scenario (BGS) and Energy Security Scenario (ESS). The two scenarios have been generated through energy systems modelling and will provide a long term energy horizon for the state and assist in strategic energy and integrated assessment of energy-engineering-economy-environment systems.

The model results for all scenarios have been generated by assuming an increase in annual GSDP growth rate from 12% in 2015 to 16.5% in 2040, an increase in annual population growth by 1.3% between 2015 and 2040 and a discount rate of 5%. Apart from these macro-economic parameters, the model has been provided with a set of 841 technology specific parameters, which provide the boundary conditions in order to generate the optimized model output.

Alternative energy growth pathways for West Bengal

Balanced Growth Scenario

The BGS scenario emulates an efficient, less polluting and improved energy system in the State by the year 2040. The scenario provides the optimal energy demand and supply situation by taking into account the following basic assumptions for terminal year i.e. 2040:

1. **Energy Supply**
    - 25% share of renewables in power generation capacity
    - Efficiency improvement in thermal power generation by 8% between 2015 and 2040
    - Reduction of technical losses in power transmission and distribution (T&D) from 24% to 8%.

2. **Energy Demand**
    - Improving energy efficiency by introducing improved technology/processes across sectors – 10% reduction in energy demand for buildings and 5% reduction in specific energy consumption for industries sector.
    - Fuel switch to gas (for industries and cooking) and electricity (for transport) from coal and oil respectively. 50% energy consumption will shift from coal to gas in the industries sector and 50% of energy consumption will shift from biomass to gas in cooking sector. The transport sector too will see a switch of 50% energy consumption from oil to electricity.
    - Share of IWT in freight and passenger transport to increase to 33% and 25% at the terminal year respectively from 1% and 0.4% in 2015.

Energy Security Scenario

ESS, on the other hand, is primarily driven by the objective of maximizing utilization of fuels that would help the state become self-sustainable in energy supply as well as lower emissions. Utilization of CBM reserves in the state can help achieve this twin goal of ESS.

The scenario provides the optimal energy demand and supply situation by taking into account the following basic assumptions:

1. **Energy Supply**
    - Efficiency improvement in thermal power generation by 8% between 2015 and 2040
    - 25% share of renewables in power generation capacity by 2040
    - Reduction of technical losses in power transmission and distribution (T&D) from 24% in 2015 to 8% in 2040

2. **Energy Demand**
    - Improving energy efficiency by introducing improved technology/processes across sectors – 10% reduction in energy demand for buildings and 5% reduction in specific energy consumption for industries sector.

- Fuel switch to gas (for industries, cooking and transport) and electricity (for transport) from coal and oil. In the industries sector, 60% energy consumption will shift from coal to gas and in the cooking sector 75% of energy consumption will shift from biomass to gas. In case of transport sector, 20% energy consumption will switch from oil to electricity and 45% will shift from oil to gas.
- Share of IWT in freight and passenger transport to increase to 33% and 25% in 2040 respectively from 1% and 0.4% in 2015.

Comparative analysis of energy scenarios of state

In order to understand the implications of the outcomes of the future energy scenarios of the state, a table providing a comparison of the values of key indicators in the terminal year of projections i.e. 2040 is given below:

Scenario	Final Energy Demand (GWh)	Emissions (MT CO_2/yr)	Share of renewable in power generation capacity (%)	Investment required (INR Cr)	Final Energy Mix
BAU	674,109	344	12%	1.5 lac	• Electricity (25%) • Coal (15%) • Gas (7%)
BGS	621,517	316	18%	7.1 lac	• Electricity (28%) • Coal (10%) • Gas (13%)
ESS	692,678	278	20%	9.2 lac	• Electricity (23%) • Coal (8%) • Gas (28%)

Note: In case of BAU, investment requirement includes only investments in the supply side viz. capital expenditure on power generation capacity addition (conventional and non-conventional), coal and gas extraction costs. Since, there is no additional initiatives undertaken in the demand side to transform the energy mix, there is no demand side investment in BAU. In case of BGS and ESS, the incremental investment as compared to BAU is due to the uptake of new technologies like EVs, gas based thermal power, energy efficient technologies etc. in the demand side as well as investment on power generation and gas extraction infrastructure on the supply side.

As given in the table, ESS is preferable over BGS as a future state for the state since it provides key benefits, in terms of increasing final energy consumption with lower emission and a higher share of renewables in the power generation capacity. However, realization of ETS is subject to the following risks:

1. Considering prevalent fuel prices and available technology for power generation, the levelized cost of energy (LCOE) of a gas based power generation plant is expected to be 10% more than coal based thermal power plant of equivalent capacity. Uptake of gas based power generation would be limited unless there is introduction of a more economical power generation technology or pricing support from the Government.

2. A notification from Ministry of Petroleum and Natural Gas[1] has provided marketing and pricing freedom to the contractors of CBM block, thereby taking CBM pricing beyond the purview of pricing

[1] For reference: Policy Framework for Early Monetization of CBM (Ministry of Petroleum and Natural Gas, April 2017)

regulations of the Ministry. The State Government has no jurisdiction over the pricing of CBM. Hence, market prices of competing fuel sources viz. coal, LPG, electricity will be a key factor in determining uptake of CBM by consumer segments.

3. Even if gas pricing becomes favourable, consumers have to undertake additional capital expenditure to either retrofit or replace existing equipment/machineries with ones which can run efficiently on gas. In such a case, propensity of the consumer to incur this additional amount, will determine the extent to which this scenario gets adopted.

4. Apart from the demand side risks/issues, adequate investment should be present in the supply side to scale up infrastructure for exploration, gas production and distribution within the state. Mobilizing scale of investment that is required to develop such infrastructure, requires substantial amount of time. Delay in receiving clearances and right of way for infrastructure development can further escalate costs. Also, technical constraints in drilling/boring wells or in extraction process can escalate costs and may lead to extraction from a particular well infeasible.

In such a case, a deeper engagement of the state government and the CBM producers is required to provide a more effective go-to-market strategy, resulting in increased utilization of CBM in the state. However, technical viability and sustenance of low gas prices is contingent on the prevalent scenario and beyond the control of the State Government.

BGS, on the other hand, projects natural gas consumption based on historical trend of gas market growth in the state. Hence, BGS provides a more feasible alternative which the State can undertake and ensure that a sustainable energy supply and consumption is achieved. Based on the outcomes of the BGS, an Energy Vision and a subsequent Energy Action Plan has been developed.

Energy Action Plan

The Energy Action Plan has been developed to achieve the targets provided in the energy demand and supply side sectors under the BGS. The key activities that need to be undertaken in each sector that will help achieve the targets given under the BGS is given below:

1. ***Energy Supply Sector:***

Adoption of clean coal technologies: Adoption of BGS for energy supply is expected to reduce emissions by over 6%, despite a capacity addition increase by 1% over BAU. This is possible through future capacity addition of coal based super critical technology in power generation for the state. Additionally, the state can look to promote low emission technologies like Fluidized Bed Combustion (FBC) and Integrated Gasification Combined Cycle (IGCC). FBC exhibits most promise for West Bengal, since it's most suitable for Indian coal grades and low grade fuels such high-ash fuels, and lignite, brown coals. Also, the technology also requires relatively simple manufacturing.

Updating Renewable Energy Policy: The State should also update the Renewable Energy Policy of 2012 to align with the targets contained under the BGS. The Focus Areas and Strategy section should be amended to reflect the emphasis on increasing solar power generation along with co-generation capacity. RE project financing section should include the proposed Clean Energy Fund (described under cross-sectoral initiatives). Also, Regulatory Issues section should be modified to incorporate regulatory changes that are required to increase penetration of solar rooftop.

Scaling up solar power generation: In order to increase penetration of solar rooftop in the state, a key action would be lowering limit for net metering from the existing 5kWp to 1kWp for residential consumers. Also, tax benefits and lower interest rates can be provided by categorizing loans for rooftop solar as "Priority Sector Lending" and by considering it as part of home loan/home improvement loan. Considering the paucity of land in the state for setting up large scale solar, the

state can increase penetration of floating solar power plant to increase share of renewables in the state. The State shall look towards increasing power storage infrastructure like residential energy storage and explore techniques like redispatch system to counter grid instability caused by integration of renewables.

Modernization of power distribution system: It entails installation of a smart grid and control the power flow or curtail the load to match generation in real time. Installation of smart grid system is essential to implement Demand Response System (DRS), Dynamic Pricing and other advanced power management initiatives in future to enable reducing losses, assist in peak load management as well as ensure efficient consumption of power.

Improved financial health of DISCOMs: Under BGS, there is a 5% increase in power consumption over the BAU scenario in 2040, resulting in an additional consumption of nearly 7700 MU in the state. A combined effect of this incremental consumption, coupled with reduction in T&D loss and efficient use of power generating assets can potentially reduce power costs as well as increase power sales, thereby improve financial health of DISCOMs

Case for CBM utilization: In case of CBM, State action would be mostly demand side since control and regulations of supply side is a central subject. State can assure gas consumption to private sector gas suppliers by developing anchor customer preferably in industrial sector, through gas purchase/sale agreement. The state can also promote cogeneration in industrial sector and trigeneration in buildings sector since trigeneration and cogeneration can provide higher efficiencies (80% and 85% respectively) as compared to a typical thermal power generating station (40%). District cooling systems, which can reduce energy consumption by 35% as compared to standard air-cooled AC system, can also be explored to create further demand for gas in the state.

The table below provides a summary of the recommended activities for energy supply sector under Energy Action Plan of the state:

No	Sub-sector	Sub Activity	Estimated Investment (INR Cr)	Implementing Agency
Short Term (2020-25)				
1.	Power Generation - Conventional	Partnership for clean coal technologies	-	DoP, WBIDC
2.	Power Generation Non-conventional	Establish potential of renewables of state	2,940	WBREDA
3.		Updating Renewable energy policy		DoP
4.		Provide regulatory support to increase penetration of solar rooftop enabling environment for increased penetration		DoP
5.		Undertake advanced load forecasting to ensure grid integration of renewables		DoP, Discoms, SLDC
Short to Medium Term (2020-30)				
6.	Coal	Increase penetration of modern technology to increase mine productivity and worker safety	36,000	DoP, WBPDCL

No	Sub-sector	Sub Activity	Estimated Investment (INR Cr)	Implementing Agency
7.		Promotion of clean coal technology for industrial consumers		DoP, WBIDC
8.	Natural Gas	Develop anchor customers in industries sector	-	DoP, WBIDC, IC&E
Short to Long Term (2020-40)				
9.	Natural Gas	Implementation of district cooling system	-	DoP, UD&MA
10.	Power Transmission and Distribution	Modernization of power distribution system within the state	20,370	DoP, Discoms
11.		Installation of infrastructure to prevent losses due to theft and damages due to natural disasters		Discoms
Medium to Long Term (2025-40)				
12.	Natural Gas	Improve overall natural gas market & increase promotion of cogeneration techniques	22,200	DoP, IC&E
13.	Power Generation – Conventional	Undertake capacity addition for clean coal technology	15,300	DoP, Power GenCo
14.	Power Generation – Non-Conventional	Development of floating solar power plants to increase share of renewables in state	18,550	DoP, WBREDA, WBPDCL
15.	Power Transmission & Distribution	Increasing penetration of power storage infrastructure and grid stabilization techniques	-	DoP

2. ***Transport Sector:***

The key transformation required in the transport sector is the increased penetration of EV in road transport and increasing modal share of IWT in the state. In order to reduce oil consumption by 9% along with 7.5% reduction in emissions in comparison to the BAU scenario, the penetration of EV should increase to 50% and modal share of IWT should increase by 20% in both passenger and freight transport by 2040.

Development of EV policy: The primary step to increase EV penetration is development of an EV policy which will present the State's vision regarding EV and propose initiatives to address issues faced by this sector. The proposed policy should contain vision, mission and specific targets for EV penetration in the state, along with an attractive package of incentives and concessions to accelerate EV, OEM, battery manufacturing and battery charging/swapping infrastructure. It should also contain directives on EV charging infrastructure standards and steps to promote private sector participation in the development of charging infrastructure along with institutional arrangement to ensure implementation of policy recommendations.

Private sector participation in growth of EV: Penetration of EVs (4W) in commercial passenger transport space can be increased by adopting ongoing "Gatidhara" financing mechanism of the State by providing a subsidy equal to 10% of car cost. The Transport Department can also introduce PPP mode for introduction of e-buses across the state, wherein the Department and private player share

procurement costs while operations and maintenance is undertaken by the player and the Department respectively. Additionally, the utilization of existing tram lines infrastructure can also be explored by the development of electric trolley buses.

Growth of EV charging infrastructure: In order to support growth of EV charging infrastructure, the State can mandate installation of EV charging stations in public parking areas, provide business model to increase private sector participation in development of EV charging station or allocate funds for development of state owned charging stations. In order to facilitate business operations by levying usage fees for EV charging station, the Department of Power should provide guidelines on the fees in accordance with any regulatory requirements, thereby providing a level field for market players, be it public or private. The State can also engage with foreign organizations and specialized institutions for technical collaboration and partnerships to tap multiple opportunities arising due to growth in EV viz. assembly and manufacturing of EV components, installation and maintenance of EV charging stations, service providers for EV and EV charging station repairing facilities and research and development on improved manufacturing techniques for EV/EV components.

Development of Inland Water Transport (IWT): IWT is an important sub-sector for West Bengal's transport sector – the State contains 17 of 111 national waterways (NWs) notified in National Waterways Act 2016. Use of IWT for freight transport can help reduce cost (INR/tonne-km) by over 100% and 30% as compared to roadways and railways respectively. In order to result in a shift in modal share from road to IWT in 2040 by 37% as compared to BAU, the State can provide last mile connectivity to the jetty locations within the state along the national waterways. In order to plan for last mile connectivity requirements, State can liaise with IWAI to understand the land-side infrastructure requirements.

The table below provides a detailed break-up of the recommended activities under Energy Action Plan of the state:

No	Sub-Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
Short Term (2020-25)				
1.	Passenger Transport	Development of EV policy	-	Transport Dept.
Short to Medium (2020-30)				
2.	Passenger Transport	Introduction of electric trolley buses to utilize existing tram infrastructure	50	Transport Dept.
3.		Providing adequate charging infrastructure to support growth of EV	1,400	DoP, UD&MA
4.		Capacity development in operation and maintenance of EV battery and charging infrastructure	-	DoP, Transport Dept.
5.		Introduction of electric ferry services in the state	15	Transport Dept.
6.	Freight Transport	Provide infrastructure support required for operating RO-RO services	1,44,000	Transport Dept, WBPWD

No	Sub-Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
7.		Build awareness among commercial transportation companies to increase presence in IWT		Transport Dept.
Short to Long Term (2020-40)				
8.	Passenger Transport	Provide incentives to increase uptake of EV by retail consumers	9,000	Transport Dept.
9.		Increase private sector participation in increased penetration of EV in passenger transport	4,10,000	Transport Dept.
Medium to Long Term (2025-40)				
10.	Passenger Transport	Engage with foreign organizations and specialized institutions for technical collaboration and partnerships	-	WBIDC
11.		Undertake modernization of traffic management system in the urban areas of the state		Transport Dept

3. ***Industries Sector:***

The key transformation required in the transport sector is the increased penetration of energy efficient activities which will lead to reduction in specific energy transformation by 5% by 2040 and replacement of energy demand for coal with natural gas, leading to 38% reduction in coal consumption by 2040. Based on the technology currently available, list of probable energy efficiency and conservation measures for industries relevant for West Bengal has been provided below:

Industry Category	Energy Efficiency & Conservation Measures	Savings Potential
Iron & Steel	Power generation & coal drying through waste heat utilization from flue gas. Sources of heat: gases from coke ovens, blast furnaces, basic oxygen furnaces, and electric arc furnaces	6%
Cement (Grinding and packaging only)	• Optimization of Vertical Roller Mills (VRM) • Reduction of Compressor power consumption • Power factor improvement • Installation of variable frequency drive (VFD)	15-18%
Pulp & Paper Industry	• Oxyfuel burning in lime kiln & black liquor boiler. • Use of shoe press • Optimize energy dispersion as per requirement • Installation of extended delignification of system for cooking of wood	10-15%
Textile	• Blowroom efficiency • Ring spinning activities • Humidification • Compressor efficiency	8-10%
Foundry	• Replacing existing conventional cupola with divided blast cupola • Replacing inefficient blower with optimally designed blower • Replacing rewound motors with energy efficient motors	15-20%

Industry Category	Energy Efficiency & Conservation Measures	Savings Potential
	• Retrofitting air compressor with variable frequency drive • Compressor efficiency improvement	

As observed in the table above, a majority of the energy efficiency initiatives provided is linked to three primary industrial equipment viz. furnace, compressor and motors. These equipment are widely used across industrial sub-sectors and as observed from sector experts, consume substantial amount of energy of any production unit. Apart from the above, a specific technology pertinent to brick industry has also been pointed by sector experts as an area which needs to be explored. The table below provides equipment specific technical improvements.

Equipment/ Technology	Energy Efficiency measure	Reference Equipment	Energy Savings Potential	Monetary Savings Achieved	Investment required
Furnaces	Conversion of fuel for forging and heat treatment furnace from furnace oil to natural gas	Medium scale Forging unit	15%-25%	INR 300-667/Ton of production	INR 4-10 lac depending on capacity
	Preheating feed water by using waste heat	Steam System with 3,000 operating hours/yr	20%-25%	INR 102,200/yr	INR 24,500
Compressor system	Installation of energy efficient compressors	Compressor with 3000 operating hours per year	10-15%	INR 1260/cubic feet minute (cfm) of compressed air	INR 2 lac for compressor with 1000cfm rating
	Installation of leakage proof compressed air pipelines		3-5%	INR 220/cfm of compressed air	Negligible
Motors	Installation of variable frequency drive (VFD) on air compressor motor, blowers, centrifugal pumps	Motor with 3600 hrs of operation	50-60%	INR 600000/yr per motor	INR 330000/motor
	Installation of energy efficient motors	Motor with 8000 hrs of operation and efficiency improvement from 88% to 93%	5-6%	INR 5000/yr per motor	INR40000/ motor

Equipment/ Technology	Energy Efficiency measure	Reference Equipment	Energy Savings Potential	Monetary Savings Achieved	Investment required
Zig-Zag Technology (Sector Experts from GIZ , 2019)	Replacement of traditional fixed chimney bull trench kilns (FCTBK) with natural draft zig-zag type kilns	Kiln with annual production capacity of 4 million bricks	20-25%	INR 875/per 1000 bricks produced	INR 20.6 lac

In order to ensure an increased uptake of energy efficient alternatives by industries, the roadmap for implementation has been provided which includes energy benchmarking of select industrial sub-sectors of State, followed by pilot project implementation and other supporting activities. Measures like extending financial support to increase loan disbursement through banks, development of a business model to implement energy efficiency measures, developing partnership with technology and service providers as well as providing training on operating and maintaining energy efficient technologies will effectively contribute to that end.

The recommended activities for the sector are mostly aimed at increasing awareness generation and market development for energy efficiency and gas consumption. Also, considering the paucity of data available on energy consumption (especially MSMEs), any estimation on investment opportunity for energy efficiency and gas penetration in the entire sector has been excluded from the Energy Action Plan.

The table below provides a detailed break-up of the recommended activities under Energy Action Plan of the state:

No.	Sector	Sub Activity	Responsible stakeholder
Short Term (2020-25)			
1.	Large Industries & MSMEs	Undertake detailed energy (and water) audit of sampled large industries and MSME clusters across the state	IC&E, MSME
Short to Medium Term (2020-30)			
2.	Large Industries & MSMEs	Prepare energy benchmark for industrial sub-sectors utilizing database prepared from energy profile and existing best practices	WBSEDCL, IC&E, MSME
3.		Develop linkages with technology providers, aggregators, R&D labs, technical institutions to provide relevant technical inputs to beneficiaries	IC&E, MSME, DoP
4.		Undertake demonstration projects and subsequently pilot projects across sub-sectors	IC&E, MSME, DoP
5.		Extend financial support to increase loan disbursement through banks	IC&E, MSME
6.		Develop business model to implement energy efficiency measures	IC&E, MSME, DoP
7.		Providing training on operating and maintaining energy efficient technologies	IC&E, MSME, DoP

No.	Sector	Sub Activity	Responsible stakeholder
Short to Long Term (2020-40)			
8.	Large Industries & MSMEs	Development of online resource for dissemination of database and best practices in energy efficiency and conservation for the industrial sector	IC&E, MSME
9.		Continue providing financial support to increase undertaking of energy audits and implementation of energy audit recommendations	IC&E, MSME
Medium to Long Term (2025-40)			
10.	Large Industries & MSMEs	Develop partnership with technology and service providers	IC&E, MSME, WBIDC

4. ***Buildings Sector:***

The key focus for buildings sector is to increase penetration of energy efficient appliances and building design in the state, both in commercial and residential buildings, leading to a 3% reduction in energy demand as compared to BAU scenario. The primary enabler for achieving this target would be the implementation of ECBC, which will require development of implementation roadmap as well as supporting infrastructure, creating model regulation for ECBC implementation and ensure incorporation of regulation in municipal bye-laws of relevant municipal authorities.

Roadmap for implementation of ECBC: Additionally, market development activities need to be undertaken to ensure adequate availability of expertise and building materials required for implementing ECBC. Accordingly, institutional and regulatory support to be provided to businesses providing ECBC compliant building material and BEMS to setup/scale up operations in the state. WBSEDCL can act as the anchor agency which will co-ordinate and organize the events (roadshows, conferences etc.) for reaching out to the market players for developing their businesses in West Bengal. These businesses could be related to training institutes/conducting certification courses in designing ECBC compliant buildings and assessing compliance of building design with ECBC; establishing manufacturing units/development centres for manufacturing and developing ECBC compliant equipment, material and control systems and establishing testing centres and develop capacity for testing compliance of material and control systems.

State Energy Conservation Award: An award can be given to those consumers of industrial, commercial, government buildings, educational institutions, hospitals, municipal committees/corporations and individuals who have excelled in adopting the various energy conservation measures in their buildings/units to save electricity/other fuels. This will help in promoting and generating awareness of ECBC and energy conservation in general among end-users in the sector.

Retrofitting energy inefficient appliances in public buildings: The State can undertake replacement of existing appliances and lighting in commercial buildings with energy efficient variants and recover implementation cost through energy cost savings achieved. In short term, public buildings (i.e. buildings owned by State Government and its agencies) can be targeted with WBSEDCL being the implementing agency. Subsequently the initiative can be extended to other commercial buildings on a voluntary basis.

Initiative for residential buildings: In case of residential buildings, a loyalty program can be started for private buildings, under which consumer will receive EE points for buying energy efficient appliances & lighting. These points can be exchanged for three types of goods: coupons and prepaid cards, energy-efficient products or products that promote regional economies. In the medium to long term, the State should also undertake implementation of ECBC for residential buildings, once the code has been finalized and published by Bureau of Energy Efficiency.

The table below provides a detailed break-up of the recommended activities under Energy Action Plan of the state:

No.	Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
Short Term (2020-25)				
1.	Residential Buildings	Develop and implement loyalty program for building efficiency	-	UD&MA
2.	Commercial Buildings	Develop model regulation for ECBC implementation in state and ensure incorporation of regulation in municipal bye-laws of relevant municipal authorities	-	DoP, UD&MA
3.		Develop ECBC implementation roadmap along with requisite supporting infrastructure	-	UD&MA
Short to Medium Term (2020-30)				
4.	Residential Buildings	Develop awareness of retail buyers on the benefits of energy efficiency for buildings and building labelling program	-	WBSEDCL
5.	Commercial Buildings	Undertake awareness programs on building energy conservation and efficiency as well as building labelling systems	-	WBSEDCL
6.		Provide support to businesses institutional and regulatory support to businesses providing ECBC compliant building material and BEMS	-	UD&MA
7.		Undertake retrofitting of existing equipment with energy efficient variants along with implementation of energy conservation options for building envelope in public buildings	3,900	DoP, WBSEDCL
Short to Long Term (2020-40)				
8.	Residential Buildings	Develop implementation roadmap of ECBC for residential buildings	-	UD&MA, WBSEDCL
9.		Provide financial incentives to increase uptake of solar water heaters	6,400	DoP
10.	Commercial Buildings	Undertake the energy conservation buildings awards to incentivize uptake of energy efficiency and energy conservation	-	WBSEDCL
Medium to Long Term (2025-40)				
11.	Residential Buildings	Develop implementation roadmap for demand response system	-	DoP, UD&MA

5. ***Agriculture and Fisheries Sector:***

In the case of agriculture sector, the key objective is to increase the share of electricity for pumping to 85% of the total energy requirement by 2040 from 42% in 2015. As a source of electricity, solar power should account for 4% of the total energy requirement for the sector by 2040 as compared to negligible penetration of solar energy in 2015. Also, improvement of energy efficiency and increased penetration of renewables should be pursued in post-harvest activities.

Increased penetration of solar and energy efficient pumps: In order to achieve the targets related to penetration of solar and energy efficient pumps in the agriculture sector, the State shall leverage the existing scheme of BEE for replacement of existing pumps with energy efficient pumps in the state. 50% penetration of energy efficient pumps for West Bengal is expected to translate to a net energy savings of over 200 MU and corresponding cost savings of around INR 90 crore for beneficiaries. The State can also develop co-operatives to provide loans to farmers at less-than-market interest rates for procurement of solar pumps. A 4% penetration of solar pumps through the scheme can lead to cost savings of around INR 63 crore on account of diesel consumption avoided. These activities need to be supported by adequate awareness generation programmes which will educate farmers about the benefits of energy efficient pumps and solar pumps.

Increased penetration of solar power in fisheries: In case of fisheries, the penetration solar power and improving energy efficiency of fishing vessels can lead to potential cost savings of INR 80 crore across the sector. The State can provide financial support in the form of loans to increase penetration of solar powered inland fishing vessels and auxiliary power consumption through solar power in marine fishing vessels. The State can capitalize its fishing co-operative BENFISH to implement the loan mechanism as well as to organize capacity building programmes on methods of increasing fuel efficiency of marine fishing vessels.

The table below provides a detailed break-up of the recommended activities under Energy Action Plan of the State:

No.	Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
Short to Medium Term (2020-30)				
1.	Agriculture Sector	Distribution of energy efficient pumps to replace existing electric pumps	560	WBSEDCL
2.		Develop co-operatives to provide financial support for procurement of solar pumps and energy efficient pumps by farmers	20,000	WRID, Agri Dept.
3.		Assess potential for energy efficiency in cold chain and develop implementation roadmap	-	WRID, Agri Dept.
4.		Undertake awareness programmes for disseminating benefits of energy efficient pumping and irrigation systems as well as solar powered pumps to farmers through co-operatives, gram panchayats etc.	-	WRID, Agri Dept.
5.	Fisheries Sector	Develop and implement financial mechanisms to increase uptake of solar power options in fishing vessels	85	Fisheries Dept.

No.	Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
6.		Undertake awareness programs to disseminate benefits of switching to solar power for fishing vessels	-	Fisheries Dept.
7.		Undertake stakeholder outreach programs to create awareness on the methods of increasing fuel efficiency of marine fishing vessels	-	Fisheries Dept.

6. ***Cooking Sector:***

In the cooking sector, the primary objective is to reduce the share of biomass from 91% in 2015 to 15% in 2040 by increasing penetration of gas in rural areas and electricity in urban areas.

Strategy for rural areas: In case of rural areas, the State can support the existing Central Government scheme Pradhan Mantri Ujjwala Yojana (PMUY) under which LPG cylinder is being distributed to BPL families across the country. A key issue in continued use of LPG by such families is with regards to availability – users have to undertake transportation of the new cylinder from the point of sales, which are usually far off from the home location of the user. In order to address the issue of transportation, the State Government can facilitate introduction of LPG distribution centres at local co-operatives by collaborating with the oil marketing companies (OMCs). The activity must be supported by rigorous awareness generation programme which disseminate the benefit of switching over to LPG from biomass to rural users.

Strategy for urban areas: In case of urban areas, the State can provide financial support in the form of subsidies to the end users to increase penetration of electric cooking equipment. The value of the subsidy can be limited to 50% of the SGST of the cooking equipment. It is estimated that in order to achieve 74% penetration of electric cooking in urban areas, a net subsidy outlay of around INR 115 crore would be required.

The table below provides a detailed break-up of the recommended activities under Energy Action Plan of the state:

No.	Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
Short to Medium Term (2020-30)				
1.	Rural	Develop LPG distribution mechanism at co-operative/panchayat level to facilitate refilling of LPG cylinders by consumers	-	P&RD, OMCs
2.		Facilitate setting up of biogas plants through setting up co-operatives	67	P&RD
3.		Undertake awareness programmes for disseminating benefits of switching from biomass to LPG.	-	P&RD
4.	Urban	Provide financial support to end user to increase penetration of electric cooking equipment	3,000	GCGSC
5.		Undertake stakeholder outreach programs through mass media channels to create awareness on benefits of using electricity for cooking	-	DoP, Discoms
Medium to Long Term (2025-40)				

No.	Sector	Sub Activity	Estimated Investment (INR Cr)	Responsible stakeholder
6.	Rural	Assess power distribution infrastructure development required to support use of electricity in cooking and develop implementation roadmap	-	DoP, Discoms

7. ***Cross-Sectoral Initiatives:***

In order to implement the core activities provided under each sector of the Action Plan, there are a number of supporting activities/initiatives that need to be undertaken which are cross-sectoral in nature.

- Undertaking awareness generation and capacity building activities
- Sectoral studies to periodically update the state energy database
- Development of a webtool to support assessment of power consumption of domestic consumers
- Preparing "Green Procurement Guidelines" to promote procurement of energy efficient technology/equipment/components by public entities.
- Developing a Clean Energy Fund which can help overcome financial barriers for adopting clean energy technologies. It can start with an initial corpus of INR 50 crore, and can be scaled later to INR 405 crore in the long term, based on the projected requirements.

The State can leverage the business promotion platforms like the Bengal Global Business Summit to showcase the initiatives undertaken to improve energy conservation and efficiency and to seek funding or technical assistance for specific initiatives in the energy sector. This can potentially create investment options, help increase engagement with international partner countries or national organizations to enhance economic activity as well as achieve better results in energy conservation efforts undertaken by the state. As an outcome of the investments, there is a considerable potential for job creation in the state in modern technology. The areas where the state can look for opportunity on collaboration is given below:

No.	Thematic Area	Collaboration/Investment opportunities	Type of Collaboration
1.	Coal Mining	1. Installing new infrastructure required for mining and extraction 2. GPS based Truck Dispatch System 3. Use of mine planning software like MINEX 4. Development of Decision Support System through enhancement in MIS of standard ERP solution 5. Implementation of automated mining system (like mine robotics, armchair mining) for enhancing worker safety and improving mine productivity. 6. Use of computerized system in underground mines	Technology collaboration
2.	CBM & Natural Gas	1. Integration of CBM extraction technologies and systems	Technology collaboration
		2. Supply, installation and maintenance of drilling equipment, fracking equipment, well-head natural gas processing equipment and control systems.	Access to markets
		3. Development of infrastructure in efficient gas transportation 4. Exploration and development of shale gas	Investment partnership
3.	Solar	1. Manufacturing of solar PV panels 2. Manufacturing/assembly of supporting power equipment required for solar rooftop viz. bi-directional meter, isolation transformers, inverters, protection devices	Investment partnership/ Technology collaboration

No.	Thematic Area	Collaboration/Investment opportunities	Type of Collaboration
		3. Supply of solar PV panels and supporting power equipment 4. ESCO services for installation and maintenance of rooftop solar systems 5. Stand-alone installation and maintenances services	Access to market
4.	Power Transmission & Distribution	1. Manufacturing and installation of power transmission equipment viz. digital switch gear and smart substations 2. Manufacturing and installation of power distribution equipment viz. smart meters, smart controllers, Remote Terminal Units, SCADA systems, distribution transformers, aerial bundled (AB) cable, meters with Low Power Radio Frequency (LPR) communication capabilities	Investment partnership/ Technology collaboration
		3. Grid and transmission line expansion to account for increased consumption of electricity	Access to market
		4. Technical expertise for assessment of grid synchronization and smart grid installation	Technology partnership
5.	Electric Vehicles	1. Assembly and manufacturing of EV components	Investment partnership
		2. Installation and maintenance of EV charging stations 3. Service providers for vehicle repairing facilities	Access to market
		4. Expertise for technical assessment of sites for EV charging 5. R&D on improved manufacturing techniques for EV/EV components	Knowledge partnership
6.	Energy Services	1. Designing energy efficient building 2. Technical expertise for developing energy optimization systems 3. Development and implementation of industrial energy management systems	Technology partnership/ Access to markets
		4. Develop R&D centres specializing in developing supporting tools and software for efficient operation of equipment/systems	Knowledge partnership
7.	Equipment Manufacturing	1. Technology transfer/technical assistance for setting up units manufacturing energy efficient household appliances 2. Setting up semiconductor fabrication plant that can supply components for manufacturing smart appliances and equipment.	Technology partnership
		1. R&D on designing and manufacturing EE equipment 2. Development of State-of-the art testing laboratory for manufactured products.	Knowledge partnership

The Action Plan is also supported with a Decision Support Tool to understand the impact of various factors on the energy scenario of the state and to understand the impact of policy level decisions on the energy supply/demand sector, there by assisting in decision making.

1. Background of the project

West Bengal, India's fourth largest economy (Govt. of WB, 2019), had a gross state domestic product of US$ 163 billion in 2017-18, at an annual growth rate of 12% between 2013 and 2018 (IBEF, 2018). The State is the gateway to North East India as well as South East Asia and holds a strategic position for the economic development of the Eastern region of India. Considering the importance of the state for regional development, West Bengal has made considerable progress in power sector – the state achieved 100% household electrification in 2018 (Ministry of Power, 2018). Despite the boom in providing new connections, substantial losses are being incurred from theft and losses in power distribution – according to Union Power Ministry data (Prod to plug power losses, 2018), the state ranks 3rd in the nation in terms of transmission and distribution (T&D) losses. The aggregate technical and commercial (AT&C) losses of West Bengal distribution companies is reported to be around 31% in 2015-16 and is expected to be around 21% by 2019-20 (Ministry of Power, Government of India, 2017).

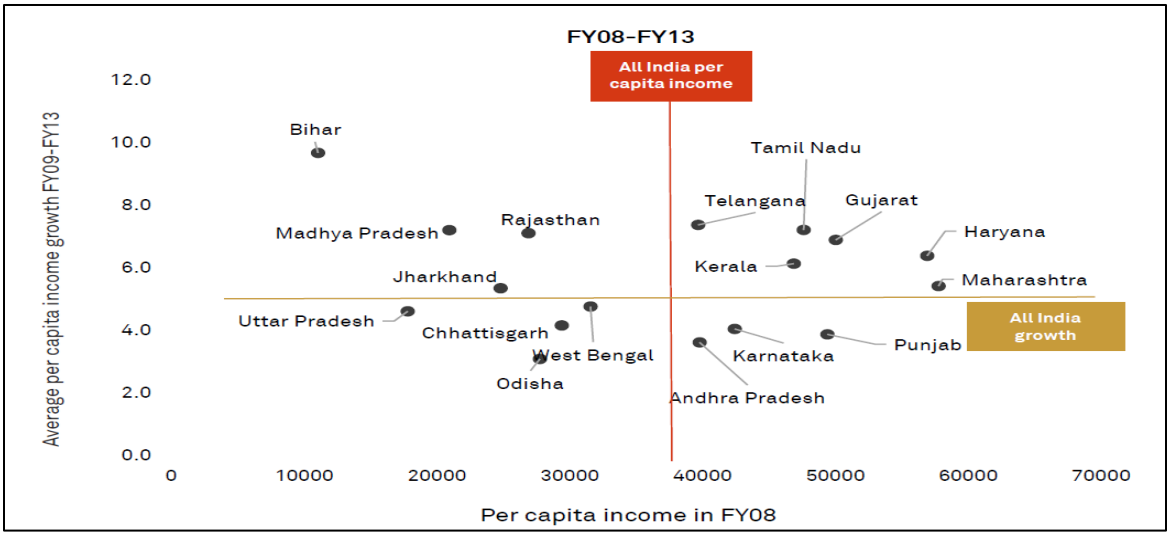
West Bengal is the 10th largest consumer of electricity in the country accounting for nearly 4.38% of total energy consumption in India. On an average, 37% demand of power comes from domestic segment followed by 32% from industrial, 15% from commercial, 7% from agriculture and 9% from other consumers (Power For All Document, 2016). Owing to significant improvement in power supply, the State witnessed only 0.4% energy shortfall in FY17 and almost no short fall in FY18, which is considerably lower than the national average of energy shortfall of 0.7% (CEA, 2018). In terms of peak power requirement as well, the State has performed significantly better than the national average, as the peak deficit has been zero compared to 0.9% of the national average in the year 2017-18. However, the average plant utilization of the State is around 55% for the State owned capacities and the State is still having certain energy deficit which corroborates the need for systematic energy planning.

Even though the State had lower growth rate in the period 2013-17 (around 4.8% y-o-y)[2] but since 2017, significant growth has been observed in the State economy due to implementation of various industry friendly policies, promotion of service sector and overall economic growth in the country. It is exemplified by the fact that in FY17 the State improved its position to 4th in the country in terms of GSDP growth rate. In FY18, the State even performed better and ranked 3rd in the country in terms of GSDP growth.

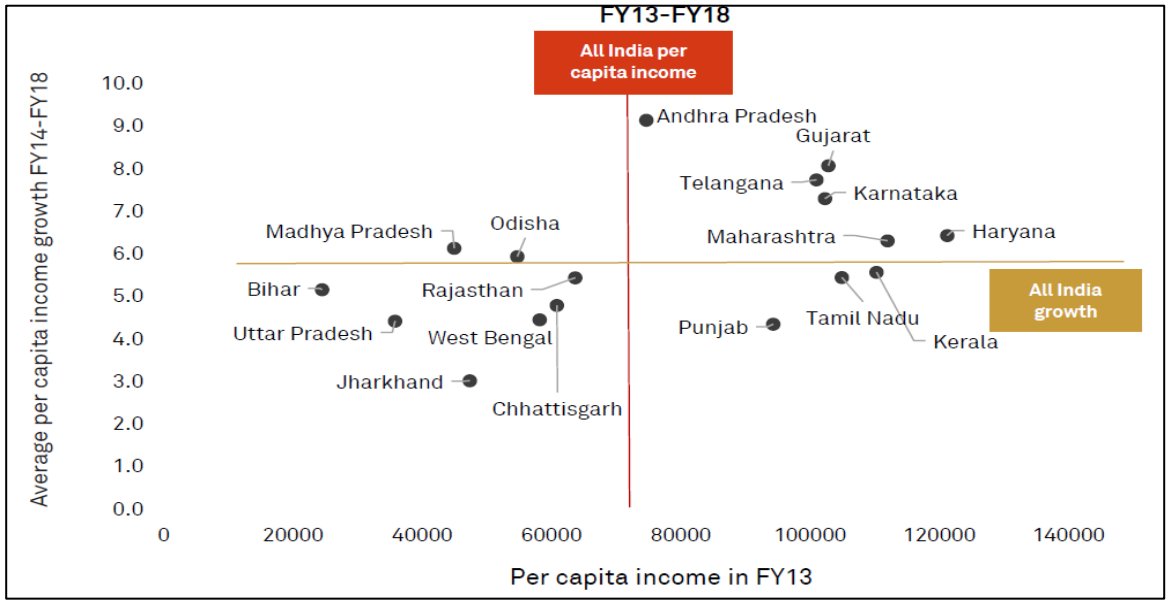
The following figure compares the economic performance of the states of India for a five year period (FY08-13 and FY13-18) based on the per capita income in the base year and the average per capita income growth in the succeeding four years. In the context of the surge of economic growth that West Bengal has been witnessing in the recent years as compared to India in general, it is expected that it should progress to the 4th quadrant by FY13-18 period, indicating high per capita income and high income growth. However, the State continues falls within the 1st quadrant of the performance matrix, indicating that GSDP growth alone cannot help the State to ensure sustainable economic development and additionally requires an integrated developmental planning approach.

[2] State GSDP nominal growth rate was around 12% in the year 2015-16.

Figure 1: Comparison of State economic performance



Source: CRISIL 2019 (States of growth 2.0)



Source: CRISIL 2019 (States of growth 2.0)

In case of West Bengal, it is also observed that economic growth and energy consumption is directly correlated (Saha & Bhattacharya, 2018), which further indicates that energy availability and consumption is essential for the State to move up in the ladder of economic and social development. Energy is one of the major resources in the economy which integrates all other sectors in one common thread and thus a comprehensive assessment and planning for energy production and consumption in the economy is an essential task.

Apart from the current issues plaguing the power sector, the broader energy sector in the state is poised to go through a transformation in the coming years. Any endeavour to draft the energy action plan, which is also futuristic in nature, has to take into cognizance of these emerging trends. The opportunities and challenges arising from these trends are as follows:

1. **Continued low to moderate growth in energy demand in the State in spite of high GSDP growth rate**[3]
   - **Near power surplus state with decreasing rate of growth of power demand**: The power demand in the state for the current decade (2010 onwards) is growing at around ~5.2% as compared to 13% in the last decade (2000-2010) (Planning & Statistics Deparment). The state has a total generation capacity of 8338MW with additional CPSU allocation of 2048 MW (Department of Power & NES, Government of West Bengal) and another 2000 MW power generation capacity is expected to be added over the next 5 years (DoP, Govt. of WB, 2018). With average plant load factor (PLF) less than 60% (DoP, Govt. of WB, 2018) reported in 2015-16 and lack of significant demand growth in the future, there is a risk of revenue loss due to under-utilization in the coming years.

   - **Increasing penetration of energy efficiency in households will reduce power demand**: There is a major thrust on introducing energy efficient appliances in households by EESL under its various programs - EESL's program on LED bulbs i.e. UJALA has been introduced in West Bengal in 2017 and around 9.2 million LED bulbs have been distributed till date, resulting in savings of nearly 1200 MU of power (EESL, 2018). Subsequently there are plans to introduce energy efficient fans as well. Considering that 37% of State's power demand comes from the domestic segment, increased penetration of energy efficient appliances is expected to result in decrease in power demand (Power For All Document, 2016). Additionally there is a clear thrust on implementation of Energy Conservation Building Code (ECBC) for commercial and residential sector buildings. ECBC for commercial buildings is expected to be enforced in the near future which will further reduce energy intensity in the buildings sector.

   - **Industrial sector will also witness reduction in power demand due to penetration of low energy intensive manufacturing processes**: West Bengal is working with BEE to enforce the energy efficiency programme for designated consumers (DC) in industrial sectors under Perform Achieve Trade (PAT) programme. Across the 4 PAT cycles, a total of 51 industries have been notified in West Bengal (BEE, 2018). Based on the report on State Energy Efficiency Preparedness, 50% of these designated consumers have achieved their energy reduction targets (BEE, 2018). With further thrust on energy efficiency and energy conservation along with development of manufacturing processes which support such measures, the energy intensity of industries sector is also expected to decrease.

2. **New demand drivers**

[3] State's main economic driver is the tertiary sector (like services, trade, transport etc.) which has recorded highest growth rate of 15.2% per annum. Also, even though primary sector of the economy (like agriculture, forestry, mining etc.) has a considerable contribution to the GSDP, the sector has been historically observed to be non-energy intensive. Therefore, even though State is scoring high in GSDP growth rate, but its energy consumption has not grown at that rate.

- **Setting up of multimodal logistics park and nautical transportation network** (WBIDC, Government of West Bengal, 2018)**:** The State Transport Department has proposals to set up rail-road enabled multimodal logistics hub at Gobra and another 5 new multimodal logistics park are planned in the State. There are several vessels and Roll-on/Roll-Off (RO-RO) services planned, with a total budget of INR 3,591 crores. Additionally, the State also has plans for a port in Tajpur as well. Development of these infrastructure are expected to increase the freight traffic, leading to an increase fossil fuel demand in the state.

- **Upcoming industrial infrastructure viz. industrial parks and MSME clusters** (GoWB, 2018): Around 14 textile parks, 6 multiproduct parks, 4 iron and steel parks, 2 gems and jewellery parks and other cement and chemical parks have been planned for the state. Also an amount of INR 123 crore have been allocated from the state budget in 2018-19 to develop and modernize these Industrial Parks and Growth Centers. This would increase the energy demand as well as necessitate development of standards/benchmarks for clusters/parks. As of now most of the MSMEs operating in these clusters do not follow EE practices and benchmarks. Such MSME clusters including new Economic Zones and industrial parks also pose opportunities for setting standards for EE infrastructure and processes.

- **Increasing electric mobility**: West Bengal is at the forefront of increasing penetration of electric vehicles (EV) in the nation. In 2016-17, West Bengal recorded the 2nd highest number of EV sales in the country (SMEV, 2018). The State Transport Department has procured 80 e-buses, along with the charging infrastructure to ply at public transport routes in Kolkata. Kolkata has also become the 3rd city in India to get e-car rental facility (Millenium Post, 2018). These initiatives indicate the intention of the state government to increase the penetration of EV across public and private transportation, leading to increased power demand and reducing demand for fossil fuels. In order to support such initiatives, adequate charging and storage infrastructure should also be scaled up accordingly.

3. **Demand for clearer energy production**
   - **Renewable mix in the grid would necessitate new skills to handle the power management**: As part of MNRE's 175 GW renewable energy addition plan, West Bengal has been provided a target of 5386 MW by 2022 (Power For All Document, 2016). While the state has taken a policy decision not to pursue the central targets of 5.3GW of solar power by 2022[4], the State Action Plan for Climate Change (SAPCC) indicates around 3000 MW of solar installation by 2030 in the State. West Bengal is also pursuing to promote around 1500 MW of hydro projects within the state and is in talks with Bhutan to develop around 500 MW large hydro, part of whose power supply will be routed to the state through bilateral power sharing agreement. It is learnt that the State is also having a plan of setting up 4800 MW of pump-storage capacity to mitigate all future need for peak demand and spinning reverse. (Department of Power & NES, Government of West Bengal). Renewable energy being intermittent and infirm, would require adequate forecasting skill, scheduling capability, development of ancillary services and flexible thermal generation – which would necessitate development of skilled work force. Additionally, ancillary services represent new revenue opportunities for state utilities and other private players.

[4] There are several technical reasons for not pursuing the central target of 5.3 GW. One of the major causes is limited land availability, leading to higher land prices. The State also enforces stringent laws of land acquisition and conservation, making land acquisition very expensive which can make the overall cost of the project prohibitive.

- **Natural gas and coal discovery in the State**. Discovery of 2.1 billion ton of coal and around 9 TCF of Coal Bed Methane have created a new paradigm of secured and affordable energy supply future of the State. If enabling environment (regulatory, institutional, financial and technological) is created on time, extraction of these resources could bring a shift in the energy mix of the State and may open up the possibility of exporting energy in the region. This can have an overall positive impact of the prevailing economic conditions of the state.

Besides the above mentioned state specific drivers, the rapidly changing socio-economic condition of the country also necessitate the formulation of an energy action plan in the state:

1. By middle of this century India will become a middle income country where more than 80% people will become middle class from 50% at current date.
2. Country will become (including the State) most populous in the world and India will have 6 additional megacities which will have more than 10 million population.
3. 2 out of every 5 citizens of the country will live in city.
4. Country will have huge demographic dividend by 2030 where more than 77% Indian will be under 44 years of age. Employment generation will be the major challenge for the government for such a massive young and employable population.
5. Rapid technological intervention with the influence of several *disruptive technologies* the country and of the State as well will become a hub of technology superpower. Overall 1 billion people will be connected to internet in India by 2030 and a proportional population within the State as well.
6. Consumer spending is envisaged to be more than doubled by 2030 in the country due to increasing middle class population indeed.

In the context of sustainable development of this burgeoning economy, certain immediate actions are required for the country and for the State as a whole to handle the upcoming situation:

a. Inclusion of rural sector in the overall economic growth model
b. Managing the pollution and externalities caused due to increasing use of fossil fuels and other natural resources.
c. Managing solid wastes generated in the urban areas and promoting resource efficiency for consumption and production as well.

Energy is an interdisciplinary area of the economy which has cross-linkages with other sectors of the economy, society and environment in such a way, that planning for energy in one particular area will require investigation in the possible cross sectoral impacts. A particular economic activity can be the consumer as well as producer of energy as well. Energy sector is also the primary contributor to the emission of pollutants in the atmosphere which ultimately has detrimental effect. Therefore, in the process of developing the State level energy plan and subsequent action plans it is important to follow an integrated approach of assessment.

The State Government and its functionaries acknowledge the implications of the above on the energy scenario of the state and there has been clear communication of the intent of individual departments in implementation of clean technology (viz. promotion of electric vehicles in public transport, increased penetration of rooftop solar and solar pumps). Development of State Energy Action plan will help communicate this intent of the State Government as well as how it intends to achieve its commitments in energy sector within a given time line.

An Energy Action Plan (EAP), developed in a rational, scientific and, data-driven fashion will aid the policy makers of the state in planning and optimally allocating resources for developing the state's energy sector for the next 15-20 years. In a sense, EAP will build on existing document such as 'Power for All' document, provide a unified energy agenda, will be forward looking and take into account emerging trends and realities. The EAP will go beyond capacity/supply planning and will heavily focus on efficiency issues along with penetration of sustainable sources of energy.

2. Approach & Methodology of formulating the EAP

In order to prepare the Energy Action Plan for West Bengal a series of activities have been performed which have been divided in to three activity groups viz. Data collection and database preparation, Data Analysis and ultimately, development of the Action Plan. A brief of these activity groups are elaborated below:

i) **Data collection:** It involved creation of a data collection framework for collecting and compiling relevant data related to energy sector of the State. The framework was utilized to collect primary and secondary data through desk research, stakeholder meetings and interviews. Post data collection, sectoral data sheets were prepared for compiling sectoral information. At the end of this activity the State energy balance sheet were prepared. The sectoral datasheets thus prepared went through several rounds of data validation and was calibrated[5] to the recorded data of base year i.e. 2015 to ensure robustness of data.

ii) **Data Analysis:** Data analysis was undertaken by building an energy model using the open source MESSAGEix Integrated Modelling Framework. In order to build the model the first step was to create a Reference Energy System (RES) for the base year, which would map the flow of energy beginning from its primary level i.e. resource extraction to its final energy level i.e. utilization at demand level. The RES captures all inflow and outflow of energy, conversion efficiency, losses etc. for each and every energy commodity used in the system. Another important activity in the section was related to forecasting of energy demand in the State for each demand category.

iii) **Developing the Action Plan:** After building the model, it was run for baseline case and thereafter, for potential future scenarios for the state which were developed based on sectoral visions, missions and overall state development objectives. Based on the model results, list of measures to be undertaken in the coming years to achieve the objectives of the preferred future scenario. Finally, these measures were converted into action plans at sector level and finally to the State level. The action plans are classified across two dimensions: temporal and categorical. Temporal aspect classifies the activities on time of implementation i.e. short term (2020-25), medium term (2025-30) and long term (2030-40) and categorical aspects classifies the activities on type of activities i.e. technical, financial, regulatory and institutional.

Figure below shows the flow of activities followed in the entire process of preparation of the Energy Action Plan for the State of West Bengal.

[5] Calibration of the model is done comparing the model projected values for the year 2017-18 and the observed data for select variables. It is important in order to make the model projection robust for the future years. Validation of data is done comparing the data collected from different sources and primary data collected on same variables.

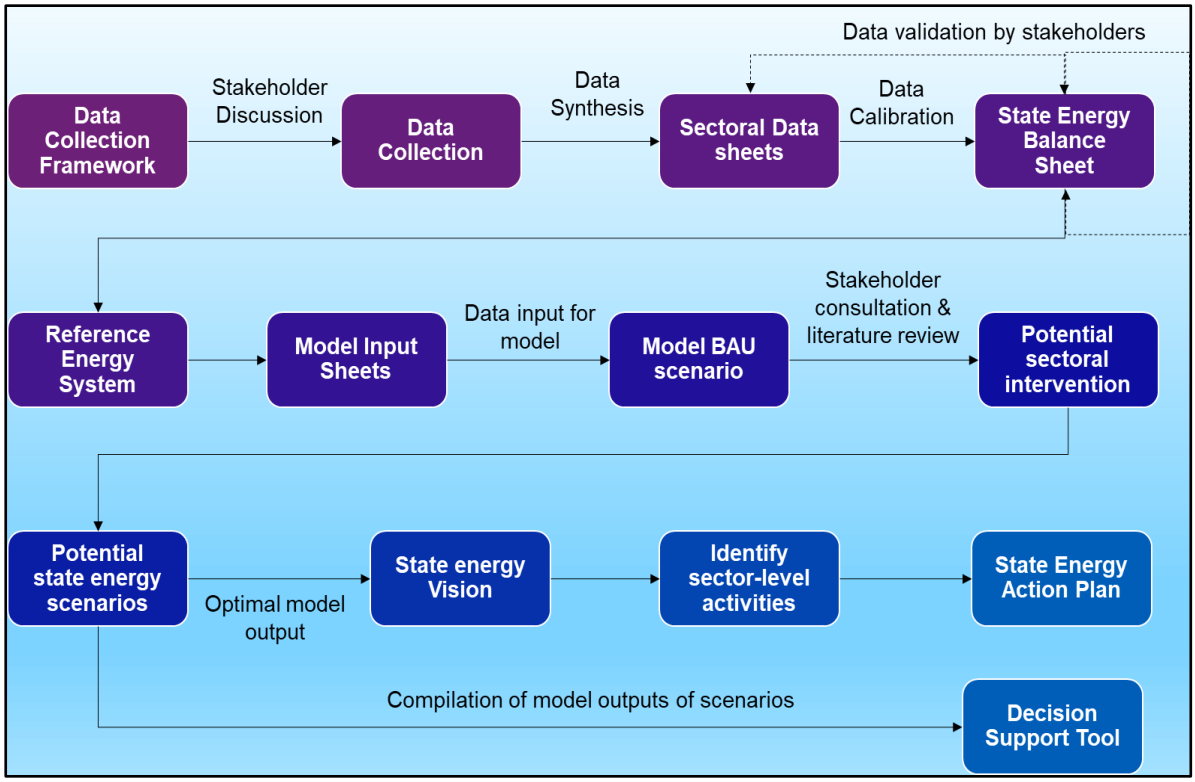


Figure 2: Detailed steps to develop EAP

2.1 Energy database preparation

As discussed, development of the state's energy database is the first step to development of the Energy Action Plan. This serves two basic purposes: i) Act as data source for model assessment exercise; and ii) Standardization of data collection framework for the State which can be used in future for updation purposes.

For the purpose of the study, the entire energy sector of the state was divided into five demand sectors and one supply sector based on preliminary stakeholder consultation. While energy demand sectors included buildings, transport, industries, agriculture and cooking, energy supply sectors comprised both primary (viz. coal, oil and gas) and secondary sources (viz. electricity). Accordingly the data collection templates were prepared and shared with the respective departments for compilation of information. Any data gaps arising from primary data collection were suitably supplemented by data collected from various secondary sources as well. One of the major data sources was India Energy Security Scenarios 2047 (IESS 2047 Ver. 2.0) which is the national energy data repository maintained by the NITI Aayog, Government of India. Several journals and literature were also referred to obtain the data and information for the analysis.

Data processing was undertaken after data collection to remove irrelevant and outlying data points as well as to validate the dataset with relevant experts and concerned state government departments. The processed data was utilized to conduct the projection of energy demand for the EAP assessment horizon (i.e. until year 2040) for the State for the five demand sectors (viz. transport, agriculture & fishery, industry, residential & commercial and cooking) and energy supply sector (which includes all

primary and secondary sources of energy). Due to limited availability of sectoral energy demand projection in the State, separate demand projection exercise had been conducted for this study using time series forecasting method. Even though the study has been completed by deriving values from national and state proxies, these values are approximate and it is recommended that in future an intensive data collection process be undertaken to identify actual values of these parameters.

2.2 State Energy Balance Sheet for 2015

Energy Balance Sheet provides the information on the supply and demand gap and subsequent energy required to balance the system. The balance sheet contains separate entries for primary energy supply, energy production and transmission, final energy consumption and non-energy use and the gives a clear picture of the conversion of primary energy to final consumption.

The energy balance sheet comprise of supply, transformation and consumption, which contains figures on the supply and consumption of energy in the state. This balance sheet is made for each energy commodity (natural gas, crude oil, hard coal and renewable energy), energy producing sectors (electricity and gas supply etc.) as well as energy consuming sectors (industry, agriculture, buildings transport and cooking).

Energy balance is used to compute the energy demand and supply status of the State of West Bengal as follows:

- Total energy supply and consumption in the state
- Energy supply mix
- Composition of energy consumption by different sectors
- Energy intensity, dependence on energy imports
- Energy losses and efficiency

However, there are two categories of energy balance sheets:

Energy Commodity Balance Sheet: The commodity balance shows the flow of commodity in its actual units i.e. tonnes, kilograms etc. Each commodity undergoes various extraction processes to unlock the energy content which is finally gets utilized one or multiple demand sectors. If the example of coal is taken, the first process is the extraction of coal from mines, after which the extracted coal undergoes processes like washing, crushing as requirements of those consumers which utilize coal in the primary form like industries and thermal power plants. The coal in the primary form is thereafter used directly to utilize energy (use of coal in furnaces in industries) or to produce secondary energy sources (generation of electricity from thermal power plants). Each process involves certain losses in the quantity which gets reflected in the balance sheet at the Supply and Use Level. The imports and exports also get reflected in the Balance Sheet as separate line items for each commodity.

Commodity balance is primarily useful to understand the share of state's energy being purchased from external sources as well as the commodity wise consumption by different sectors. This form of the Energy Balance Sheet can be referred by individual departments dealing with respective fuel sources.

West Bengal Energy Balance 2014-15 (in original units)					
	Electricity (GWh)	Natural Gas & other Gas (000't)	Oil (000't)	Coal (000't)	Biomass (000't)
Supply					
Primary Energy	0	0	0	29213	12388
Imports	1000	1166	6375	25133	135
Direct Exports	9925	0	401	10130	31
Total Energy Supply	-8925	1166	5974	44216	12491
Energy Conversion					
Statistical adjustments	621	-2	-1560	-726	-461
Conventional Hydro Power	2069	0	0	0	0
Thermal Power Plants	65409	0	0	39485	0
Small Hydro Power	201	0	0	0	0
Wind Power Plants	0	0	0	0	0
Biomass Power Plants	567	0	0	0	564
Solar Power	1	0	0	0	0
Losses in Transmission and Distribution	20075	0	0	0	0
Total Energy Conversion	48172	0		39485	564
Use					
Agriculture	692	0	246	0	0
Domestic Buildings	12662	0	0	0	0
Commercial Buildings	5372	0	0	0	0
Cooking	5	75	549	727	12388
Fisheries	413	0	50	0	0
Transport	2305	56	5104	0	0
Industries	17177	1036	1584	4730	0
Total Energy Use	38626	1167	7534	5457	12388

Figure 3: Energy Commodity Balance of the State

Energy Balance Sheet: In this category of balance sheet, energy supply, consumption and losses are balanced in energy unit like kWh, TOE etc. Each commodity in the energy systems has certain energy content which is denoted by the gross caloric value of the commodity (represented in kcal/kg). In the energy calculation each commodity (in tonnes or kg) is multiplied with gross calorific value to get the total energy content available in the commodity. This is useful for analysis of energy production, consumption, efficiency measurement of the conversion processes and also for energy modelling for optimal supply mix.

In Figure 4, it is observed that there is a statistical difference of 1637 TOE under the oil category which is due to non-availability of data for certain fuels under this category. The statistical difference of up to 10% has been taken as the acceptable limit of statistical difference. This statistical limit has been adopted based on the information collected from various energy balances prepared by the International Energy Agency. It is envisaged that there is a need to further update this balance sheet in future to reduce the statistical difference and omit existing data gaps.

West Bengal Energy Balance 2014-15(in toe)					
	Electricity	Natural Gas & other Gas	Oil	Coal	Biomass
Supply					
Primary Energy	0.00	0.00	0.00	9932.42	4211.77
Imports	0.07	1.06	6693.35	8545.19	45.82
Direct Exports	0.71	0.00	420.76	3444.13	10.67
Total Energy Supply	-0.64	1.06	6272.59	15033.47	4246.91
Energy Conversion					
Statistical adjustments	0.04	-0.08	-1637.69	-246.77	-156.60
Conventional Hydro Power	0.15	0.00	0.00	0.00	0.00
Thermal Power Plants	4.69	0.00	0.00	13424.93	0.00
Small Hydro Power	0.01	0.00	0.00	0.00	0.00
Wind Power Plants	0.00	0.00	0.00	0.00	0.00
Biomass Power Plants	0.04	0.00	0.00	0.00	191.75
Solar Power	0.00	0.00	0.00	0.00	0.00
Losses in Transport and Distribution	1.44	0.00	0.00	0.00	0.00
Total Energy Conversion	3.45	0.00	0.00	13424.93	191.75
Use					
Agriculture	0.05	0.00	258.07	0.00	0.00
Domestic Buildings	0.91	0.00	0.00	0.00	0.00
Commercial Buildings	0.39	0.00	0.00	0.00	0.00
Cooking	0.00	0.08	576.37	247.13	4211.77
Fisheries	0.03	0.00	52.84	0.00	0.00
Transport	0.17	0.06	5359.36	0.00	0.00
Industries	1.23	0.99	1663.63	1608.17	0.00
Total Energy Use	2.77	1.13	7910.28	1855.31	4211.77

Figure 4 Energy Balance of the State

2.3 Reference Energy System of the State

The Reference Energy System (RES) describes the entire system of the state through a schematic line diagram which depicts the flow of energy across processes undertaken within the system to convert one form of energy to another. Since each energy conversion process involves a dedicated technology, RES provides the total set of available energy conversion technologies involved in resource extraction, transformation, transport, distribution as well as end-user technologies. The final layer of the RES provides information on a key metric required for developing an energy system optimization model i.e. useful energy demand.

As there are few conversion technologies available which convert resources directly into useful energy, the RES works on 5 energy levels:

- Resource (r), like coal, oil, natural gas in the ground or biomass on the field
- Primary (a) energy, like crude oil at the refinery
- Secondary (x) energy, like gasoline or diesel fuel at the refinery, or wind- or solar power at the power plant
- Final (f) energy, like diesel fuel in the tank of a car or electricity at the socket
- Useful (u) energy that satisfies some demand for energy services, like heating, lighting or transportation.

Figure 5 below shows the simplistic version of the State Energy Reference system mapped and used in developing the Energy Action Plan.

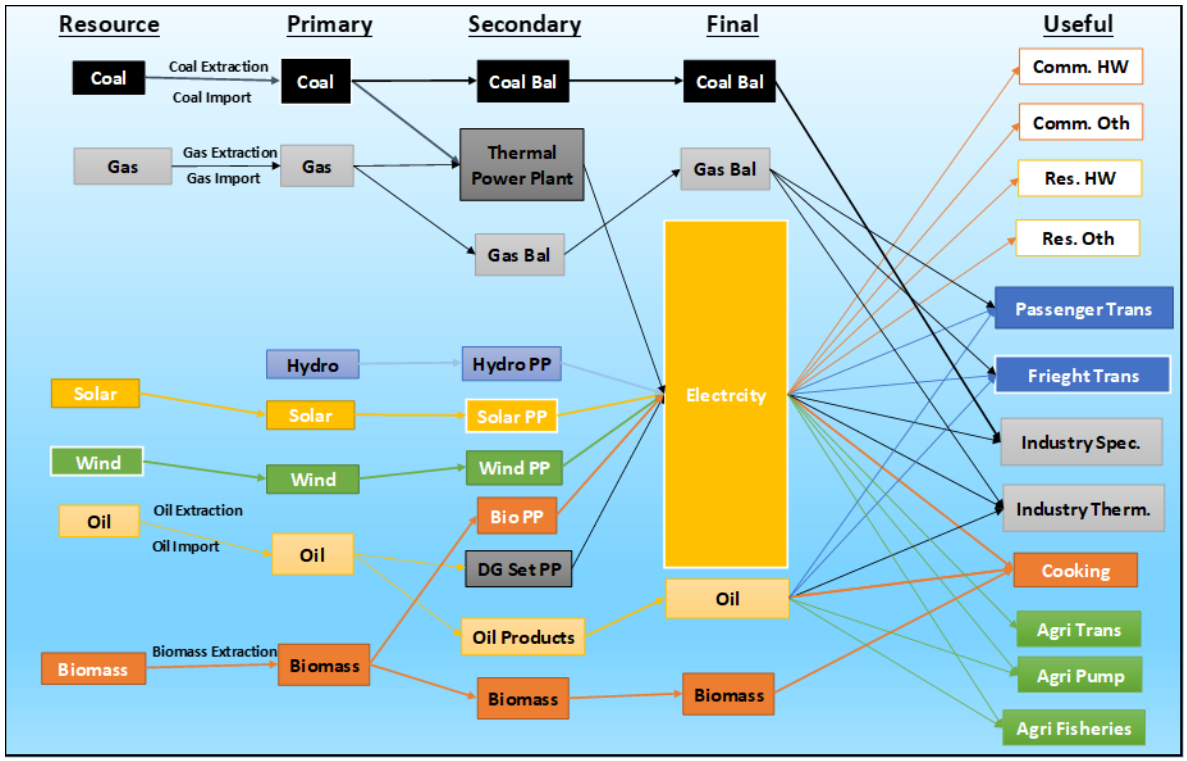


Figure 5 Reference Energy System (RES) of the State

The RES for West Bengal comprises all technologies that are currently available or are expected to come up in the future. RES is used as the basis for considering each available or most likely available technology/fuel in the future for long terms projections in the energy model.

2.4 Energy System Model & its importance

An energy system model is a framework for medium to long term energy systems planning, energy policy analysis and scenario development (IIASA, n.d.). Energy systems models are important methods to generate a range of insight and analysis on the supply and demand of energy in a particular region. Developed over the second half of the twentieth century, system models are now seeing increased relevance in the context of stringent climate change concerns, increasing geo-political disturbance and subsequent energy security threat and rapid economic development (Pfenninger et.al 2014). Energy availability and energy security are factors which defines the stability in any country, state or region in today's economic and trade scenario. Global issues like GHG emissions, energy scarcity, depleting fossil fuels are driving the policy makers to think seriously on the developing secured and accurate future plans with proper implementation of energy policies in the state. This requires developing future scenarios which includes future impacts and interventions through policies being developed in the state. Energy systems modelling certainly help policy-makers with updated information, meaningful figures and analysis on the impact of policy measures.

The energy systems model optimises the long term scenario generated in terms of cost, least emissive and viable technology/fuel to be considered in the state for future energy planning and policy making. Energy systems modelling uses mathematical optimization in the selection of best technology/fuel from the set of available alternatives. This optimisation is required to come out with the most viable and accurate result from modelling which makes the analysis robust.

For example, by taking the example of per capita electricity consumption in the state. Figure 6, shows area between two curves which state difference between per capita electricity consumption at final energy level vs per capita electricity consumption at secondary energy generation level (for better understanding please see the RES above). During 2015 (the start year of the optimization) the model is exogenously calibrated to the actual generation recorded in 2015 by the State. In the same year the model also estimated the total useful energy required from electricity to meet the demand which is also exogenously calibrated (based on 2015 consumption data). From the generation side in 2015 it is estimated that 610 unit per capita should be the consumption after adjusting all technical losses but it is estimated that the actual consumption was only around 410 units. Eventually when the model starts projecting the generation optimally for the future years, the gaps start disappearing and by 2025 it becomes fully balanced. Thus the importance of the energy systems model is unparalleled in terms of long term energy planning for a State where the supply is optimally done to meet the exact demand in the system which can minimize the costs of supply.

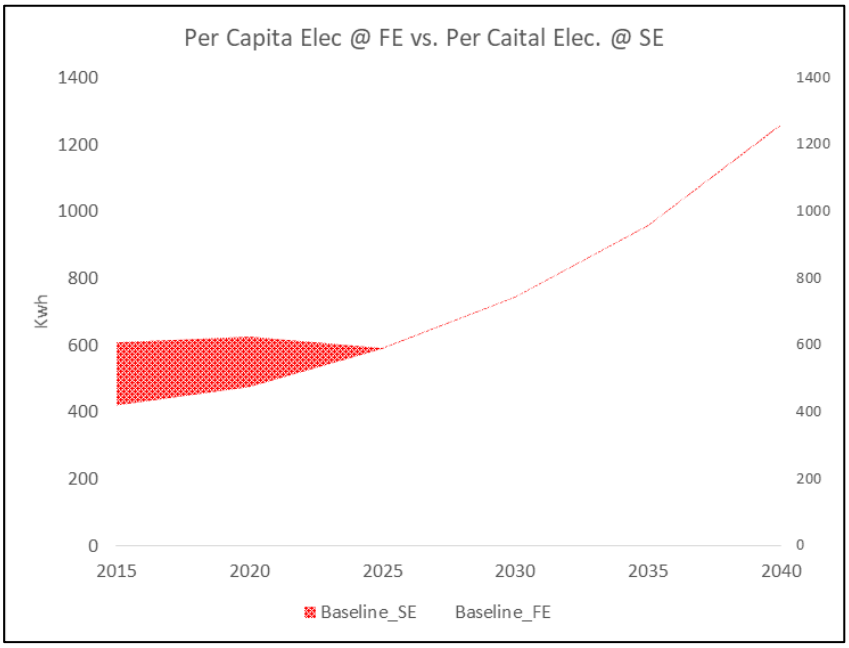


Figure 6: Per Capita FE vs Per Capita SE Electricity Supply in 2015

2.5 Description of Model

The model assessment is done on MESSAGEix framework which is a versatile, open-source, dynamic systems-optimization model. It was developed for strategic energy planning and integrated assessment of energy-engineering-economy-environment systems (E4). It can be applied to analyse scenarios of the energy system transformation under technical-engineering constraints and political-societal considerations. The optimization model can be linked to the general-economy MACRO model

to incorporate feedback between prices and demand levels for energy and commodities. The equations are implemented in the mathematical programming system GAMS for numerical solution of a model instance (IIASA, Internation Institute for Applied Systems Analysis, n.d.).

The MESSAGEix framework is fully integrated with IIASA's ix modelling platform (ixmp), a data warehouse for high-powered numerical scenario analysis. The platform supports an efficient workflow between original input data sources, the implementation of the mathematical model formulation, and the analysis of numerical results. The platform can be accessed via a web-based user interface and application programming interfaces (API) to the scientific programming languages Python and R. The platform also includes a generic data exchange API to GAMS for numerical computation (see Figure 7).

Key components in model framework are:

- **Messageix** (The integrated assessment and energy systems model MESSAGEix)
- **ixmp** (The ix modelling platform for integrated and cross-cutting scenario analysis)
- **GAMS** (Mathematical Solver)
- **Python** (Input Interface)

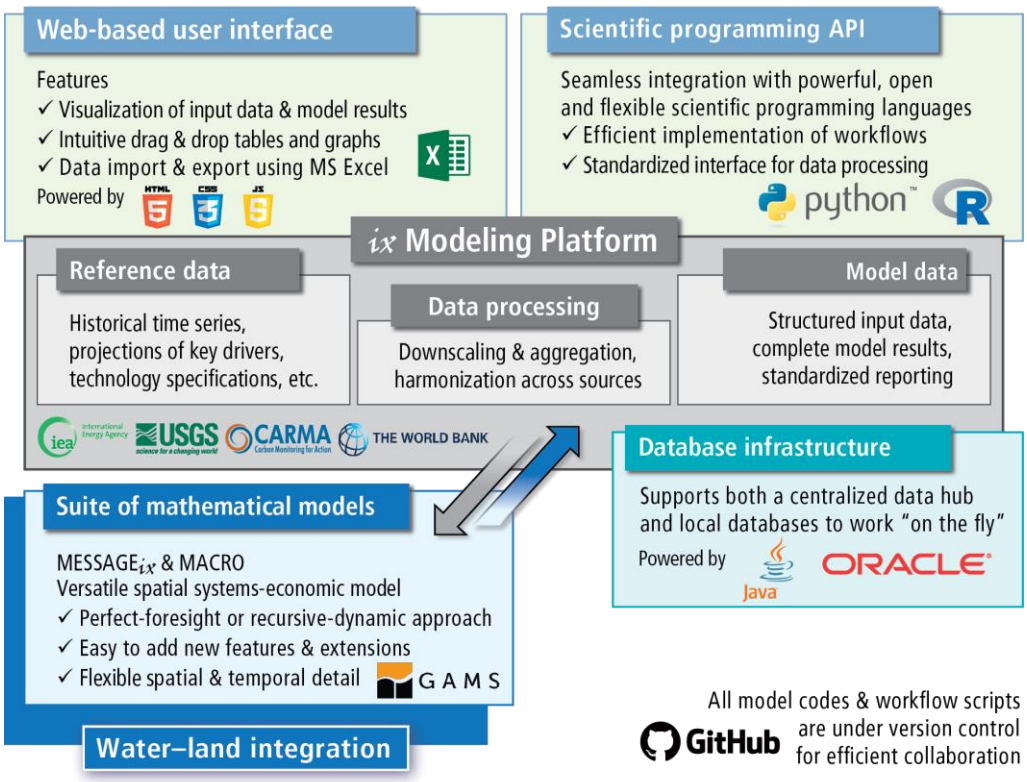


Figure 7: MESSAGEix Framework

Mathematical formulation of MESSAGEix

The MESSAGE*ix* systems-optimization model minimizes total costs while satisfying given demand levels for commodities/services and considering a broad range of technical/engineering constraints

and societal restrictions (e.g. bounds on greenhouse gas emissions, pollutants, system reliability). The Objective Function of the core model is to minimize total discounted systems costs including costs for emissions while relaxing the dynamic constraints of the model.

The model is further balanced on Commodity and Stock both. The commodity balance equations ensures the balance between output/import and input/export for all commodities. Stock balance equation ensures the inter-temporal balance of commodity stocks in the system. Another important factor considered in the model is dealing of renewable energy in the overall energy system. Electric-sector flexibility in MESSAGEix is represented as follows: each generating technology is assigned a coefficient between -1 and 1 representing (if positive) the fraction of generation from that technology that is considered to be flexible or (if negative) the additional flexible generation required for each unit of generation from that technology. A negative coefficient on load reveals a parameterization of the amount of flexible energy the system requires solely to meet changes and uncertainty in load.

To maintain operational reliability in MESSAGE, the model designed a dynamic shadow price on capacity investments, for wind and PV-dynamic with respect to the amount installed, the relative flexibility of the conventional power supply, and demand-side reliability requirements. For instance, a large amount of storage capacity should, all else being equal, lower the shadow price for additional wind. This constraint ensures that there is sufficient firm (dispatchable) capacity in each period (Sullivan et.al. 2013). The peak load factor used in the model is 2.43 times the baseload.

2.6 Implementation of the Model

Based on the information collected from the departments and different literatures, secondary sources etc. the State Energy Balance Sheet is prepared for the year 2014-15. Several parameters for supply and demand sectors are further estimated or collected from different sources. In this case the model has taken the reference from IESS 2047 of NITI Aayog, GoI from where several crucial parameter values are obtained which are not available at State level. Especially the technology cost data (CAPEX, OPEX etc.), modal share in transport sector, energy conversion efficiencies etc. are the major adopts from IESS. After obtaining all the required data the model input file is prepared. The numbers are further validated either through stakeholder meetings or through expert consultation. The validated numbers from the calculation sheets are then given as input to the MESSAGEix model input in the form of useful energy demand. The model is then run and scenarios are subsequently generated.

The figure below shows the operational flow of the model which starts from the bottom most layer of the entire value chain of energy system. The model estimates the primary energy demand and resource requirement for the same by moving upward with a basic algorithm as follows:

$$Energy_{(L-1)} = Energy_{(L)} * \mu$$

where (L) indicates the level of energy and μ is the efficiency of conversion

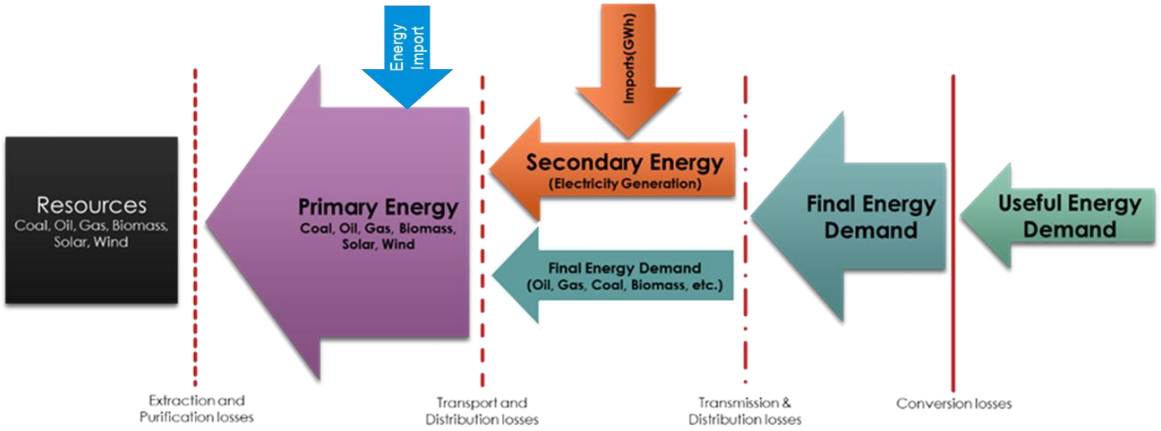


Figure 8: Flow of the Model

3. Baseline Assessment

The study first investigates the baseline scenario of optimal energy supply and demand situation of the State until 2040. The optimal condition identifies the least cost energy supply mix to meet the given energy demand in the state in a given time period and in a secured manner. The main purpose of identifying the optimal baseline condition is to define the reference for assessing the alternative scenarios of developmental pathways. The baseline assumptions are based on the understanding that all the existing government policies and plans are implemented successfully by the given timeline.

The basic assumptions for the baseline assessment are:

- Domestic and state owned energy resources utilization is the first priority for the State.
- Renewable energy is envisaged to play an important role in the future and thus increasing deployment is considered.
- Economic development of the State continues to be at highest priority and GSDP continues to grow.
- State's prosperity is envisioned to be based on sustainable development pathway where economic, environmental and social developments are given equal importance.

As the optimization model used in this study (MESSAGEix) is an energy system optimization model based on the principle of least cost optimization, the prime exogenous factor for the modelling analysis is the useful energy demand in the economy. The useful energy demand as explained in the previous section indicates the energy required to obtain particular economic services in the system, therefore, it is important to assess the useful demand as precisely as possible. Often it is observed that the useful energy is directly correlated to the economic growth of the State and the sector itself. It has been estimated that for every INR 1,000 increase in GSDP, domestic & residential sector electricity consumption increases by 8 units. Similarly for commercial, industrial and agriculture sectors for every INR 1,000 increase in GSDP, electricity consumption increases by 5, 6 and 3 units respectively (Saha & Bhattacharya, 2018). However, based on further assessment of other sectoral demands, the study assumes the useful demand for the State until 2040 for five major sectors of the economy as shown in the figure below:

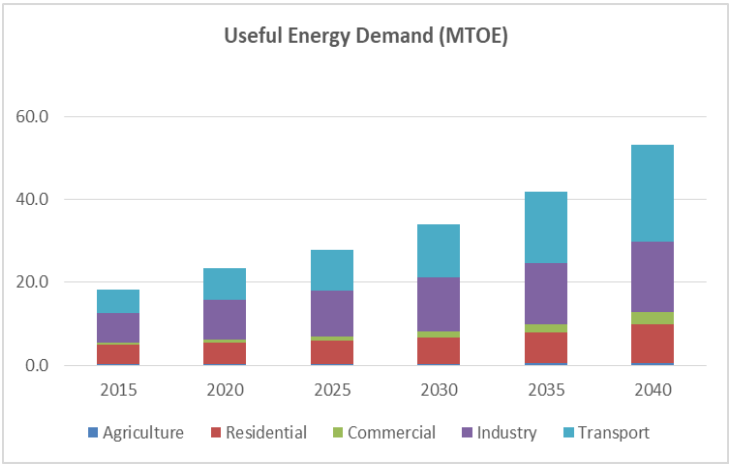


Figure 9: Useful energy demand in the State until 2040

3.1 Primary Energy Supply

It is observed that the total primary energy supply in the state is expected to grow at a moderate rate of 2.1% per annum cumulatively. Coal will remain the major source of energy in the state comprising of about 52% of total primary energy supply in 2015 and 58% in 2040. Oil is expected to take a growth at a good rate and reach up to 30.6 MTOE by 2040 and will comprise 35% of total primary energy supply in the State by that time. However, the oil demand increase is mainly driven by the transport sector which is observing the second highest demand growth in the State after the commercial sector. It is also observed that the biomass use in the State is continually declining until 2040 due to increasing penetration of oil, gas and electricity. In the baseline situation, natural gas use demand in the State is not increasing much and almost remain steady until 2040. The main reason behind this being the non-availability of gas in the market. The existing gas consumption is attributed to LPG supply for household and commercial cooking and CNG use for public transportation. Industrial use of gas is negligible for the State under the baseline scenario.

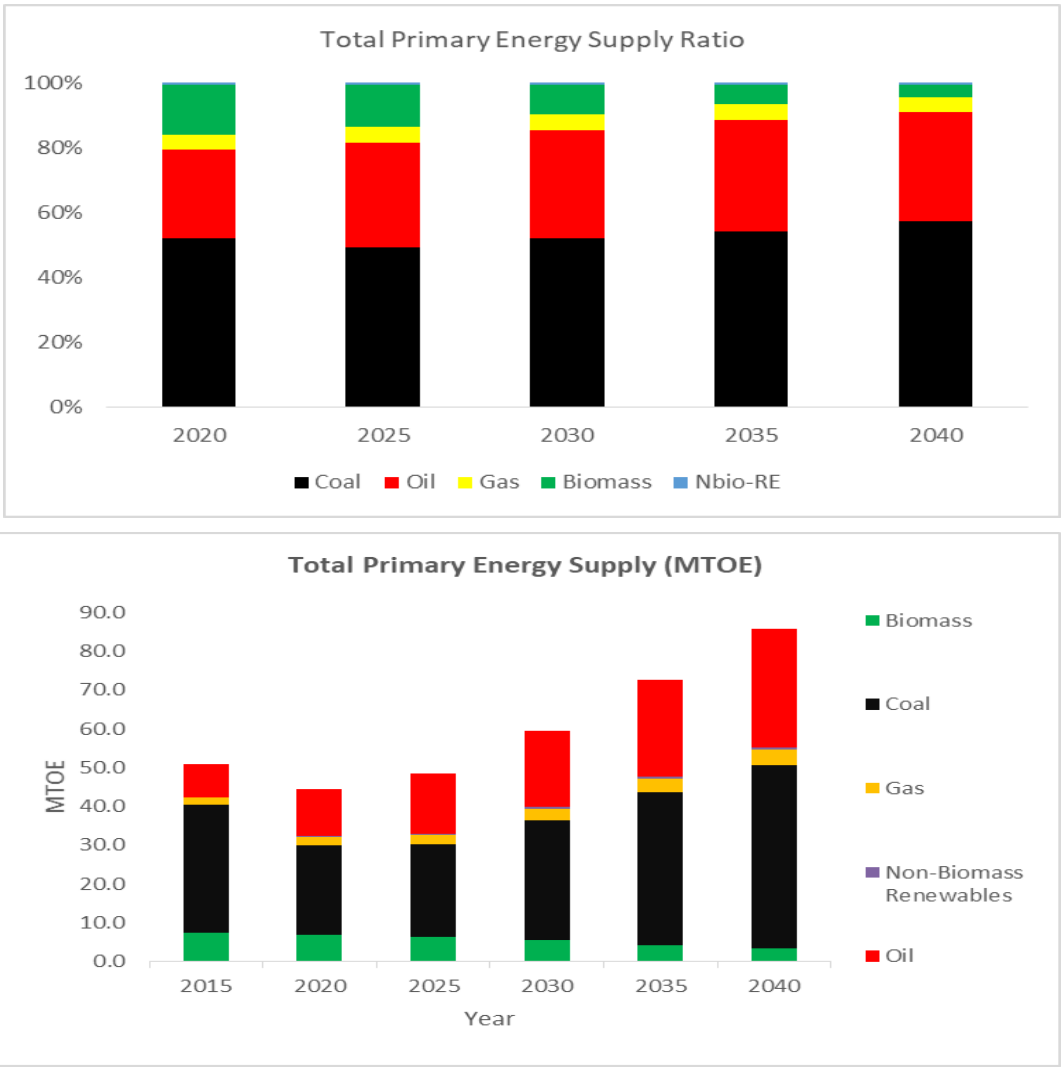


Figure 10: Primary Energy supply by fuel type

3.2 Electricity Generation

In the baseline situation coal remains as the major fuel for power generation in the state. However, the power generating companies in the State are facing multiple problems in running the power plants. Availability of coal with Grade 4 & 5 is an issue for the power companies for direct use as it is of high grade and very expensive. Importing low grade coal and mixing with the high grade coal is an age old practice in the State. However, blended coal used for power generation continues to be a source of problem for the power companies especially in terms of compliance with the pollution norms (CPCB, 2015) and ash handling regulations. Setting up the ESPs and FGDs are not only space consuming but also expensive which increases the cost of power generation.

By regulation power companies are unable to pass on the additional costs to the consumers and thus facing huge financial challenges in this regard. Besides, the State power companies are also suffering from low plant utilization (PLF< 60%) which is causing huge financing losses. Besides, currently more than 90% of the coal based capacities in the State is sub-critical and half of them are more than 30 years old. These aging low efficient plants are additionally creating trouble for the power companies in terms of increasing unscheduled downtime of the plant operation (>26%) and consuming more coal due to poor heat rates. In summary, the State owned thermal power generation system is vulnerable towards rapidly changing power market situation in the state and in the country as a whole in the context of emissions and efficiency. State power companies are also increasing high grade coal imports to match the emissions requirement and improve the heat rate to gain over the declining overall plant efficiency described above.

3.3 Electricity generation and capacity by fuel sources

As of 2018, the total generation capacity of the State is around 11 GW which comprises 9 GW de-rated thermal power generation capacity (actual installed capacity is around 12.8 GW), 1.4 GW is hydro (400 MW of large hydro and 1000 MW of Pump Storage) and around 300 MW is solar power generation capacity. As demand increases and capacity addition continues to fulfil the rising demand, the total installed capacity is expected to reach up to 35 GW by 2040. Nevertheless, coal based capacity will remain the major source of generation until 2040 and account for around 30 GW of the installed capacity. Solar based capacity is expected to grow steadily after 2030 to reach 3.3 GW by 2040. Hydro based capacity would remain 0.39 GW till 2040 (excluding pump storage).

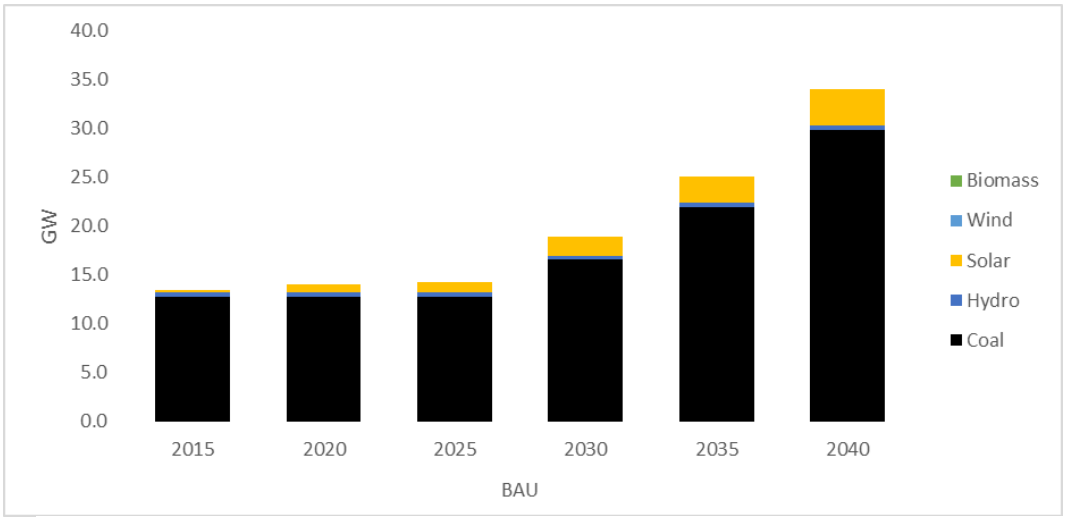


Figure 11: Electricity generation and capacity fuel type

Annual growth rate of electricity generation in the State is expected to be around 3.7% between 2020 and 2040. Considering the continued dominance of thermal power generation, as depicted in Figure 11, efforts need to be undertaken to reduce dependency on the thermal power and increase installation of renewable based generation capacity to reduce emissions.

Even though dominance of coal based power generation is expected to continue, it is envisaged that more efficient super-critical thermal power generation technologies will replace the existing sub-critical technologies by 2030. Use of State owned coal (of low grade) in the high efficient power generation is a concern of the future. Thus import of high grade coal is expected unless alternative fuel sources are not explored. Plant utilization is around 60% in the State compared to the national average which stood at 65% in 2014-15 but has declined to 61% in 2018-19 (Power Ministry, GoI, 2019). Under the solar and other RE expansion plan, the State can increase its generation capacity for Solar up to 3.5~4 GW by 2040. Estimated grid stabilization, storage and spinning reserve put together could be around 3 GW by 2040 (around 10% of the total capacity following the CERC guideline, 2015).

3.4 Final energy use

It is observed that in terms of final energy use by different sectors in the State, oil and oil product is the largest share followed electricity, coal and gas. Biomass is also being used in the State mainly for cooking and certain industrial use. In the base year (2015) the total final energy consumption in the State is around 23 MTOE out of which 8 MTOE is from oil and 7.4 MTOE from biomass (commercial and non-commercial together). By 2040 the total consumption is expected to go up to 58 MTOE where oil consumption will amount to 27 MTOE, electricity 14 MTOE, coal 9 MTOE and biomass only 3.5 MTOE. This clearly indicates that the State is expected to move towards more fossil fuel use and access to modern energy is also expected to increase indeed. Nevertheless, dependence on liquid hydrocarbon like oil and oil products is a matter of concern from cost and emissions point of views. Since the State is fully dependent on imported oil and completely exposed to oil price variation (except State tax component), it is an energy security threat to the State in the long run. Figure 12 below shows the final energy consumption in the State until 2040 with fuel composition. The final energy consumption is expected to grow at the rate of 3.7% per annum until 2040.

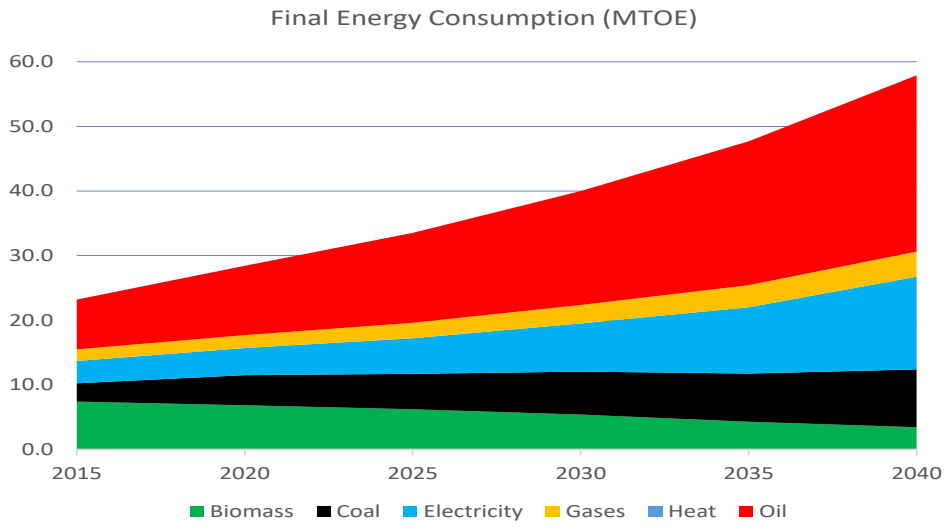


Figure 12: Final energy demand by fuel type

3.5 GHG emissions profile of the State

Due to increasing energy production and consumption, the GHG emissions in the State is expected to grow steadily at an annual rate of 4.4% between 2020 and 2040. It is estimated that in 2015 the total CO_2 emissions from energy and non-energy sector (excluding land and land-use change) was around 118 million ton and by 2040 it is expected to reach up to 344 million ton. The energy sector remains the main source of emissions contributing around 55% of total emissions on an average. Among all demand sectors, transport sector happens to be the single largest contributor of CO_2 emissions followed by the industry sector. Figure 13 shows the composition of emissions contribution of the State from various sectors between 2015 and 2040.

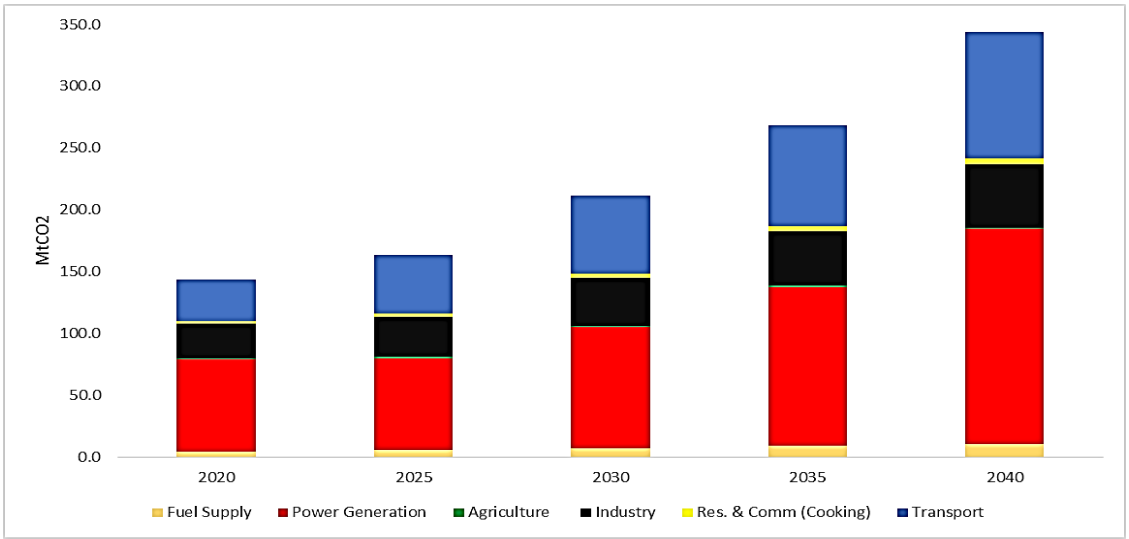


Figure 13 CO_2 Emissions from Electricity Generation in Mt CO_2/yr

4. Future energy scenarios of the State

Coal, oil, gas and electricity are the major sources on energy for the State. Majority of the coal produced and also imported in the State is consumed by the power plants to produce electricity. Remaining coal is used by the industries (large and small). Due to various reasons like efficiency improvement, change in technologies for power generation etc. coal consumption in the State will increase with a declining growth rate. It is estimated that coal will be around 55% of total Primary Energy supply of the state until 2040 whereas, in terms of final energy share it will only be around 20% of total supply. Due to cost implication of using Grade 4 & 5 coal in the State (which are of good quality with higher price) for power generation and having around 35% of mineability of the coal seams, utilization of coal in the State is a complex issue. Also continued focus towards cleaner sources of energy jeopardizes the future of coal in the State.

Coal production in the State in the year 2015-16 was around 25.7 Million ton compared to the national production of 640 Million ton which is around 4% of total national production. It is also observed that the state owned coal production (coke and non-coke) has also declined marginally between 2013-14 and 2016-17 by around 1% per annum. Otherwise, it can be inferred that State coal production almost remain unchanged over the last five years whereas the coal consumption continues to grow.

Nevertheless, allocation of Deocha-Pachami coal block to West Bengal (in the year 2017), the largest coal block of the country and in Asia, has further opened up the potential of producing around 500 Million ton of additional coal in the near future by the State. The coal block is estimated to have around 2.1 billion ton of reserve. However, due to heavy overburden on the block, mining of this block is coming with huge technical difficulty and associated costs. In future, if the mining starts in the block, it will make the State not only fully coal sufficient but can also make the State one of the major coal exporters in the country.

Oil is the second largest source of energy supply in the State. From around 18% of oil share in the Primary Energy supply in the year 2015 it increases to 37% by 2040. In the Final Energy segment, oil and oil products comprise of 33% in the year 2015 and it grows up to 48% by the year 2040. It is estimated that between 2020 and 2040 the oil consumption in the State will increase at a rate of 5% per annum. Transport sector is the major consumer of oil and oil products followed by the industry in the State.

Currently gas consumption in the State is low due to non-availability of gas in the country. However, increased utilization of Coal Bed Methane in the Ranigunj belt can dramatically change the future scenario of gas in the State. With total recoverable shale and CBM gas potential of 5-9 TCF (which could supply around 230 MTOE of energy) the State can become a hub of gas production in Eastern India. Though there are several technical challenges in extraction of gas and market barriers in utilization of gas, if these issues are adequately addressed the state can potentially become self-sufficient in energy.

Besides, the State is also planning to have a wide network of city gas (by 2020-2021) using the benefits of GAIL's Urja Ganga project which is linking Haldia and Jagadishpur via pipeline. It is expected to bring 9 million metric ton of gas every day to the State. Construction of 450km long Kolkata city gas network is also starting soon which will serve more than 14 lakh consumers in the city itself. Besides this, GAIL is also planning to enhance the gas supply in the State and in the region by bringing LNG from Malaysia. H.Energy Pvt. Ltd. is building a LNG terminal near Haldia which is

expected to import around 3 million ton of LNG from Malaysia out of which 2 million ton will be exported to Bangladesh and 1 million ton will be sold to GAIL for domestic use.

More than 95% of the electricity is produced from coal based power plants in the State. There are around 11 GW of total installed capacity in the State including central stations (around 1.2 GW) which comprises of thermal (coal and gas), large hydro and renewable sources. Out of 11 GW, around 9 GW is coal based generation capacity followed by 1.4 GW of hydro capacity (including pump-storage) and only 300 MW of solar renewable (CEA, 2018). The average utilization of the thermal plants are around 60% (for WBPDCL it is around 55% in 2017-18) which is similar to the national average of 61% in 2017-18 (Power Ministry, GoI, 2019).

However, West Bengal Power Development Corporation (WBPDCL) is planning to set up additional 2500 MW of coal capacity within their existing plants in three different locations. At Sagardighi WBPDCL is planning to install 660 MW capacity of supercritical technology in order to enhance the generation efficiency and compliance with the new environmental regulation. Environmental concerns of thermal power generation is becoming a major issue in the State. Central Pollution Control Board's power plant emissions control guideline published in December 2015, has further made coal fired power plant operation difficult and expensive in terms of compliance to stringent emissions norms.

While the State Renewable Energy Policy (2012) mentions the major sources of renewable power as solar, wind, biomass and small hydro, there is limited to no penetration of these sources in the state. Most notable among these sources, is solar, for which state has an installed generation capacity of around 300 MW. However, this is considerably lower than the potential for solar power in the State, estimates of which vary across sources. While State Action Plan for Climate Change (SAPCC) suggests a solar power potential by providing a target of 3 GW capacity by 2030, independent studies suggest a higher solar power potential – varying from about 6 GW of commercially viable solar PV potential (GIZ, 2011) to 27 GW of potential considering 3% utilization of total degraded waste land. (National Institute of Wind Energy, 2018).

Following the discussion mentioned above in this study two major energy scenarios have been developed which are described below:

4.1 Balanced growth scenario

The Balanced Growth Scenario (BGS) envisages an efficient energy generation and consumption system in the State by the year 2040 leading to a sustainable society. This includes better access to modern energy sources like electricity, gas and cleaner fuels and also sustainable consumption of resources, which if used efficiently can supplement the long term economic growth of the state. The State needs a guided plan to use these resources optimally and effectively so that sustainable economic and social prosperity can be achieved without compromising the quality of the environment and ecosystem.

1. **Energy Supply**
    - 25% share of renewables in power generation capacity
    - Efficiency improvement in thermal power generation by 8% between 2015 and 2040
    - Reduction of technical losses in power transmission and distribution (T&D) from 24% to 8%.

2. **Energy Demand**
   - Improving energy efficiency by introducing improved technology/processes across sectors – 10% reduction in energy demand for buildings and 5% reduction in specific energy consumption for industries sector.
   - Fuel switch to gas (for industries and cooking) and electricity (for transport) from coal and oil respectively. 50% energy consumption will shift from coal to gas in the industries sector and 50% of energy consumption will shift from biomass to gas in the cooking sector. The transport sector too will see a switch of 50% energy consumption from oil to electricity.
   - Share of IWT in freight and passenger transport to increase to 33% and 25% at the terminal year respectively from 1% and 0.4% in 2015.

Summary of sectoral targets for achieving Balanced Growth

A set of targets which are determined for Balanced Growth scenario are summarized below. The percentage changes are in comparison to baseline condition of sectoral intervention in the year 2040.

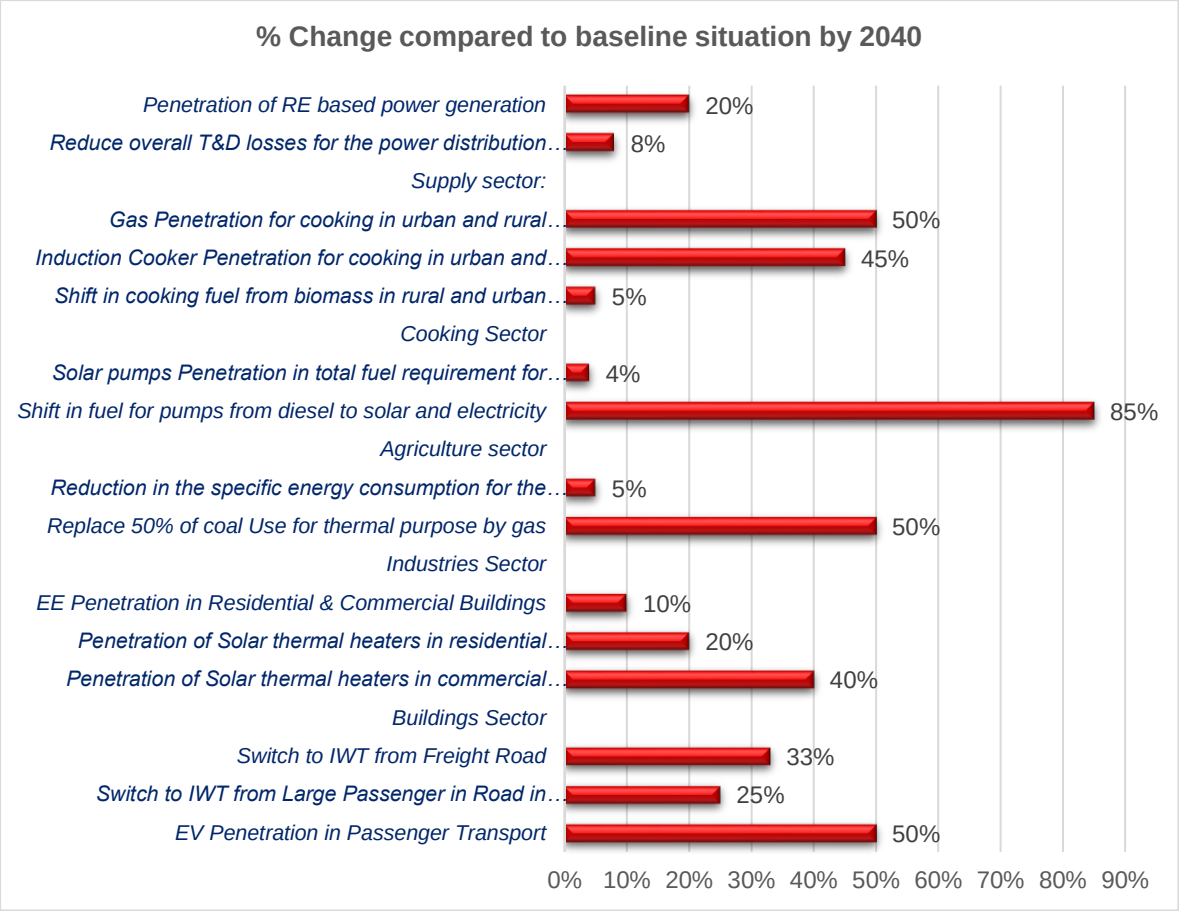


Figure 14: Comparison of BGS with BAU Scenario

4.2 Energy Security Scenario

Energy Security Scenario (ESS) of the State is primarily driven by the objective of promoting utilization of low carbon fuel use all across the sectors of the economy in the State. In this scenario, the major

low carbon fuel source for the State is natural gas. The reserves of coal bed methane and shale gas in the Ranigunj belt (with 9 TCF of proven reserve) can potentially change the energy supply and demand scenario in the state by 2040. Penetration of natural gas in the energy system is envisaged to change the fuel mix primarily in the demand sectors like industry, cooking and transport.

1. Energy Supply

- Efficiency improvement in thermal power generation by 8% between 2015 and 2040
- 25% share of renewables in power generation capacity by 2040.
- Reduction of technical losses in power transmission and distribution (T&D) from 24% in 2015 to 8% in 2040

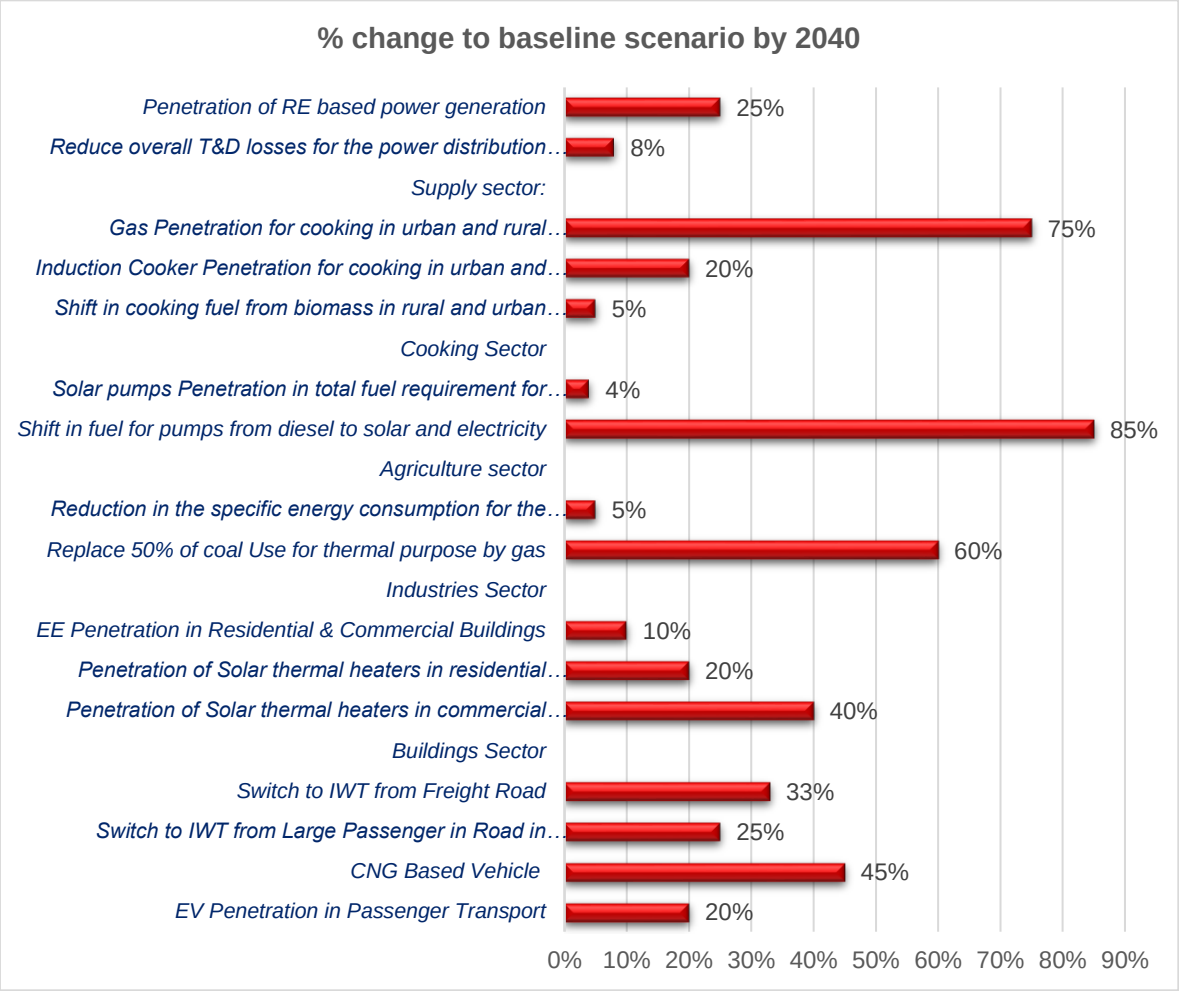
2. **Energy Demand**

- Improving energy efficiency by introducing improved technology/processes across sectors – 10% reduction in energy demand for buildings and 5% reduction in specific energy consumption for industries sector.
- Fuel switch to gas (for industries, cooking and transport) and electricity (for transport) from coal and oil. In the industries sector, 60% energy consumption will shift from coal to gas and in the cooking sector 75% of energy consumption will shift from biomass to gas. In case of transport sector, 20% energy consumption will switch from oil to electricity and 45% will shift from oil to gas.
- Share of IWT in freight and passenger transport to increase to 33% and 25% in 2040 respectively from 1% and 0.4% in 2015.

Summary of sectoral targets for achieving Energy Security Scenario

A set of targets which are determined for Energy Security scenario are summarized below. The percentage changes are in comparison to base line condition of the sectoral intervention in the year 2040.

Figure 15: Comparison of ESS with BAU Scenario



4.3 Comparative analysis of energy scenarios of state

In order to understand the implications of the outcomes of the future energy scenarios of the state, a table providing a comparison of the values of key indicators in the terminal year of projections i.e. 2040 is given below:

Scenario	Final Energy Demand (GWh)	Emissions (MT CO_2/yr)	Share of renewable in power generation capacity (%)	Final Energy Mix
BAU	674,109	344	12%	• Electricity (25%) • Coal (15%) • Gas (7%)
BGS	621,517	316	18%	• Electricity (28%) • Coal (10%)

Scenario	Final Energy Demand (GWh)	Emissions (MT CO_2/yr)	Share of renewable in power generation capacity (%)	Final Energy Mix
				• Gas (13%)
ESS	692,678	278	20%	• Electricity (23%) • Coal (8%) • Gas (28%)

As given in the table, ESS is preferable over BGS as a future state for the state since it provides key benefits, in terms of increasing final energy consumption with lower emission and a higher share of renewables in the power generation capacity. However, ESS has been developed on the basic assumption that consumer is price insensitive and gas pricing has the following implications:

1. Considering prevalent fuel prices and available technology for power generation, the levelized cost of energy (LCOE) of a gas based power generation plant is expected to be 10% more than coal based thermal power plant of equivalent capacity. Uptake of gas based power generation would be limited unless there is introduction of a more economical power generation technology or pricing support from the Government.

2. It also needs to be noted that a notification from Ministry of Petroleum and Natural Gas[6] has provided marketing and pricing freedom to the contractors of CBM block, thereby taking CBM pricing beyond the purview of pricing regulations of the Ministry. The State Government has no jurisdiction over the pricing of CBM. Hence, market prices of competing fuel sources viz. coal, LPG, electricity will be a key factor in determining uptake of CBM by consumer segments.

3. Even if gas pricing becomes favourable, consumers have to undertake additional capital expenditure to either retrofit or replace existing equipment/machineries with ones which can run efficiently on gas. In such a case, propensity of the consumer to incur this additional amount, will determine the extent to which this scenario gets adopted.

4. Apart from the demand side risks/issues, adequate investment should be present in the supply side to scale up infrastructure for exploration, gas production and distribution within the state. Mobilizing scale of investment that is required to develop such infrastructure, requires substantial amount of time. Delay in receiving clearances and right of way for infrastructure development can further escalate costs. Also, technical constraints in drilling/boring wells or in extraction process can escalate costs and may lead to extraction from a particular well infeasible.

In such a case, a deeper engagement of the state government and the CBM producers is required to provide a more effective go-to-market strategy, resulting in increased utilization of CBM in the state. However, technical viability and sustenance of low gas prices is contingent on the prevalent scenario and beyond the control of the State Government.

[6] For reference: Policy Framework for Early Monetization of CBM (Ministry of Petroleum and Natural Gas, April 2017)

BGS, on the other hand, projects natural gas consumption based on historical trend of gas market growth in the state. Hence, BGS provides a more feasible alternative which the State can undertake and ensure that a sustainable energy supply and consumption is achieved. Based on the outcomes of the BGS, an Energy Vision and a subsequent Energy Action Plan has been developed.

4.4 How to bring more renewable energy in the State?

As discussed in Section 3, the State's solar power generation potential is estimated to vary between 3 GW (as per State Government estimate) to a maximum of 27 GW (as per NIWE estimation). However, the estimate of 6.2 GW provided by NISE, can be taken as a feasible option considering existing infrastructure of grid connectivity and corresponding demand pattern of the State. Hydro power is also an important resources for the State, which is now estimated to be around 1500 MW including small, medium and large scale projects.

In order to understand the implications of an aggressive renewable energy utilization, an alternative Renewable Energy Scenario (RnES) has been developed. In this scenario it is assumed that the State installs 6 GWp of ground mounted solar and 1500 MW of hydro resources as well as maximizes utilization of gas production on the supply side. Correspondingly, the assumptions for ESS are adopted to replicate electricity and gas consumption pattern on the demand side. A key implication of the RnES is that coal generation capacity would be replaced by the additional solar power generation capacity. The result indicates that achieving 18 Million Tonnes CO_2 emissions reduction is feasible within 2030 and the share of renewables can go up to 25% and 13% by 2030 with and without RPO share respectively. Figure below shows the emissions reduction potential of the RnES in the State as per the discussion.

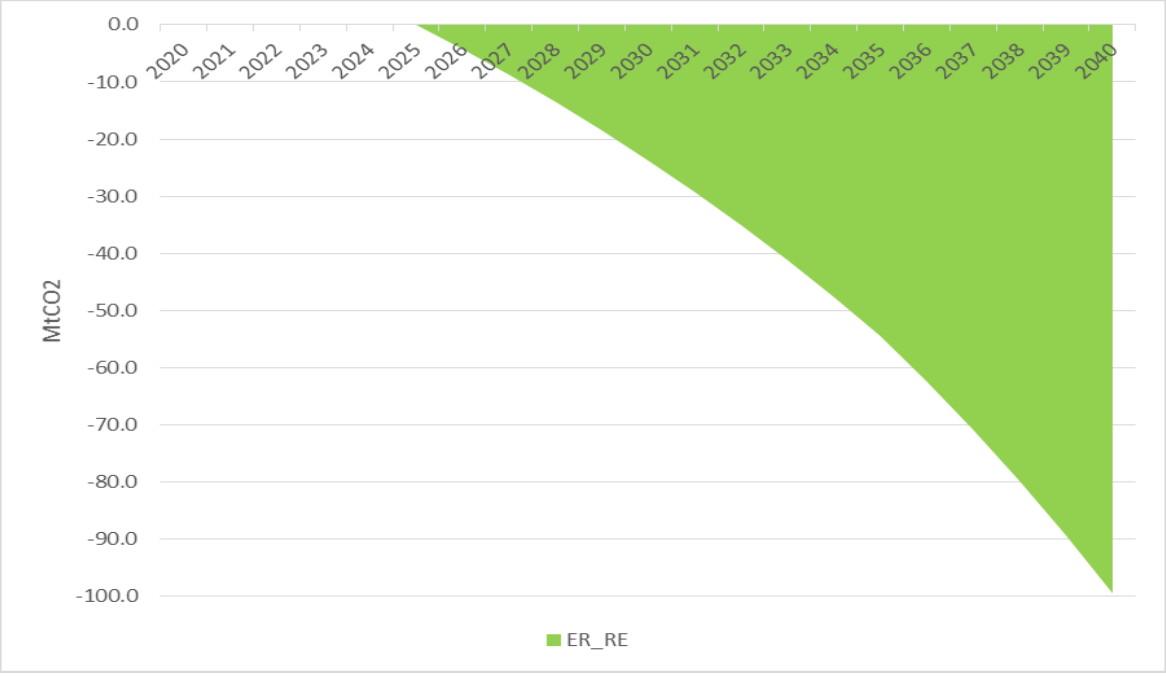


Figure 16: Emissions reduction under RE Scenario

It has been estimated that with a 6 GWp of solar potential and with 1500 MW of hydro potential, the State can generate around 9200 GWh of solar power and 8500 GWh of hydro power by 2030 compared to 3000 GWh of Solar and around 2050 GWh of hydro under baseline condition. In the scenario, the share of renewable (including hydro and import of RE through RPO route) can go up to 30% by 2030 and then will gradually decrease to 24% by 2040. However, RE share without RPO can go up to 20% by 2030. The decline in share is mainly due to increasing overall power supply in the system due to demand growth and RE generation cannot grow accordingly due to capacity limitation. Thus it is important to control the energy demand growth in a reasonable manner so that majority of the demand can be met through cleaner and green energy. Figure below shows the generation mix under the RE Scenario along with the share of RE to total generation.

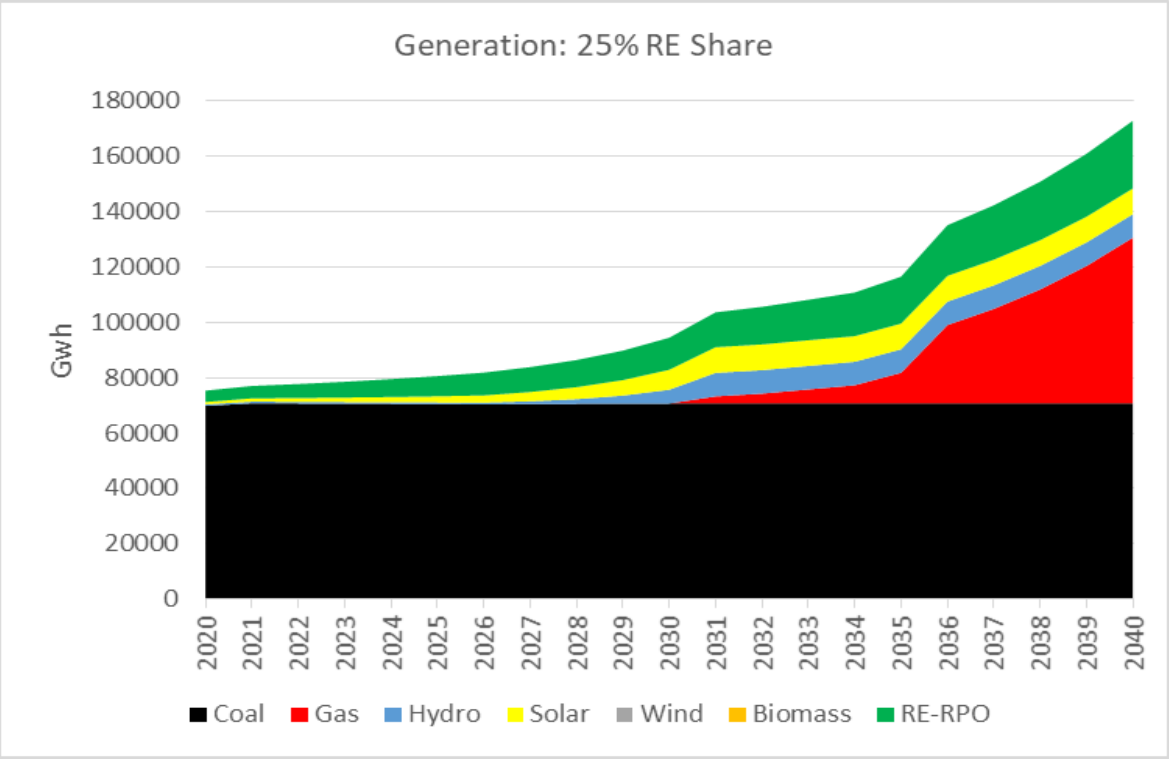


Figure 17: Electricity generation mix under RE Scenario

Having more renewable energy supply in the grid requires more flexible generation capacity in the system which can supply power in a very short notice (may be less than 15 minutes). Coal is currently inflexible as it requires considerably longer time to start supplying power to the grid, but in the future it can be used as flexible source, even though certain efficiency loss will occur. Gas based generation, on the other hand, is relatively more flexible and thus can be used to avoid the RE curtailment in the system.

It is estimated that the maximum economically exploitable solar potential of 6 GW can produce around 10,000 GWh by 2040 and the estimated Capacity Value[7] of solar potential is around 2 GW (30% of the total capacity at the 20% share of RE supply). Further, in order to have grid stability in the system,

[7] The capacity value is the contribution of a technology to overall system adequacy, which is defined here as a technology's contribution to the firm capacity requirement.

it is estimated that the firm capacity requirement in the State would be around 2.3 times of the average daily load (approx.13 GW) i.e. around 30 GW. It has also been observed that until 25-30% of RE share (without RPO) is reached, there is no need for storage capacity in the State (Johnson et. al 2016). It is estimated that with 3.5-4.0 GW of spinning reserve (existing and planned pump hydro of 3800 MW), the state can support 6 GW of solar capacity addition considering future power requirements.

Daily load management is also another key element which needs to be implemented to minimize the curtailment of RE generation during off-peak hours. Short term forecasting of RE supply and demand in the system is essential to increase the firm capacity in the system. Currently only 30% of the total power generation capacity in the state is considered to be firm. But if it is increased to 50% then more generation and supply of RE is possible with lower cost and higher stability.

In terms of cost implication of renewable energy supply in the power sector of the State it is estimated that if the 6 GW solar potential is pursued along with 1.5 GW of hydro and adequate amount of gas base capacity addition, the overall cost of energy supply reduces by around 20% compared to the energy security scenario which is predominantly a scenario of large scale gas utilization. Overall the scenario indicates a better off situation for the State if renewable energy is promoted along with gas. Figure 18 below shows the comparison of present value costs of four different scenarios discussed before.

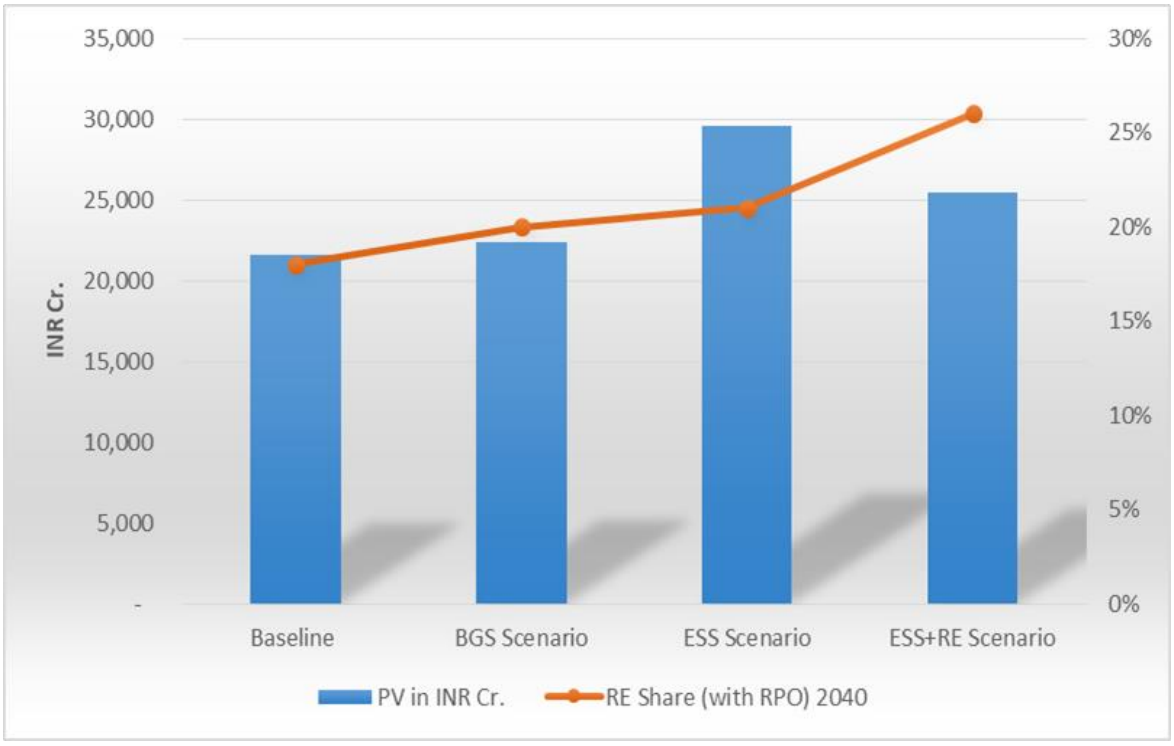


Figure 18: Present Value comparison of different scenarios

5. State Energy Vision & Action Plan

According to the Inclusive Wealth Report of 2018 (UNEP, 2018), the state is under-performing in conservation of its natural capital through various economic activities like agricultural land use, crop production, forestry and forest produce, mines and minerals and use of fossil fuels, in spite of having any significant amount of natural resources. It has been estimated that the state's natural capital is declining at a decadal rate between 5 to 10%, indicating that the state is rapidly exhausting its resources, thereby jeopardizing future generations.

Apart from the issues discussed in Section 1, the Energy Vision for the state has thus been developed to address this sustainability issue as well, thereby ensuring an overall economic, social and environmental development of the state. Moreover, the State vision also focusses on promoting energy self-sufficiency through reduction in import of fossil fuels and increasing in supply of energy resources generated within state (through new discovery and extraction of proven reserves) and by increasing resource use efficiency across the value chain in various economic activities.

Based on the discussion, the state's Energy Vision has been given as follows:

1. **Improving living standard of the people of the State by providing access to modern energy in an affordable, reliable and sustainable manner.** It envisions:
   a. Providing adequate supply of energy in an affordable, reliable and sustainable manner.
   b. Creating enabling environment to increase the per capita energy consumption for decent standard of living.
   c. Generate scope of employment through development of modern power generation and energy production technology.
2. **Ensuring cleaner production and efficient consumption of energy.** It envisions:
   a. Utilization of full potential of renewable energy resources available in the State.
   b. Promoting use of highly efficient technologies in energy production and consumption areas to optimize resource utilization and reduce GHG emission.
3. **Increasing wealth of the State by ensuring growth of natural capital of energy and related resources.** It envisions:
   a. Ensuring optimal use of energy resources in the State by bringing resource use efficiency in the system.
   b. Reducing dependency on imported fuels & increasing optimal use of local resources.
   c. Recognizing the importance of resource use nexus, creating an integrated planning and monitoring framework for energy production and consumption in the State.

5.1 Structure of Energy Action Plan

Given the complexity of macroeconomic scenario of any state along with cross-linkages with energy demand and supply sectors, it is important to develop an action plan which is integrated in nature and comprehensive in coverage. Keeping these two issues in mind the study has developed a detailed set of Energy Action Plans for the State based on the assessment of an optimization model. The figure below shows the schematics of the integrated planning of energy sector for the State of West Bengal.

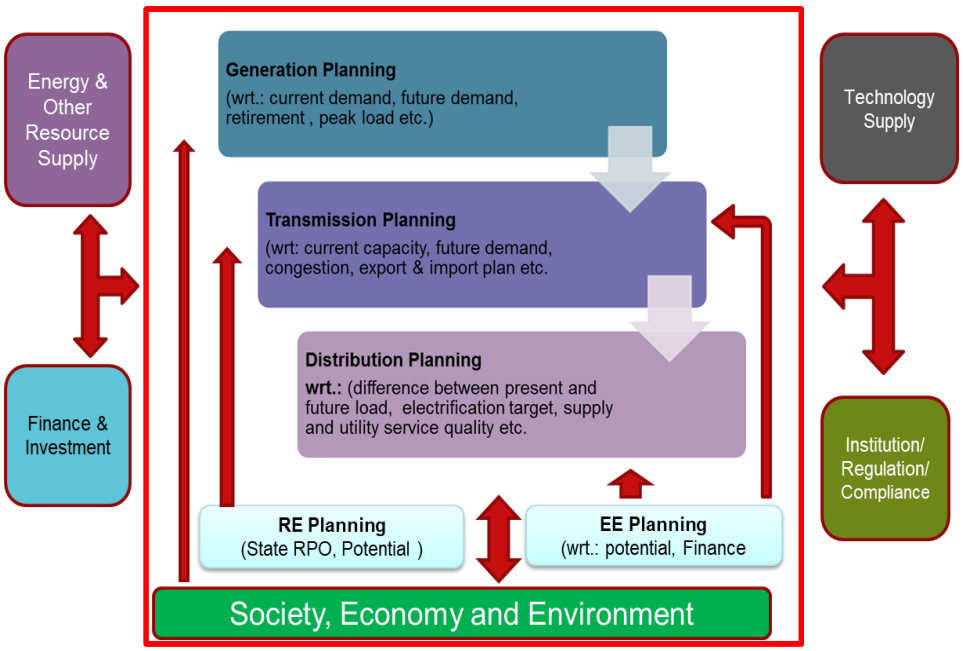


Figure 19: Schematics of State Energy Planning

The fundamental of energy planning is to link the energy sector to economy, society and environment through a causal chain relationship. Energy generation is linked to demand of energy which is further linked to economic growth and development. Economic development takes place through social development, employment creation and other economic activities. Generation of energy has a variety of negative externalities, the most crucial one being air pollution and GHG emissions. Thus generation technologies need to be upgraded to higher efficiency and cleaner technologies so that negative externalities can be minimized. Access to finance is critical for adoption of such advanced technologies in the market as well as increased awareness among end users on the benefits to adopting such technologies. In order to provide successfully implement such activities a robust institutional framework should be in place along with requisite policy and regulatory support. Thus Energy Plan, apart from being multi-sectoral should also be multi-dimensional, catering to various functional areas as well. An idea of how this has been achieved in case of West Bengal is given in succeeding sections.

5.2 Mapping of State Energy Visions & Sectoral Action Plans

State energy visions are classified into three main categories: **Improved Energy Access**, **Cleaner Energy Production** and **Growth of Natural Capital**. Energy Action Plan has been developed in a way such that all three areas fulfilled through several set of activities over the period of time until

2040. Following table shows the mapping between different sectoral interventions proposed for the State to act upon and the State Energy Visions. This mapping is extremely important for the policy makers to understand the impacts areas of a new policy and also to revise and update the existing policies in the future.

Table 1: Mapping of Energy Vision and Action Plan

Sectoral Interventions	Energy Availability & Access	Cleaner Energy Production & Consumption	Growth of Natural Capital
Energy Resource			
Promoting resource extraction efficiency		✓	
Exploration of new resources	✓		✓
Creating infrastructure for efficient transportation of resource materials		✓	
Electricity Generation			
Increasing utilization of existing assets	✓		✓
Promotion of renewable energy generation	✓	✓	
Incorporation of efficient thermal technologies (SC, USC, IGCC etc.)		✓	✓
Transmission and Distribution			
Reduction of T&D losses	✓		
Creating new assets for improved capacity of power evacuation	✓		✓
Transport Sector			
Fuel shift (Shifting to electric mobility)	✓	✓	✓
Modal shift (shifting to efficient transportation mode ~water/rail)		✓	✓
Fuel efficiency (Greater emissions reduction)		✓	
Industry Sector			
Fuel Shift		✓	✓
Process efficiency improvement (mainly small and medium scale industries)		✓	✓
Residential and Commercial Sector			
Implementing building energy efficiency plans		✓	
Use of renewable energy for heating and lighting demand		✓	
Agriculture & Fishery Sector			

Sectoral Interventions	Energy Availability & Access	Cleaner Energy Production & Consumption	Growth of Natural Capital
Fuel shift in irrigation activities (diesel to electricity)	✓	✓	✓
Renewable energy use in irrigation pumping		✓	✓
Cooking Sector			
Fuel shift from biomass to LPG		✓	
Higher penetration of electricity as cooking fuel	✓	✓	✓
Introduction of PNG in urban areas		✓	✓

The following section deals with the detailed description of the proposed action plans for each of the sectors in the economy assessed in this study.

The main purpose of developing the action plans is to provide the State with suitable pathways of development which can ultimately help the State to reach the goals and materialize the visions into reality within a given timeline. **The action plans would also help the state to achieve the Balanced Growth scenario.** Action plans are reasonably ambitious, implementable and effective in nature, which are derived through energy optimization model described above. The model test indicates the impacts of each of every action plan proposed on the energy system of the State as a whole especially in the context of three main policy dimensions***: i) Economic and financial impact of the plan, ii) Environmental impact of the plan and iii) Social impact in terms of access to energy and achieving decent living standard***.

6. Detail Action Plans for Energy Supply Sectors

A. Brief Description of Sector

West Bengal has the 4th highest geological reserve of coal in India and accounts for nearly 10.04% of the national reserves. (Indian Bureau of Mines, 2018). This mostly includes non-coking coal and other forms of coking coal. In terms of the quantity of production in coal, the state ranked 7th in the year 2017-18. (Ministry of Coal, Govt. of India, 2018) A total of 75 mines in West Bengal were reported to have production in 2015-16. The total coal production for the state is 29.241 million tonnes, while total coal despatched was 29.95 million tonnes (Ministry of Coal, Govt. of India, 2018).

West Bengal does not have any proven petroleum reserves, all the petroleum consumption in the state comes from external sources. The state has a petroleum refinery complex in Haldia. The Haldia Refinery is one of the two refineries of Indian Oil Group Companies producing Lube Oil Base Stocks (LOBS). Petroleum products from this refinery are supplied mainly to eastern India through two product pipelines, namely Haldia-Mourigram-Rajband Pipeline (HMRBPL), and Haldia-Barauni-Kanpur Pipeline (HBKPL), as well as through barges, Tankers, tank wagons and tank trucks.

West Bengal has natural gas in the form of coal-bed methane (CBM) gas and there are 2 such fields in Raniganj area which has recoverable reserves of 65.92 billion cubic metre (BCM) as on 2018 (Ministry of Petroleum & Natural Gas, Economic & Statistics Division, 2018). This accounts for 62.2% of total recoverable reserves of CBM in India and 12.77% of the total onshore natural gas in India. (Ministry of Petroleum & Natural Gas, Economic & Statistics Division, 2018). The production of CBM in West Bengal for 2017 is 554 million metric standard cubic meter (MMSCM), which accounts for 81% of the total CBM production and 5.27% of the total onshore gas production in India.

The major electricity generation in the State is from coal based plants. State's total generation capacity includes state owned capacity (DPL,WBPDCL), privately owned capacity (CESC, DPSC etc.) and centrally owned capacities (NTPC) together. Although there is an installed capacity of 100 MW for 2 gas based power plants in Haldia and Kasba, there has been no reported power generation from these plants in 2017-18. There are 5 hydroelectric power station (HPS) in West Bengal – 3 under State Sector and 2 under Central Sector with a total monitored capacity of 1.4 GW until 2018. State has produced around 2200 GWh of electricity from these hydro sources in during 2017-18.

Transmission license in the state is solely with West Bengal State Electricity Transmission Company Limited (WBSETCL). State has total 128 EHV sub-station nuder WBSETCL with installed capacity of 32671 MVA. The state has 13935ckm of EHV lines, which transmitted around 49560 MU power in 2017-18 at a loss of about 2.5% (DoP, GoWB, 2018). There are currently 5 DISCOMs with distribution license in West Bengal – CESC, DPL, WBSEDCL, DVC and IPCL. The consumer category wise power consumption is primarily driven by residential & commercial sector followed by the industry sector.

B. Existing initiatives related to energy sector

"Alosree"

State Government has launched an ambitious programme of rooftop solar systems namely "Alo-Shree" programme. The objectives of this programme is to install Grid Connected Solar Photovoltaic (GRTSPV) System in all government buildings and buildings of local bodies which are technically fit for such installations within two years i.e. by 2017-18. The target to install GRTSPV under 'Alo Shree' is 60 MW and 120 MW by 2016-17 and 2017-18 respectively with total financial commitment of Rs.

1260 crore. First phase tendering for 'Alo Shree' is underway. WBREDA has taken up the matter with MNRE, Government of India for obtaining central financial assistance under National Solar Mission.

Floating Solar Power Plant

West Bengal government is in the process of installing two floating solar power plants by 2019 at Sagardighi and Mukutmanipur with generating capacities of 5 MW and 100 MW respectively. Accordingly, DPR of both projects have been completed.

Construction of gas pipeline

Hiranandani Group-promoted H-Energy is executing a ₹3,700-crore project to import and distribute LNG in West Bengal, as well as export to Bangladesh. The first phase of the project includes setting up of a re-gasification terminal at Kukrahati in the Purba Medinipur district of West Bengal, at an estimated cost of ₹1,500 crore over a 47-acre plot. The other part entails setting up of a pipeline — worth ₹2,200 crore — from Haldia to the India-Bangladesh border and a smaller city gate station on the outskirts of Kolkata for supply of city gas. It is expected that construction shall commence in June/July this year and is expected to be completed in 18 months. (H-Energy, 2019). While GAIL was entrusted with developing city gas distribution (CGD) networks in six cities, state-owned Greater Calcutta Gas Supply Corporation (GCGSC) was earlier authorised to distribute gas in Kolkata and its surrounding areas. Subsequently, it was decided that the CGD in the eastern metropolis would be developed jointly.

Modernization of distribution grid

WBSEDCL is undertaking a pilot project to install smart meters in Siliguri targeting 5,000 households and connecting to a single feeder (Smart Energy International, 2018). The pilot project is expected to cost INR 5 crore and will help curb hooking and pilferage as well as ensure an uninterrupted supply of good quality power. After is completion in 2018, WBSEDCL is monitoring the use of the meters for at least a year, post which decision will be taken on scaling up the initiative. WBSEDCL has also implemented SCADA in Siliguri and Asansol by 2017 and Kolkata town with 26 sub-stations in March 2018 (WBSEDCL, 2019)

CESC also has installed an advanced metering infrastructure (AMI) with approximately 25,000 smart meters in its distribution license area of Kolkata and Howrah (CESC Limited, 2018).

Collaboration with International partners

On the sidelines of the Bengal Global Business Summit 2019, West Bengal state government partnered with Polish government to implement innovative technologies and solutions for the development of the coal mining sector in India, with particular regard to the Deocha Pachami coal block. The collaboration will bring assistance of Polish companies that offer solutions that could be adapted to conditions in the Deocha Pachami coal block: detailed exploration of coal reserves; demethanation and the use of technologies for the commercial exploitation of underground methane; advisory solutions on the development of underground coal mines; longwall machinery and continuous miners; mine safety and personnel security equipment; exchange of technical know-how through academic exchange programs; and dry coal treatment technologies.

Improvement in power distribution system to reduce AT&C losses

The work being undertaken by WBSEDCL under various state and central level schemes to reduce aggregate technical and commercial (AT&C) losses is given below (WBSEDCL, 2018):

a. *Restructured Accelerated Power Development and Reforms Programme (R-APDRP), Part-B:* R-APDRP is a central scheme which provides financial assistance to states for reducing AT&C losses with a focus on urban areas – towns and cities with population of more than 30,000 (10,000 for special category states).. It consists of two parts – Part A & B. Part B of the scheme is for renovation, modernization and strengthening of distribution systems for which central government will provide 25% of total fund requirements. 50% of this loan amount gets converted in to grant on achieving the 15% AT&C loss in the project area on a sustainable basis. For West Bengal, the scheme covers designated 68 towns, with a sanctioned value of INR 808.78 crore. Works have been awarded for 67 towns for which INR 490.13 crore has been spent by WBSEDCL.

b. *National Electricity Fund (Interest Subsidy) Scheme:* NEF scheme is a central government funded scheme where interest subsidy on loans are disbursed to DISCOMS, both in the Public and Private Sector, to improve the distribution network not covered by Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) and R-APDRP project areas. Under this scheme two projects have been completed and are on on the verge of closure.

   i. Cabling and Upgradation of sub-transmission and distribution system in Bolpur and Nabadwip towns with project cost is INR 90.76 crore
   ii. Replacement of 33 & 11 KV OCB by VCB & Capacity augmentation of 33/11 KV sub-station under Midnapur, Kolkata and Burdwan Zones with project cost is INR 114.55 Cr

c. *High Voltage Distribution System (HVDS) works funded by State government:* Under this project, HVDS works to reconfigure the existing HT/LT network using distribution transformer (DTR) and HT/LT aerial bundled (AB) cable in various districts of West Bengal have been taken up. The project is underway for Burdwan and Birbhum districts (project cost INR 308 crore) and Hooghly, Paschim Midnapur, 24 Parganas (North and South) districts (project cost INR 2200 crore)

d. *UG cabling works under Green City Mission:* Replacement of existing overhead distribution lines with underground (UG) cables in Coochbehar and Nabadwip Towns will be completed under Green City Mission project with a total project cost of INR 75 crore.

e. *UG Cabling under Strengthening and Extension of Electricity Distribution Network (SEEDN) scheme:* Replacement of existing overhead distribution lines with underground cables in Suri and Barasat towns will be done under SEEDN project with a cumulative project cost of INR 420 crore which has gone into re-tendering process because of high quotation by bidders.

f. *Integrated Power Development Scheme (IPDS):* IPDS is a Central Government scheme for strengthening of sub-transmission and distribution network, metering of distribution transformers /feeders / consumers and IT enablement of distribution sector and strengthening of distribution network in urban areas. For West Bengal, the following is the status of the works:

No.	Scope of Work	Quantity	Project Cost (INR Cr)	Status (as on Nov'18)
1.	New 33/11 kV sub-station with associated 33 kV line.	47 Nos. (2x10 MVA)	387.64	20 nos. sub stations commissioned.

No.	Scope of Work	Quantity	Project Cost (INR Cr)	Status (as on Nov'18)
2.	33 kV system augmentations with renovation of existing 33/11 kV sub-station.	112 Nos.	379.65	Completed at 44 nos. substations.
3.	Drawal of 11 kV line (New & augmentation).	2,097.42 KM	376	59 KM
4.	Drawal of LT line (New & augmentation).	440.93 KM	145.72	9 KM
5.	Drawal of AB Cable.	14,504 KM	1,082.58	3585 KM
6.	Installation of DTR. (New & augmentation).	7,735 Nos	230.69	2557 Nos.
7.	Replacement of Meter.	8,27,853 Nos	220.93	4,59,884 Nos.
8.	Installation of Roof top Solar panel.	3,016 Nos	43.59	Installation of Roof top Solar panel.

C. Comparative analysis of alternative pathways

It has been estimated that the Balance Growth Scenario (BGS) and the Energy Security Scenario (ESS) both can help the state to reduce the overall primary energy consumption and its related expenditure while meeting the energy demand fully. For BGS the total primary energy consumption reduces by 8.5% by 2040 compared to the BAU scenario while for the ESS scenario the reduction is even more i.e. 10% compared to BAU in 2040.

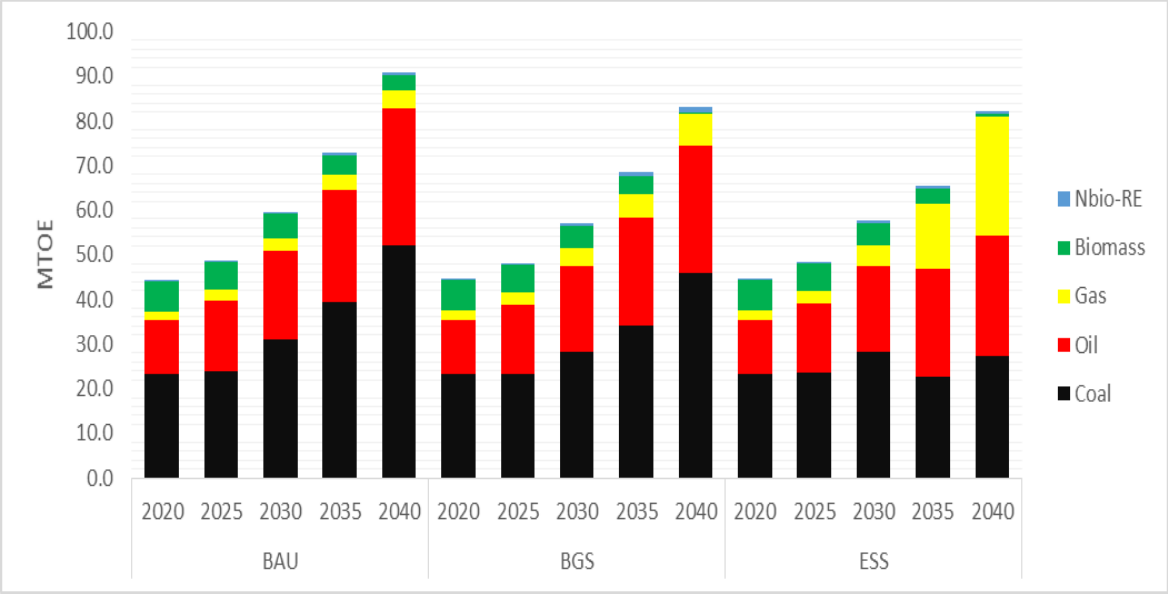


Figure 20: Comparison of primary energy consumption

In terms of electricity generation, the BGS scenario is 4.5% lower than the BAU scenario while the ESS scenarios is almost 10% lower than the BAU in 2040. This indicates that both the scenarios

rationalize the electricity demand through various measures like efficiency improvement, loss reduction etc. and subsequently reduces the generation requirement while meeting the same demand. Lower the generation lower the cost of energy supply and hence the greater benefit of the State. Figure below shows the comparison of power generation fuel type wise for different scenarios.

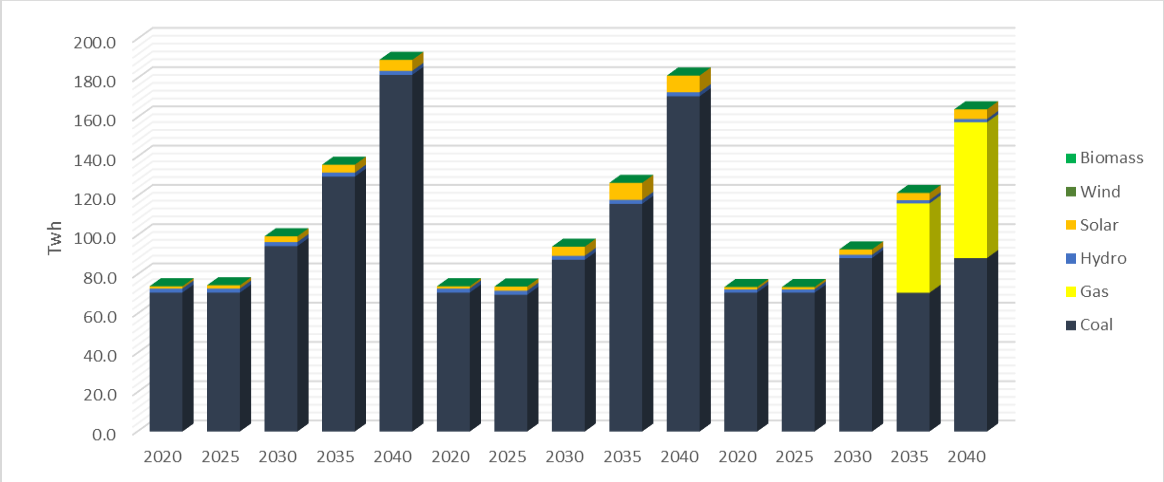


Figure 21: Comparison of electricity generation fuel wise

In terms of total generation capacity BGS is not very different from BAU but it is promoting solar and other renewable sources as much as possible from the early years. As a result, BGS is expected to have solar installation of 3 GW by 2030 and 5.5 GW by 2040 compared to 2 GW and 3.5 GW during the same time for baseline. ESS on other hand pushes for gas base generation in the system using the well anticipated CBM gas supply starting 2030. Figure below shows the comparison of power generation fuel type wise for different scenarios.

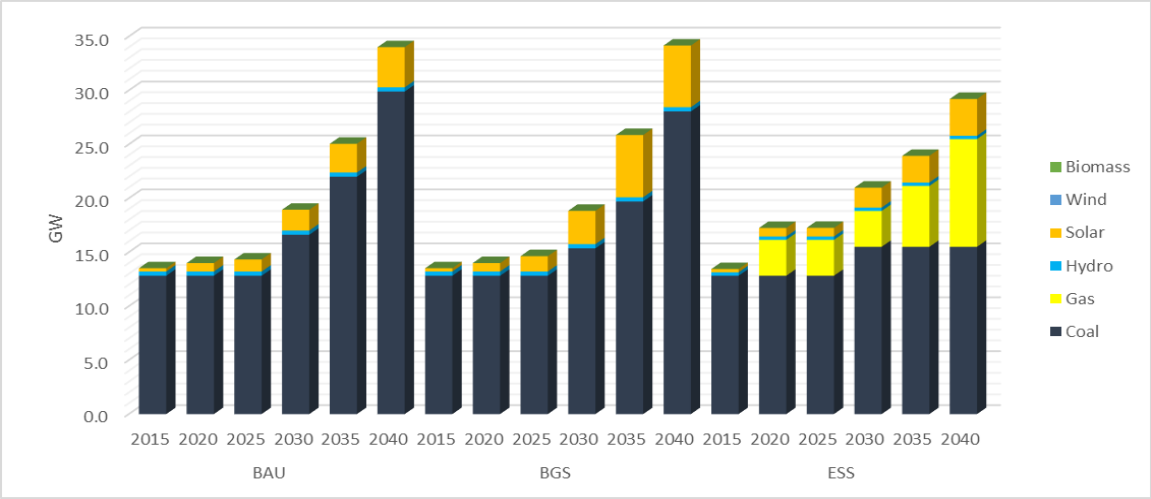


Figure 22: Comparison of electricity generation capacity fuel wise

In terms of emissions from the energy sector, both BGS and ESS scenarios can help the State to reduce GHG emissions. BGS can reduce CO_2 emissions cumulatively by around 60 Million ton between 2020 and 2040 while ESS can reduce 113 Million ton cumulatively in the same time period compared to the baseline emissions. While BGS scenario is envisaged to reduce emissions from both supply and demand side in a balanced manner, ESS scenario reduces the emissions mainly from

supply side by replacing coal based power generation to gas. Figure 24 below shows the comparisons of emissions reduction by two scenarios compared to the baseline.

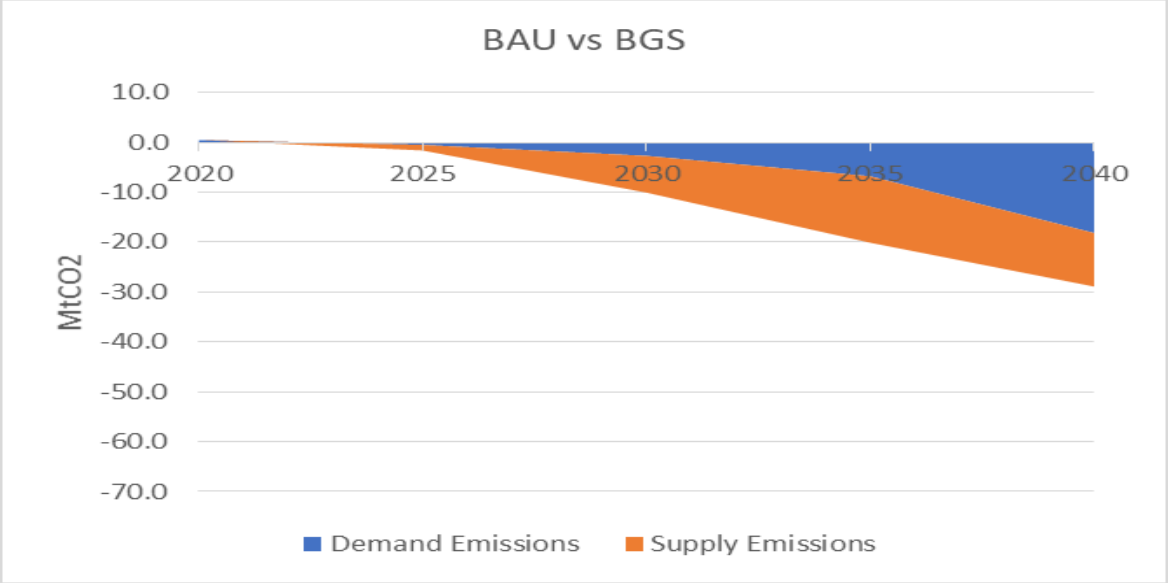


Figure 23: Comparison of emission in BAU scenario & BGS

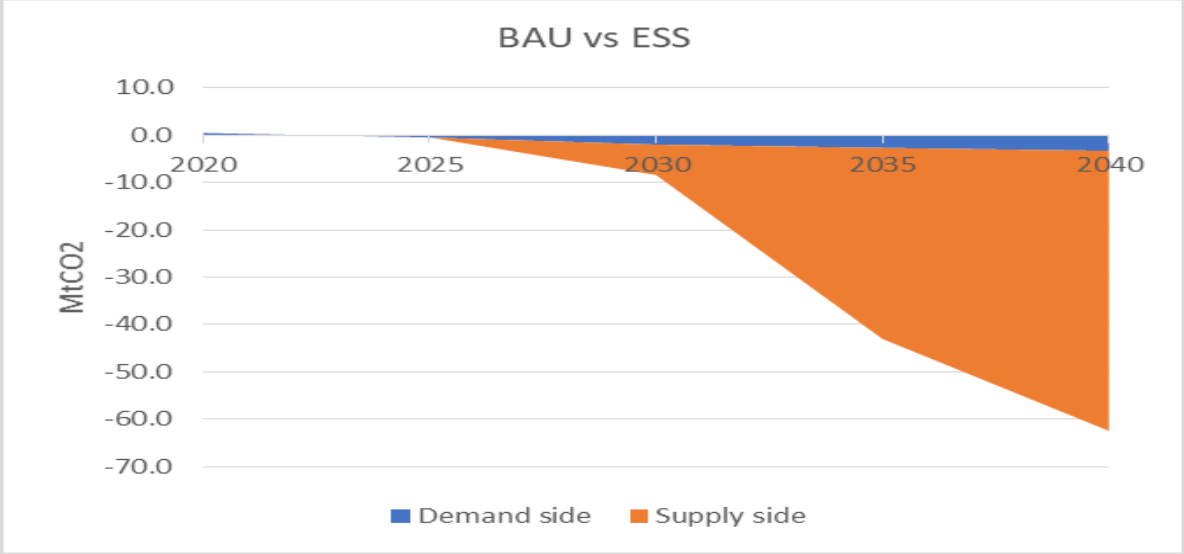


Figure 24: Comparison of emission in BAU scenario & ESS

D. Sectoral Vision

i) Coal

Coal production in the state has stagnated over the past five years while coal demand has been increasing. State can reduce the demand and supply gap by utilizing the state's coal reserves

which can additionally bring 500 million tonnes of coal per year in the market, provided adequate investment are in place.

Vision: ***State will utilize its coal resources adequately and efficiently which can enhance energy supply in the state as well reduce emissions***.

ii) Oil and natural gas

State has no oil reserves, however utilization of CBM/shale gas reserves in the Raniganj belt has the potential to create a new horizon of gas based economic development. 9 TCF of gas equivalent to more than 300 MTOE of energy can provide sufficient gas supply for power generation, industrial, commercial and residential use.

Vision: State will utilize its recoverable gas reserves adequately and efficiently which can enhance energy supply in the state in an affordable manner.

iii) Power Generation – Conventional and Renewable

State has existing power generation capacity which is largely under-utilized and there is no immediate plan of introducing efficient power generation technologies. Also, generation potential from renewables in the state is yet to be fully utilized.

Vision: State will maximize the utilization of existing assets for power generation, reduction of losses, bringing in efficient power generation technologies in the future as much as possible. Promotion of renewable energy shall be prioritized.

iv) Power transmission and distribution

The distribution losses of the state is around 25-30% which has negative impact on the commercial condition of the DISCOMs of the state. Revamping the power distribution systems can help address this issue

Vision: State shall work towards reducing the T&D losses to the maximum extent possible.

E. Action Plans

i) Coal

Objective: The State shall increase the domestic coal production to reach at least 20% share of national coal production by 2040. Currently the share is only 4%.

Activity:

A.1: State shall explore the mining options of newly discovered mines in the Deocha-Pachami coal block so that production increases to 100 Million ton by 2030 and 250 million ton by 2040 as compare to 28 Million ton in 2016-17.

A.2: State shall adopt clean coal technologies in order to reduce emissions arising from coal consumption in its primary form

ii) Natural Gas

Objective: The State shall increase the domestic natural gas production to enhance the share of gas use in the primary energy level to the level of 30% by 2040 and to 20% at the final energy level by 2040.

Activity:

B.1: State shall explore the options of newly discovered CBM blocks in the Ranigunj block so that by 2035 1 TCF gas and by 2040 2 TCF gas is extracted.

B2: State shall ensure development of market for natural gas in the state

iii) Power Generation-Conventional

Objective: The State shall focus on adopting efficient technologies for thermal generation. By 2035 State shall achieve at least 10% super critical coal based capacity followed by 10% gas based capacity. By 2040, State shall achieve 20% super critical coal capacity and 20% gas based capacity. Optimizing PLF of existing power plants can help reduce the auxiliary consumption of these by power plants (currently at 10% of total power generated in the state) by 2%.

Activity:

C.1: State shall utilize the existing power plants to its optimal capacity (which is around 75%) by 2030 as compared to 60% at current level.

C.2: State shall prepare for new capacity addition of 1 GW by 2030, 2.5 GW by 2035 and 10 GW by 2040 with super critical technologies.

iv) Power Generation – Renewable

Objective: The State shall maximize the renewable energy resource utilization by promoting technologies and creating enabling environment for financial and regulatory support which can bring share of renewables to the level of 20% (including RE import) of total power generation in the state by 2030.

Activity:

D.1: State shall conduct resource potential estimate for all categories of renewable sources within the state

D.2: Assessment of local level grid integration flexibility of LT network and creating digital grid map of the identified locations

D.3: State shall update the Renewable Energy Policy which will provide the State's vision in renewables sector as well as the incentives to be provided for promoting renewables in the state.

D.4: State shall ensure grid stability after integration of renewables in the power system.

v) Power Distribution

Objective: The State shall urgently focus on reducing the losses in the power system by adopting required technologies. By 2030 State shall reduce the distribution losses to 15% compared to 27% at the current level and by 2040 the State shall reduce the distribution losses to 8%.

Activities:

E.1: State shall focus on strengthening distribution network by collecting and digitizing the line information and data. State shall use modern technologies like GIS, SCADA and smart meters for digitization of LT distribution network data.

E.2: State shall install infrastructure to prevent losses caused due to theft and damages due to natural disasters.

Table 2 shows the summary of all activities and their corresponding sub-activities which are to be implemented over the period of time until 2040 to help achieve the targets in West Bengal Action Plan. The activities, which is further divided in to sub-activities are derived from the State Vision statement. In order to achieve the objective of each sub-activity, multiple projects may need to be undertaken. Identification of these projects would be the next level of action required for implementation of the Energy Action Plan.

The sub-activities are divided into three time frame: Short Term (2020-2025), Mid Term (2025-2030) and Long Term (2030-2040) and the sub-activities have been sequenced based on the relative importance of activities.

The sub-activities are also further classified into four categories to help assign roles and responsibilities within the implementation agencies:

1. ***Technical:*** Sub-activities which involve technical studies or infrastructure development.
2. ***Financial:*** Sub-activities which involve providing financial incentives to beneficiaries.
3. ***Institutional:*** Sub-activities which involve reforms in processes/structure of an institution
4. ***Policy/Regulatory:*** Sub-activities which involve introduction of new regulations/regulatory reforms or new policies/update existing policies.
5. ***Capacity building/Awareness generation:*** Sub-activities which aims to generate awareness regarding clean/energy efficient technologies/processes as well as enhance knowledge and skills of users regarding use of such technologies and processes.
6. ***Market Development:*** Sub-activities which help identify and develop new market segments for a clean/energy efficient technology/process.

Furthermore, the appropriate implementing agency which are empowered to implement the particular sub-activity has also been provided.

Table 2: Summary of action plans for energy supply side

No.	Sub-sector	Activity	Sub Activity	Time period	Type of Intervention	Implementing Agency
1.	Coal	Ensure emission reduction in mining and consumption	Increase penetration of modern technology to increase mine productivity and worker safety	Short to Medium	Technical	DoP, WBPDCL
2.			Promotion of clean coal technology for industrial consumers	Short to Medium	Market Development	DoP, WBIDC
3.	Natural Gas	Market development for natural gas	Develop anchor customers in industries sector	Short to Medium	Market Development	DoP, WBIDC, IC&E
4.		Increased utilization of natural gas	Increase promotion of cogeneration techniques	Medium to Long	Technical	DoP, IC&E
5.			Implementation of district cooling system	Short to Long	Technical	DoP, UD&MA
6.	Power Generation – Conventional	Ensure reduction in emission	Undertake capacity addition for clean coal technology	Medium to Long	Technical	DoP, Power GenCo
7.			Partnership for clean coal technologies	Short	Institutional	DoP, WBIDC
8.	Power Generation – Non-conventional	Utilization of renewable energy potential of state	Establish potential of renewables of state	Short	Technical	WBREDA
9.			Updating Renewable energy policy	Short	Regulatory/Policy	DoP
10.			Provide regulatory support to increase penetration of solar rooftop enabling environment for increased penetration	Short	Regulatory/Policy	DoP
11.			Development of floating solar power plants to increase share of renewables in state	Medium to Long	Technical	DoP, WBREDA, WBPDCL
12.		Ensure grid stability due to integration of renewables	Undertake advanced load forecasting to ensure grid integration of renewables	Short	Technical	DoP, Discoms, SLDC
13.			Increasing penetration of power storage infrastructure and grid stabilization techniques	Medium to Long	Technical	DoP
14.	Power Transmission and Distribution	Strengthening of transmission and distribution network	Modernization of power distribution system within the state	Short to Long	Technical	DoP, Discoms
15.			Installation of infrastructure to prevent losses due to theft and damages due to natural disasters	Short to Long	Technical	Discoms

F. Description of sub-activity

1. Increase penetration of modern technology to increase mine productivity and worker safety

The State has been allocated the Deocha-Pachami mines which if utilized optimally can increase the share in national coal production as well as contribute to energy security of the state. The State has already partnered with Polish government to introduce mining technologies, particularly Deocha-Pachami mines. The State can further enhance the level of automation in coal extraction to increase mine productivity as well as improve worker safety.

In order to increase penetration of modern technology the State can collaborate with international partners to attract investment in:

- Installation of GPS based Truck Dispatch System
- Use of mine planning software like MINEX
- Development of Decision Support System through enhancement in MIS of standard ERP solution
- Implementation of automated mining system (like mine robotics, armchair mining) for enhancing worker safety and improving mine productivity.

The State can utilize the investment promotion platform of Bengal Global Business Summit to reach out to potential partners like Dassault Systèmes (France, USA), DAQRI (USA), Mojix (USA), Mine Site Technologies Pty Limited (Australia), Clarke Energy (UK), Autonomous Solutions Inc.(USA) etc. which specialize in such technologies.

2. Promotion of clean coal technology for industrial consumers

Considering the BAU scenario, industries is the only energy demand category which utilizes coal for final energy supply. The use of coal accounts for nearly 63% of total final energy supply for the sector and contributes to 71% of the total CO_2 emission for the sector (West Bengal Energy Model Analysis , 2019). In order to ensure greater efficiency of coal consumption as well as to reduce the emission from coal use, coal liquefaction can be considered.

Coal liquefaction, also called coal to liquid (CTL) technology, is an industrial process in which coal as raw material is converted into liquid hydrocarbon mixture through chemical reaction. There are two methods, one by direct conversion and second by indirect conversion via gasification route[8]. The use of CTL helps in effectively capture CO_2 emission which can be transported and injected into underground storage reservoirs (a procedure known as Carbon Capture and Storage or CCS).

While coal liquefaction requires considerable investment, it has been a proven technology globally with multiple examples of CTL plants in South Africa and China. CSIR-Central Institute of Mining and Fuel Research (CSIR-CIMFR), Dhanbad has installed and commissioned an indigenously developed integrated Coal-to-Liquid pilot plant (MyGov.in, 2017). Accordingly, communication with CSIR-CIMFR can be established to understand the possible scope of such technology in West Bengal and the target industrial sector that can undertake such technology in medium and long term.

In order to promote this technology for industrial consumers, DoP can collaborate with IC&E to increase awareness of CTL technology in the target industrial sector through roadshows, targeted programmes for industrial association etc. Support from CSIR-CIMFR can also be taken to develop collaterals which can be used for the purpose of promotion.

[8] For further information: Green growth and clean coal technologies in India (TERI, 2015)

3. Develop anchor customers in industries sector

The existing reserves of CBM is expected to be a key fuel source to ensure energy security for the state. In 2040, the share of energy from gas is set to increase from 4.3% in BAU scenario to 8.6% in BGS (West Bengal Energy Model Analysis , 2019). In order to increase utilization of CBM reserves both demand and supply side measures need to be undertaken. Since supply side infrastructure development for natural gas is a central subject, State can provide support in increasing demand of gas consumption.

In order to ensure viability of their investment and business, private sector gas suppliers would be inclined to tie up with at least one anchor customer through gas purchase/sale agreement. However, such a customer will not be willing to sign an agreement unless they are assured of gas supply in time. The state can help resolve this conundrum and stimulate the market for CBM by developing anchor customers for suppliers. The development of anchor customers can be through the two options:

a. Pursue any private utility that can consume sufficient gas from a gas supplier as an anchor customer. To fructify this Government of West Bengal will have to act as a facilitator.

b. Alternatively, the State Government can itself arrange for such consumption through its different arms of utility businesses including city gas distribution wing i.e. Greater Calcutta Gas Supply Corporation Limited (GSGCL)

Natural gas is used both as a fuel and a feedstock in various industries. It is used as a fuel in the power, industrial, tea plantation, Cement, Ceramics, Glass, as city gas for cooking and heating and for transportation, as CNG, sectors. It is used as a feed stock in Fertilizer, petrochemicals, LPG industries. DoP, with support from IC&E department can identify the target industrial sectors and entities which can potentially benefit from increased consumption of gas i.e. a robust business case. Simultaneously co-ordination with gas supply agencies should be undertaken to connect the gas suppliers to the potential anchor consumers.

4. Promotion of cogeneration/trigeneration

A typical power generating station can provides an efficiency of 40% i.e. 40% of energy content of the fuel is ultimately converted to electricity, while the remaining is lost as heat (Bureau of Energy Efficiency, n.d.). This waste heat can be used to either for only heating or both heating and cooling purpose. The technology which helps in utilization of waste heat for heating purpose is called cogeneration (or combined heat and power plant/CHP) and utilization of waste heat for both heating and cooling purpose is called trigeneration (or combined cooling, heat and power/CCHP).

Cogeneration can provide efficiencies up to 85% while in case of trigeneration it is upto 80%. Hence, use of these technologies can help in efficient consumption of fuels.

Cogeneration is more prevalent in industrial sector since there is limited use of both heating and cooling in any particular industrial sub-sector. Trigeneration on the other hand is more applicable for commercial buildings like malls, hotels, hospitals, offices, SEZs etc.

Even in terms of cost, the two technology can provide substantial gains to the user:

a. *Cogeneration* (Bureau of Energy Efficiency, n.d.): Taking the case of a gas turbine based co-generation plant with a capacity of 4000kW, annual plant operation of 8000 hrs, plant load factor

(PLF) of 90% and price of gas being INR 6550/scm, the total cost of power is INR 9.04 crore per annum (including fuel, cost of capital and operation charges).

The alternative to such an arrangement would be procuring power from grid and utilizing steam from conventional fired boiler. Such an arrangement would cost the user INR 10.54 crore to provide the equivalent amount of power and heat input as in case of cogeneration plant. This cost includes the cost of power from grid and the fuel cost for boiler.

Hence co-generation plant can provide a definitive cost benefit of INR 1.5 crore over the conventional alternative. Taking into consideration the capital investment of setting up of co-gen plant i.e. INR 13.00 crore, the payback period of approximately 8.7 years.

b. *Trigeneration* (Down to Earth, 2015): The example of Jai Prakash Narayan Apex Trauma Centre (JPNATC) at All India Institute of Medical Sciences (AIIMS) has been considered for cost-benefit analysis. GIZ provided support to Bureau of Energy Efficiency (BEE) in implementing a pilot project which involved installation of trigeneration plant in JPNATC.

   The plant at JPNATC, which has an engine capacity of 350kW, supplies 40% of the total power requirement of the centre. This is expected to give an annual cost savings of INR 2 crore and reduce emission by 40,000 tonnes of CO_2. The evaluation was on the basis of the existing gas prices which was around INR 20/kg. As per current prices, the gas prices for Delhi region is INR 44.20/kg (Indraprastha Gas Limited, 2019). Hence annual cost savings would be around INR 1 crore considering current gas prices.

Hence, while implementation of cogeneration/trigeneration provides distinct cost benefits, it is contingent on the natural gas prices and the plant installation costs. It is expected that increasing penetration of such plants would help bring down the installation costs and the increased production of gases from the Raniganj fields would prevent any substantial rise of natural gas prices in future.

Hence, the state can undertake stakeholder outreach programmes and awareness programmes for promotion of cogeneration and trigeneration. Also, providing interest free/low interest loan rates can help stimulate the market for cogeneration and trigeneration in the state.

5. Development of district cooling initiatives

District cooling system (DCS) distributes thermal energy in the form of chilled water from a central source to multiple buildings through a network of underground pipes for use in space cooling. The cooling or heat rejection is usually provided from a central cooling plant, thus eliminating the need for separate systems in individual buildings. The user pays for the consumption of chilled water from the plant and does not need to have a standalone AC system in his/her premises. Its major components are centrally located chiller plants, underground distribution networks and heat exchangers.

The benefits of installing a District Cooling system are as follows:

a. Reduces energy consumption by 35% of air-cooled AC system and 20% of fresh water cooled system for the same amount of cooling

b. Reduce noise, heat and vibration arising due to standalone cooling systems. Can provide critical solution to urban heat island effect.

c. Corresponding reduction in energy consumption help reduce carbon footprint of cooling system.

d. Apart from the above it can also help save plantroom space in buildings, enhance system reliability, flexibility in building design

While the concept provides clear benefits in favour of DCS, implementing it requires the following pre-requisites:

a. Detailed site planning and interfaces: The sites for the construction of DCS plants and pipeworks are extensive and the construction will generally be carried out in phases extending over a long period. Inevitably there will be interfaces with other infrastructure, especially at the chilled water and condensing water pipeworks, and with other parties who may be affected by the DCS. The interfacing issue is instinct which will also happen in green field site. An integrated planning approach is required to minimize its implications on construction and cost.

b. Development of human capacity: The wide network of pipelines and chilling infrastructure requires manpower for operation and maintenance (O&M) works. While in the initial phases, the O&M works can be given to third party service providers, imparting training to personnel can help reduce cost and increase avenues for employment of local populace in this field.

c. Tariff structure: A market supporting tariff structure should be in place which would ensure business viability of the venture. The tariff structure should ideally be in place and mutually agreed upon by both the parties before commencing business operations. This would provide clarity in the revenue stream for the developer.

d. Variability of use: The cooling requirement in any area would be contingent on the weather conditions and will accordingly vary. Consumption of a commercial user is usually weather agnostic and demand from cooling from these consumers would be relatively stable than a household. Hence, it is recommended that a short term agreement (which can be scaled up to medium term) be in place with such anchor consumers before the plant is made operational.

6. Capacity addition in state for energy efficient and less polluting power plants

Under the BAU scenario, sub-critical thermal power generation technology is considered for all future capacity additions. This would lead to a capacity addition of nearly 17GW of power generation capacity by 2040 and an annual emission of 174 MT of CO_2, which accounts for 52% of the total emission from the energy sector of the state (West Bengal Energy Model Analysis , 2019). Also, the existing group of sub-critical power generation is considered to be inefficient due to lower performance parameters and higher auxiliary power consumption.

In order to increase efficiency and reduce emissions, future addition in power generation technology should be of super critical technology. Additionally, super critical technologies are suitable for Indian coal and has been commercialized globally. If the complete power generation capacity for the state is converted to super critical for the state, emission in 2040 in BG scenario will reduce to 163 MT of CO_2 (West Bengal Energy Model Analysis , 2019).

Alternatively, the state can also look to promote low emission technologies as given below (TERI, 2015):

a. *Fluidized Bed Combustion (FBC):* It is a method of burning coal in a bed of heated particles suspended in a gas flow and at sufficient flow rates, the bed acts as a fluid resulting in rapid mixing of the particles, encouraging complete combustion and a lower temperature than that of pulverized coal fire boiler. A particular variant of FBC i.e. Circulating Fluidized Bed Combustion (CFB) is most suitable for Indian coal grades and using low grade fuels such high-ash fuels, and lignite, brown coals. Along with the flexibility of fuels SOX and NOX emission is low. The technology also requires relatively simple manufacturing making it suitable for West Bengal.

The main disadvantages of the technology compared to pulverized coal technology is higher solid waste generation and availability of limited size commercial power plant sizes (typically only up to 300 MW). The cost of installing of FBC is similar to the cost of super-critical power plant of equivalent capacity i.e. INR 4 crore/MW

b. *Integrated gasification combined cycle (IGCC):* IGCC is a combined cycle of steam based and natural-gas-based electricity generation, using coal and natural gas as fuels respectively. It has a higher overall efficiency, low emission, suitability for carbon capture. However the technology is yet to mature and is approximately 30% higher than similar sized super critical plants i.e. INR 5.2 crore/MW, thus making it commercially unfeasible at current prices. It is expected that cost of technology will reduce as the technology mature, making it commercially feasible.

As discussed, there are limitations in implementing FBC and IGCC for large scale power plants due to existing technological and commercial limitations. The implementation of these technologies can be evaluated on a case-to-case basis, as per future trajectory of costs and project-wise requirements.

In order to develop these technologies, the state can look for co-operation and partnership opportunities with countries having mature technology options

7. Establish potential of renewables of state

The State in its Renewable Energy Policy, 2012 has provided the potential for each source of renewable energy (under Section 5: Goals) along with the cumulative target for 2017 and 2022 (Department of Power, 2012). However, there is no independent verification of the achievable potential of renewables in the State, especially solar power. A conclusive assessment of renewables potential of the state would be critical in developing a renewable policy more attuned to the actual resources available with the state.

A more in-depth study of the renewables potential of the state needs to be established. As an outcome of the study, a district wise potential assessment of the various renewable sources would be helpful for planning activities aimed at developing a particular renewable source. It is recommended that the energy model of the state be run with the verified potential figures to understand the change in trajectory of the renewable growth for the state.

8. Update Renewable energy policy

The state had released a policy on co-generation and generation of electricity from renewable energy sources in 2012[9]. Given the development of Energy Vision and Energy Action Plan is being undertaken, the policy needs to be updated to ensure alignment of the policy with the vision and action plan for the state.

The recommended broad-based changes in respective sections of the policy document is given below:

a. Vision and objective (Section 1&2): These section should reflect the overall Energy Vision and renewables related targets provided in the Action Plan. The objective should contain the targets contained in the action plan and can be verified by the energy potential established for the state in the previous step.

[9] For further information: Policy on co-generation and generation of electricity from renewable energy sources (DoP, 2012)

b. Goals: Based on the potential established by the study mentioned above and existing installed capacities for each form of renewables, a policy decision on the targets for the short, medium and long term can be taken.
c. Focus Areas and strategy: In the current condition where extraction and use of natural gas reserves of the state holds a distinct possibility of energy security for the state, co-generation can hold immense opportunity for stepping up power generation. Also there is a clear thrust from the state government on increasing penetration of solar – both rooftop and ground-mounted/floating. The section should be revised to reflect this focus of the state. This section shall provide the step-wise activities to be undertaken in the short, medium and long term to reach the targets given in the objectives.
d. RE project financing (Section 10): The provision for 'Clean Energy Fund' which is discussed in detail in subsequent sections should be included in this section. This will provide a clear communication of the type of projects and the extent of financing that can be availed through this fund.
e. Regulatory Issues (Section 11): This section should be adequately modified to incorporate the proposed regulatory changes that are under consideration for increasing penetration of renewables especially solar rooftop.

9. Provide enabling environment for increased penetration of solar rooftop

The current grid connected solar installation of the state is around 80MW with grid connected rooftop solar accounting 25% of the total installed capacity (Department of Power & NES, Government of West Bengal). Since availability of large tracts of land in the state required for installing solar parks is limited (a solar PV installation of 1MW requires 4 acre of land), promoting solar rooftop should be the recommended step to increase penetration of solar power in the state.

In order to understand the key policy/regulatory reforms required to stimulate the solar rooftop market in the state, the solar policies of relatively mature solar markets like Gujarat[10], Andhra Pradesh[11], Telangana[12], Karnataka[13] and Tamil Nadu[14] as well as market like Delhi[15] which is focused on solar rooftop were studied. The key differences in the solar policies and regulations of the states regarding solar rooftop, which can be implemented in case of West Bengal are given below:

a. Reduce the lower limit for net metering: Currently, the minimum size of rooftop solar has to be 5kWp to be eligible for net metering. As per the policies referred, the minimum capacity is 1kWp while the maximum is 1MWp.

b. Maximum limit in solar power generation capacity: In most cases, a limit is specified for the cumulative capacity of the solar systems connected to a local distribution transformer (DT) capacity. This regulation has been made with a view to ensure grid stability and the value of cumulative capacity is limited between 30%-60% of the local DT capacity.

c. Provision of Loans: Each state studied has a provision for providing loan up to certain limits for different category of consumers under 'Priority Sector Lending'. Also, the individuals under residential sector can avail loans for solar as part of home loan/home improvement loan. This will

[10] For reference: Gujarat solar policy, 2015
[11] For reference: Andhra Pradesh Solar policy 2018
[12] For reference: Telangana Solar Policy, 2015
[13] For reference: Karnataka Solar Policy 2014-21
[14] For reference: Tamil Nadu Solar Policy, 2019
[15] For reference: Delhi Solar Policy, 2016

help residents get associated tax benefits and lower interest rates, providing indirect financial incentives to beneficiaries.

d. Incentives in form of exemption from charges: The net metering provisions for the states studied provide exemption from a wide range of charges including transmission charge, wheeling charge, cross subsidy surcharge, electricity duty etc. Exemption from such charges can help reduce the financial burden on beneficiaries and help in the uptake of solar rooftop PV.

10. Development of large scale solar projects

As discussed, land availability in West Bengal is a challenge for large scale solar power project. Floating solar power plant, which utilizes the surface of water bodies can be a viable option for the state. Apart from land angle, floating solar power plants provide multiple benefits as given below:

a. The modules in floating systems operate under much cooler environment which reduces thermal losses and also the long term heat induced degradation. Additionally the dust collection issues would be minimum leading to enhanced generation and reduced cleaning frequency. It is estimated that floating PV systems generate 11-20% more energy than an equivalent land based system.

b. PV systems floating on the water surface provides an effective method to reduce evaporation losses as they would reduce substantially the sunrays from reaching the water below. It is estimated that water losses can be reduced by 70%.

c. The modules and the floats anchoring them reduce photo-synthesis process that promotes algae and other organic growth. This is particularly of interest to water utility companies as it reduces the water treatment and labor costs.

While there are clear benefits, the technology also has its share of challenges:

a. The primary challenge is costs involved in installation. A typical floating solar power plant costs nearly 50% more than ground mounted unit of similar capacity, primarily due to cost of floaters (Climate Investment Fund, 2017).

b. Module racking systems are to be designed for fixing on to pontoons / HDPE plastic floats. All metallic components have to be kept above water level with floats alone in contact with water to prevent corrosion. Since this is a relatively new technology, there are no historical evidences to understand the long term impact of water on plant components like modules, cables, floats etc.

c. The environmental float material should not inject any toxic material in the water they float.

In case of West Bengal, the state is already in the process of undertaking floating solar plants with a cumulative capacity exceeding 500MW. Considering the power requirement of the state based on projection of BG scenario, there is no immediate need of further capacity addition in the short term. The state can undertake commissioning of the existing power plants. It is expected that further maturity in technology for floating solar shall be forthcoming, which can reduce the prices.

The state can instead look for partnership with foreign countries institutions to develop operation and maintenance capacity in the state and explore scope for development of assembly units, component production in the state. The state can look towards partnership with countries exhibiting considerable experience in installation of floating solar like China, Singapore, USA etc.

11. Improve load forecasting and scheduling practices

The key impediment to integration of renewables in the grid is the inherent variability of renewable sources on prevalent climatic conditions. The unpredictable forecast of power injection in to the grid from renewable sources leads to power generation scheduling challenges from conventional power sources. In order to resolve this issue, implementation of high quality forecasting techniques need to be incorporated. The current regulation requires RE operators for commercial purposes to schedule their power production on pooling station level; however schedules are often not delivered or inaccurate and cannot be used for system operation. Also there are no centralized forecast by either SLDCs, RLDCs or the NLDC which can be used for system operation (GIZ-IGEN, 2015).

In order to overcome the barrier of forecasting for renewables, the state can look for partnership with countries and institutions with the requisite tools and forecasting models which can be implemented in case of West Bengal. For example, as part of EWeLiNE project in Germany (EnergyMatters, 2016), vastly improved wind and solar PV forecast models and optimised weather predictions have been developed to predict how much electricity Germany's installed photovoltaic systems and wind farms will produce over coming hours and days. The transmission system operators (TSO) are provided access to this system which has helped the country have a 22% share of electricity supply for renewable sources.

12. Increasing penetration of power storage infrastructure and grid stabilization techniques

While advanced forecasting techniques can help predict the supply trend from renewable sources, there needs to be alternative sources of power which can help stabilize the grid in case of variable supply from renewables. For West Bengal, nearly 94% of power generation capacity in 2015 was sub-critical thermal power plant. It is envisaged under the WB Energy model that state will develop super critical thermal power plants and gas based power generation capacity. Considering the technology being used, thermal power plants will be unable to modulate power supply to the grid in case of variability in renewable supply. The ramp up/ramp down time for conventional coal based generation plants is unsuitable to accommodate sudden changes in power supply. This requires adequate power storage and grid stabilization techniques to accommodate such changes in power supply from renewables.

The state is already installing pump storage capacities and plans are present to install a cumulative capacity of 3.3GW pump storage in the state (Department of Power & NES, Government of West Bengal). Apart from pump storage, the following can be considered for grid stabilization:

a. *Residential Energy Storage* (McKinsey report, 2019): It is an emerging area of power storage infrastructure wherein customers invest in "behind the meter" residential energy-storage systems, taking advantage of falling battery prices. While the installation have been made primarily for household supply during outages utilities gain another potential lever for balancing energy demand and supply. Residential batteries could be linked together and dispatched to deliver grid support services. Since the batteries are already in place, the marginal cost of dispatching residential energy storage resources could be quite low.

b. *Redispatch system* (Next-Kraftwerke, n.d.): It is a system being used in regions with a high proportion of renewable power production, such as California or Germany. The transmission system operators in the system uses the schedule provided by power plants to undertake a load flow or grid load calculation to prepare an overview of the grid's expected feed-in and consumption for the next day. They analyze the dispatch to determine if any parts of the electricity grid might be negatively impacted, and to what degree. To keep the number of the next day's short-term, grid-stabilizing interventions at a minimum, the transmission system operator can

instruct plant operators to postpone schedule power production based on the next day's load flow calculation to prevent grid bottlenecks.

While it is envisaged that the planned pump storage capacity when completed will be sufficient to account for any variations in renewable energy, the state can look to develop the two systems to provide additional flexibility to grid for stabilization.

13. Modernization of power distribution system within the state

As with the national and global level cases, the modernization of the electricity distribution grid is a critical area that can help the state adapt to the changing landscape of energy scenario in the state. The key drivers for a smart, modern distribution grid are as follows:

a. The share of renewables is expected to grow in the state and as per the BG scenario, the state is expected to have a renewables capacity of 6.1GW by 2040 (combining solar and large hydro), out of total installed capacity of 34.3GW. A power system of this size growing at annual growth rate of about 4% with an increased share of renewable energy requires smarter systems to manage it efficiently and ensure its stability and reliability. Such systems can help in implementing multiple options for peak load management from direct load control to consumer pricing incentives.

b. The share of EV in the passenger transport is set to increase expected to grow by 50% by 2040 from nearly zero in 2015. This upsurge in EV penetration will require electrical distribution infrastructure upgrades and smarter systems are required which will control/limit simultaneous charging of hundreds of EVs from the same feeder

c. The state had T&D at 25% (Ministry of Power GoI, 2016) and AT&C loss at 29% (Ministry of Power GoI, 2017) as on 2014-15. While efforts are underway to reduce these losses, a modern distribution grid infrastructure will help monitor, measure and even control power flows in real time that can help identify losses and thereby appropriate technical and managerial actions can be taken to arrest the losses.

d. A modern distribution grid can help in improving financial health of utilities by better asset management, reduction in power purchase cost through increased grid visibility and better control of peak demand.

e. The user can also benefit from a smart grid through improved reliability and quality of supply, providing option of reducing power costs through consumption optimization

Modernization of the distribution grid entails installation of a smart grid - an electrical grid with automation, communication and IT systems that can monitor power flows from points of generation to points of consumption (even down to the appliances level) and control the power flow or curtail the load to match generation in real time or near real time.

The traditional electric grid need to build additional layers of automation, communication and IT systems to transform to a smarter grid which are given as follows (India Smart Grid Forum, 2013):

a. Supervisory Control and Data Acquisition Systems (SCADA) with Energy Management Systems (EMS) and Distribution Management Systems (DMS)
b. Enterprise IT network covering all substations and field offices with reliable communication systems
c. Enterprise Resource Planning (ERP)/Asset Management Systems

d. Geographic Information Systems (GIS) – mapping of electrical network assets and consumers on geospatial maps
e. Modernization of the substations with modern switchgear and numerical relays
f. Advanced Metering Infrastructure (AMI) with two way communication and Meter Data Management Systems (MDMS)
g. Electronic Billing Systems and Customer Care Systems
h. Distribution Automation (DA) and Substation Automation Systems Outage Management Systems (OMS)
i. Mobile Crew Management Systems
j. Wide Area Measurement (WAM) and Control Systems
k. Forecasting, Dispatch and Settlement Tools
l. Enterprise Application Integration Analytics (converting data into business intelligence)

The installation of a smart grid is a prerequisite for introducing dynamic pricing – a concept of reducing peak load by incentivizing off load consumption through lower power charges. Smart grid network assists in dynamic pricing experiments which intend to gather information about how consumers respond to electricity prices and help identify the most promising mechanisms suitable for wide-scale deployment.

In case of West Bengal, the building block to implementation of smart grid is infrastructure and financial assessment followed by implementation on pilot basis in the short term. Based on the learnings from pilot initiatives, the roll out can be expanded across the state over medium to long term.

The recommended actions for smart grid roll-out in the state from short to long term is summarized below:

Short Term	Medium Term	Long Term
Identify SG Pilots and undertake full SG roll out in pilot project cities	SG roll out in all urban areas taking learnings from pilot projects	SG rollout across state
Assess and undertake infrastructure for AMI roll out on pilot basis	State wide AMI roll out for customers with 3-phase connections	State wide AMI roll out for all customers
Assess utility-wide deployment of Wide Area Monitoring Systems (WAMS)	Deployment of WAMS at all substations and grid connected generation units	Continued deployment of WAMS at all substations and grid connected generation units
Undertake Cost-Benefit Analysis of pilots projects and assessment of direct and indirect benefits to consumers and other stakeholders	Standards Development for Smart Infrastructure (SEZ, Buildings, Roads/Bridges, Parking lots, Malls)	Continuous Research & Development; Training & Capacity Building
Initiation of Customer Outreach and Engagement Programs	Development of business models to create alternate revenue streams by leveraging the smart grid infrastructure to offer other services (security solutions, water metering, traffic solutions etc) to municipalities, state governments and other	

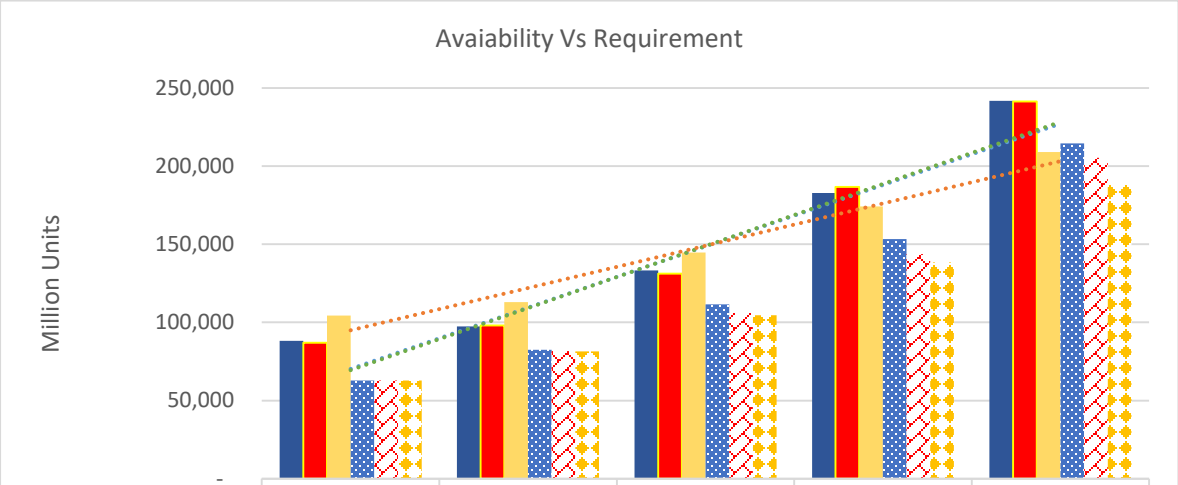
Short Term	Medium Term	Long Term
	agencies; integration of meter data with other databases etc.	
Research & Development, Training & Capacity Building - 10% Utility technical personnel to be trained in smart grid technologies	Continued customer outreach and engagement programs	

14. Installation of infrastructure to prevent losses due to theft and damages due to natural disasters

The state DISCOM is already undertaking projects for technical upgradation of power distribution infrastructure to prevent losses as discussed in the section of existing initiatives of state. It is recommended that these activities are continued to help achieve the target reduction of T&D loss for the state.

G. Managing power supply security

Power supply security is an important factor for the policy makers and the Government to act upon. In this study we have estimated the annual total power demand and corresponding power availability to demonstrate that in none of the scenarios the power supply security (margin of availability) is compromised. It is observed that currently there are plenty of excess capacities in the system which is non-performing given the demand in the system. Model optimizes those capacities over the period of time and adjusted the supply in such a manner so that future energy demand is securely met (including peak demand) and on the other side system does not have unnecessary capacity as well. Figure 25 clearly shows that in none of the scenarios requirement of power is higher than the availability. Power requirements are including of T&D losses and the availability is including of schedule maintenance time and corresponding shutdown.



	2020	2025	2030	2035	2040
Availability_BAU	88,222	97,471	133,240	182,915	241,726
Availability_BGS	87,092	97,987	131,297	186,825	241,339
Availability_ESS	104,328	113,090	144,656	174,334	208,998
Requirement_BAU	62,779	82,387	111,503	153,427	214,503
Requirement_BGS	62,818	81,690	105,970	143,676	205,443
Requirement_ESS	62,818	81,416	104,587	138,486	188,246

Figure 25: Comparison of power availability and requirement

H. Managing peak demand

Peak demand is another important issue for the power supply in order to maintain reliability. System needs to have sufficient supply option ready to meet the scheduled peaks during days and seasons. The study estimates that the peak demand of the State has grown between 6 to 8% CAGR between 2008 and 2015 using the data published by POSOCO in 2016 (Electricity Demand Pattern Analysis-Vol-II). Assuming the same growth rate of peak demand it is further estimated that by 2040 the State will have around 12,000 MW of Daily Average Peak demand with 16000 High Peak Demand and 10,000 MW low peak demand. Both the proposed scenarios are comfortably placed in terms of

managing peak demand with sufficient amount of capacity in place. Figure 26 shows the daily peaks recorded in the State between 2008 and 2015.

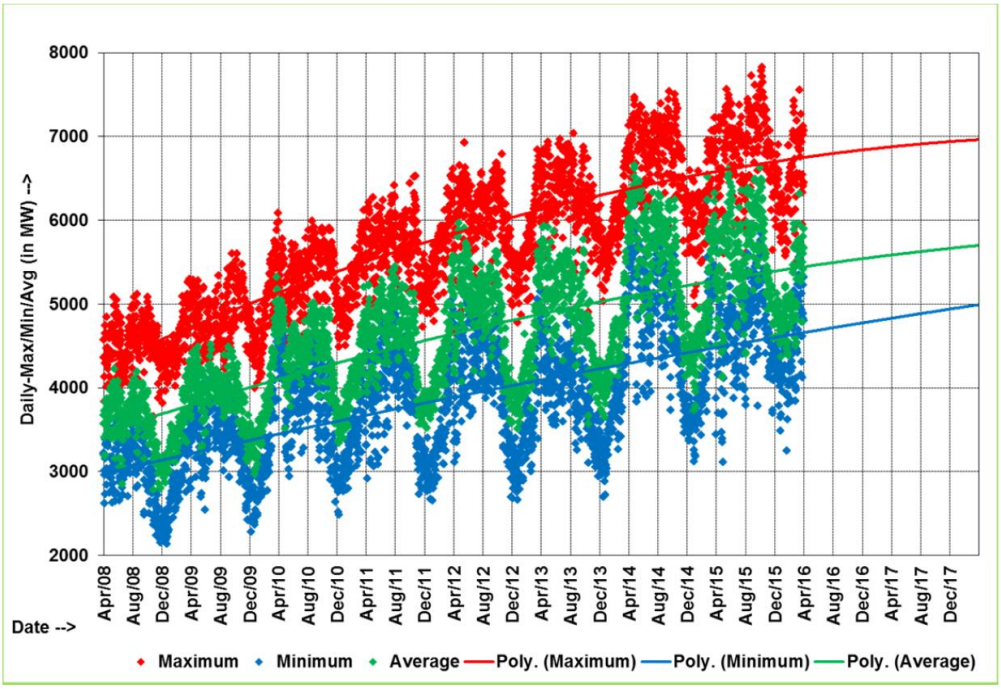


Figure 26: Daily peak demands recorded dugong 2008-2015

Source: POSOCO, 2016

To manage the peak loads the scenarios consider all the flexibility and reliability factors of the infirm power (coming from renewable sources) and all schedule and unscheduled outages that might occur in the system and designed the capacity addition which comes around 2.3 times the Daily Average Peak Demand in the system. Based on this assumption it is estimated that by 2040 with a daily peak demand raging between 10 to 16 GW, around 36 GW of installed capacity is required in the system. Figure below shows the status of peak demand and available capacity under different scenarios in the State until 2040 and this further corroborates the robustness of the supply system indeed.

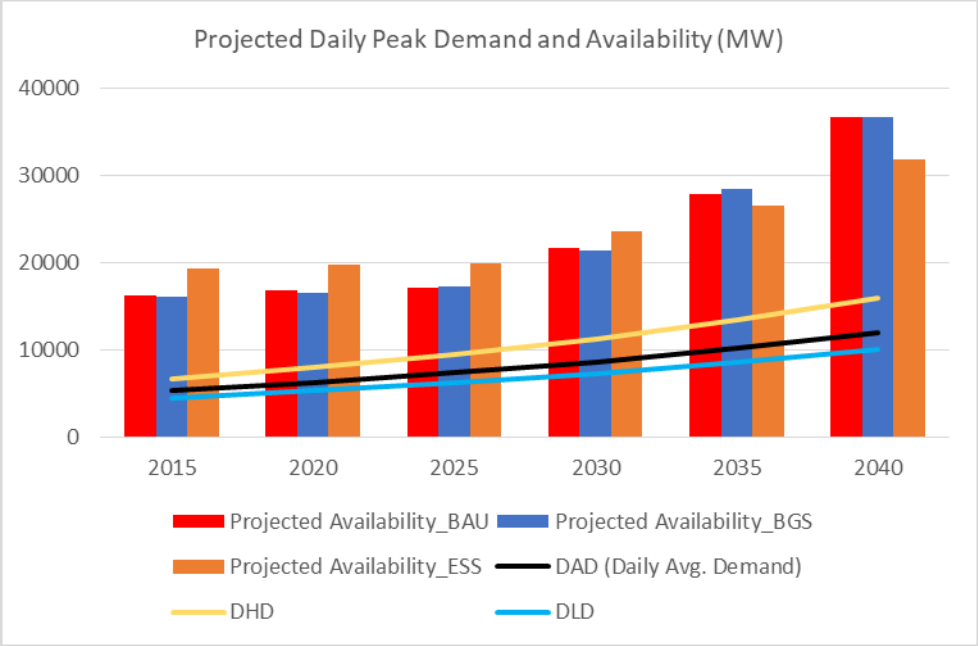


Figure 27: Peak load vs available capacity under different scenarios

I. Potential tariff implication of different scenarios

In the context of policy making activities and its implementation, cost of generation and corresponding implication on tariff is very crucial. The implementability of the plan often depends on its cost implication. In this study levelized cost of power generation has been estimated with some basic assumptions as follows (Table 3).

Table 3: Basic assumptions for LCOE calculation

Coal Base Generation	CBM Gas Base Generation
Plant Heat Rate = 2800 Kcal/Kwh	Plant Heat Rate = 2100 Kcal/Kwh
Plant Load Factor = 60%	Plant Load Factor = 80%
Operating hours = 8000 /year	Operating hours = 8000 /year
Capital cost = INR 6 Cr./ MW	Capital cost = INR 3.7 Cr./MW
Coal Price = INR 4000/MT	Gas Price = INR 600/MMBtu
Fuel Oil Price = INR 40,000/KL	Fuel Oil Price = INR 40,000/KL
Technical Life Time = 30 Years	Technical Life Time = 30 Years
Discount Factor = 5%	Discount Factor = 5%

Based on the above mentioned assumption the LCOE costs for both the two scenarios has been estimated which indicates that the over the life span the gas base tariff could be 10% more expensive than the coal base generation costs in the year 2015-16. Figure below shows the LCOE cost

differentials for two fuel types. This further indicates that given the other additional benefits of gas, it is prudent to explore the gas option in the State. Figure 27 below shows the comparison of levelized costs of various technologies of power generation in the State

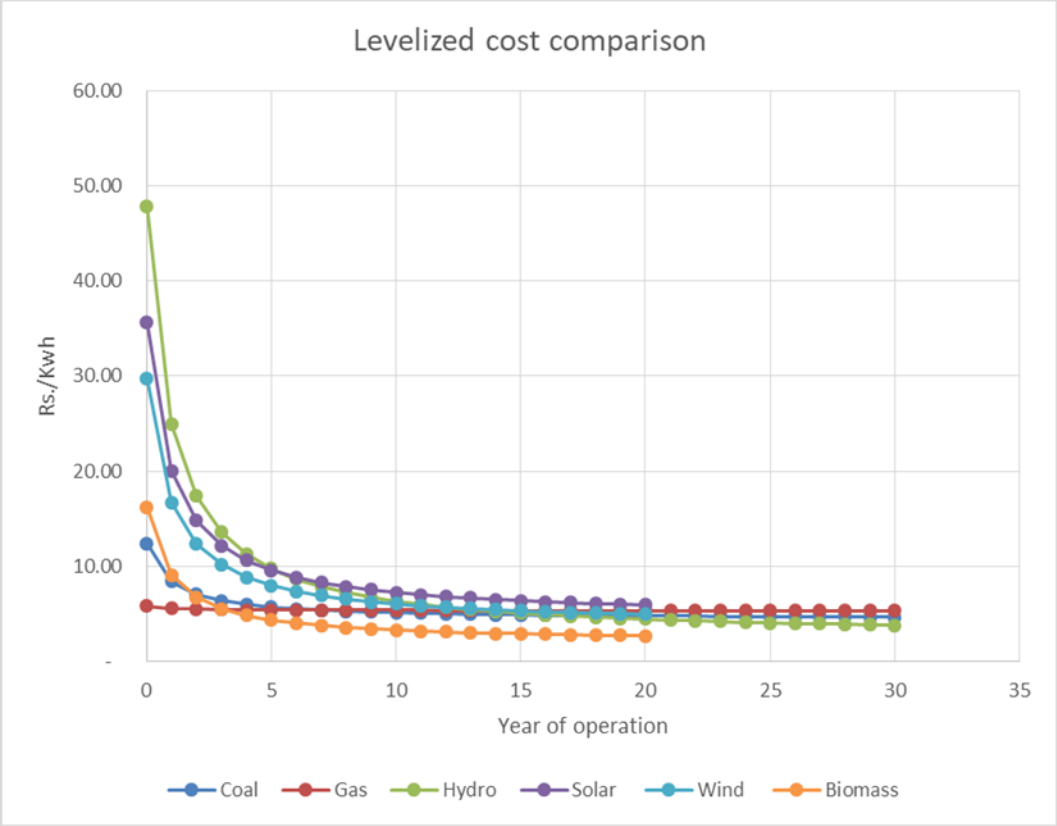


Figure 28: Comparison of LCOEs of coal and gas based generation

J. Investment requirement

The total investment required for implementing the activities mentioned in the Action Plan is provided in this section. The investment involves both capital investment in installing new infrastructure along with the operational cost for these infrastructure. Investment has been calculated based on current prices and empirical calculations for infrastructure development in each supply source. The table provides the total investment required in each of the 3 time frames i.e. short term (2020-25), medium term (2025-30) and long term (2030-40):

Table 4: Cumulative Investment requirement for energy supply sector (INR crore)

No.	Energy Supply Source	Short Term (2020-25)	Mid Term (2025-30)	Long Term (2030-40)
1.	Coal	6860	9100	19950
2.	Natural Gas*	3990	6300	11900
3.	Power – Conventional	-	18987	66378
4.	Power – Non-Conventional	4316	3662	8806
5.	Distribution	1050	4340	14980
Total		**16216**	**42389**	**122014**

Note:
Reference cost structure which has been used to calculate the investment:

1. **Coal:** Investment needed in surface coal mining in India are in the range of INR 1500-2100 (Coalspot, 2012)
2. **Natural Gas:** $5-6/MMBTU for coal bed methane and Shale gas
3. **Power – Conventional:** Cost of installing 1GW super-critical generation capacity is approximately INR 4000 crore. (RGPV, 2017)
4. **Power – RE:** Cost of installing grid-connected ground mounted Solar PV at INR 560 Lakh /MW without tracking at 2018.
5. **Power distribution (operational and capital costs for network expansion) :** INR 37 crore/ GW year (IESS Ver 2.2, 2016)
   *****Natural gas related investment is only for extraction and transportation of the gas. Costs for exploration and drilling are not included. An estimated cost for the same (especially for the Ranigunj belt) could be around INR 35,000~ 40,000 Cr.

7. Action Plan for Energy Demand Sectors

The Action Plan to reach the energy targets under the BGS for the five demand sectors have been provided under this sector. In terms of share of energy consumption transport and industry are the front runner in baseline situation. Transport sector is expected to grow from 26% to 44% by 2040 while the industry remain almost same at 30%. However, the share of residential final energy consumption will decrease drastically to only 20% by 2040 from 40% in 2015 mainly due to efficiency improvement in consumption. Shifting from biomass to LPG and electricity will significantly impact the share of final energy in this sector. Moreover, efficiency and energy conservation in lighting and cooling load will also impact to control of share. Nevertheless, there will be increase in consumption of final energy by 3.5% per annum overall in the State.

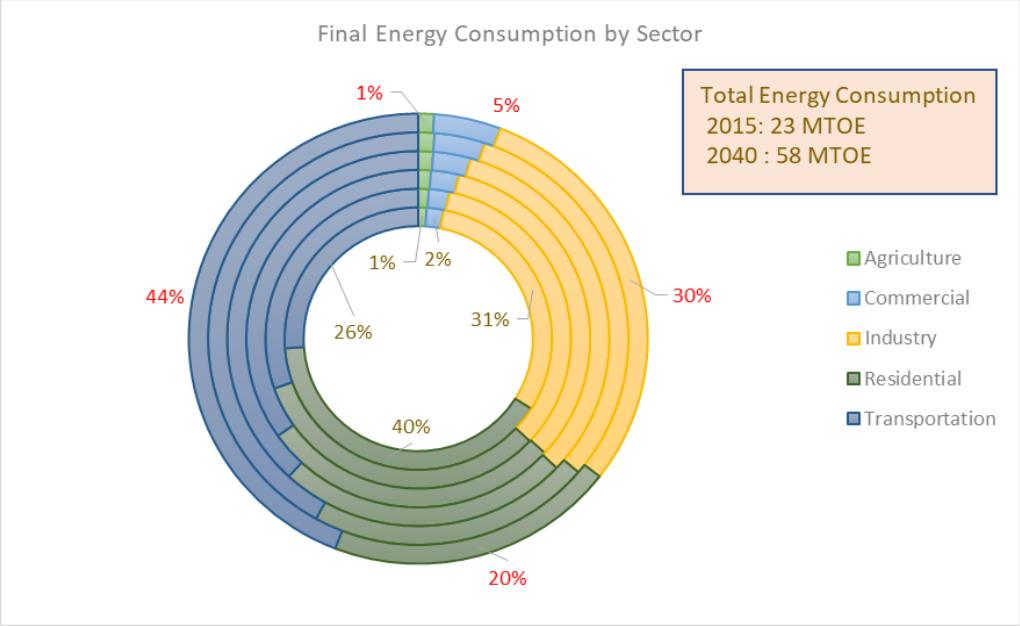


Figure 29: Final energy consumption share by sector (2015-2040)

7.1 Transport Sector

A. Brief Description of Sector

The transport sector of West Bengal comprises the vehicles used for transport of passenger and freight through land, sea and air. The use of public transport is considerably prevalent in West Bengal, since 85% residents of Kolkata use public buses for their commute and a similar scenario is expected in other parts of the state as well (Representative of Transport Dept., 2019). Kolkata Metro Rail, having an annual passenger base of 21 crore passengers (2017-18), is also a significant mode of public transport in Kolkata (Indian Railways, 2018). However, the state has witnessed an increase in passenger vehicles by CAGR of 12.86%, between 2009 and 2017. (Transport Department GoWB, 2019) It is expected that the planned expansion and upgradation of Metro lines across Kolkata, would help retain the existing share of public transport in the city (Representative of Transport Dept., 2019). There is a strong focus of Central and State Government in improving inland water transport along NW-1 – Jal Marg Vikas project (JMVP) is being undertaken at an estimated cost of INR 5,369 crore to enable commercial navigation of vessels with capacity of 1,000 to 2,000 tonne (Financial Express,

2017). Although it is expected that freight movement through inland waterways would increase, in order to counter siltation maintenance dredging need to be carried out.

The modal share of road, rail and air transport for the state for passenger transport in 2014-15 is given in the graph below (West Bengal Energy Model Analysis, 2019). In case of road transport, the fuel being used in the sector is primarily diesel and petrol with sparing consumption of electricity. Similarly for rail, the fuel source is either diesel or electricity. As for air transport, it is aviation turbine fuel (ATF). The total number of vehicles in West Bengal has witnessed 13.7% CAGR growth between 2010 and 2017. 87% of the total registered vehicles of West Bengal run on petrol – majority of these vehicles being 2 wheelers, with the remaining running on diesel and penetration of electric vehicles being minimal. The share of petrol and diesel vehicle is given below (Transport Department, 2018).

Based on a study conducted by Society of Manufacturers of Electric Vehicles (SMEV), West Bengal stands second in the sale of e-vehicles (2 wheelers and 4 wheelers) for 2016-17 (News18 report, 2017). Recently, West Bengal has figured 6th from among 30 states in penetration of hybrid and electric passenger vehicles as part of the study on State Energy Efficiency Preparedness Index conducted by the BEE and NITI Aayog (State EE Preparedness Index dashboard, 2018). As of 2018, 0.148% of the total passenger vehicles registered vehicles in the state are hybrid or EVs. Demand for passenger transportation is measured in terms of billion passenger kilometre (bpkm)[16] per year, while freight transport demand is measured in billion tonne kilometre (btkm)[17] per year. The share of various types of passenger and freight transport demand for 2015 is provided in the figure below (West Bengal Energy Model Analysis , 2019):

[16] Billion passenger kilometer (bpkm): Unit to measure movement of passengers by a mode of transport. Product of total passengers carried (measured in no. of passengers) & total distance covered (km)
[17] Billion tonne kilometer (btkm): Unit to measure movement of freight by a mode of transport. It is a product of total weight of freight carried (measured in tonnes) and total distance covered (measured in km)

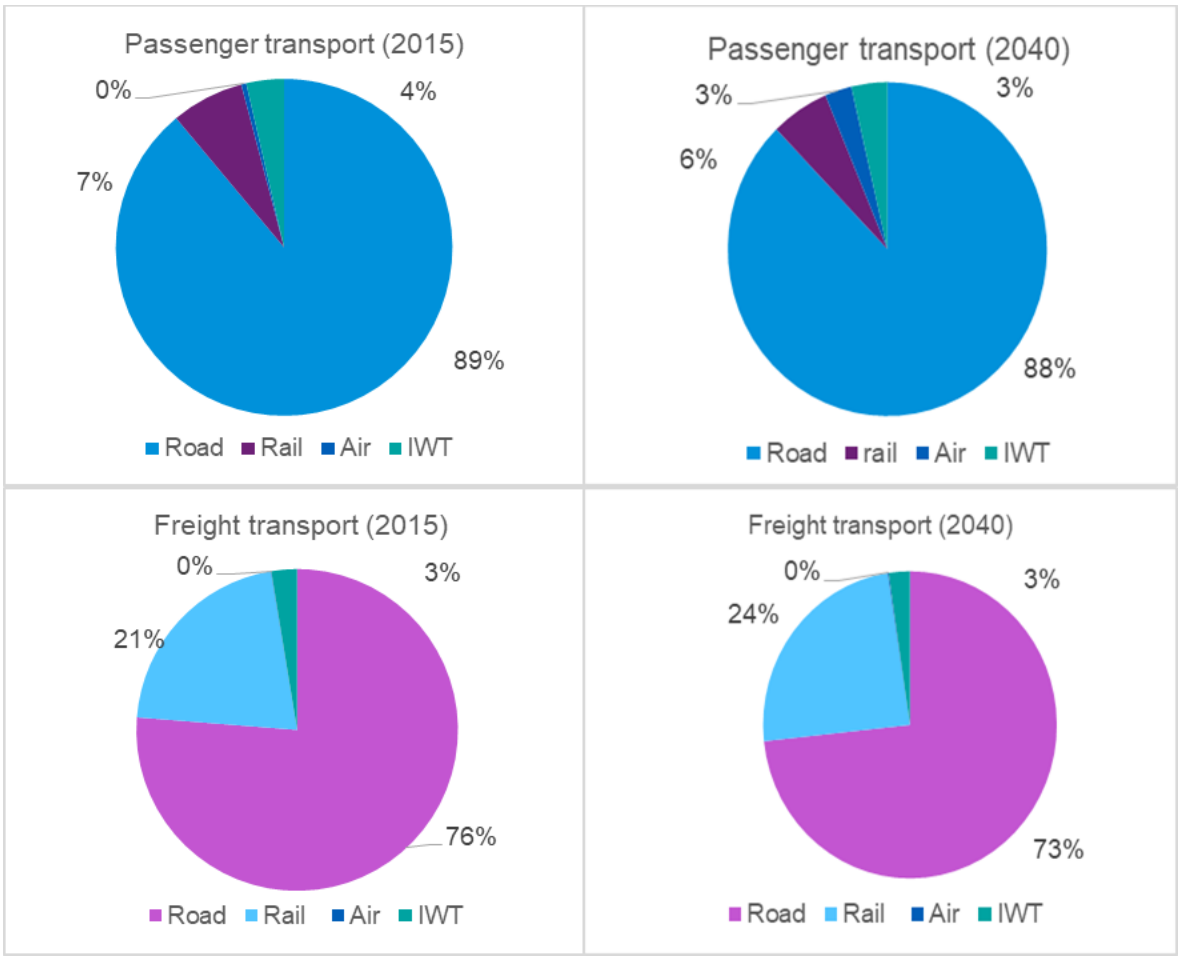


Figure 30: Projected transport demand by category

B. Energy Consumption of Sector

Energy consumption for passenger road and freight road transport accounts for 46% and 37% of the total sectoral energy consumption. Although total consumption of energy by air transport is minimal, both passenger air and freight air witnesses the highest growth at 12% and 15% respectively. The share of passenger transport in total transport energy demand increases from 33% in 2015 to 50% in 2040.

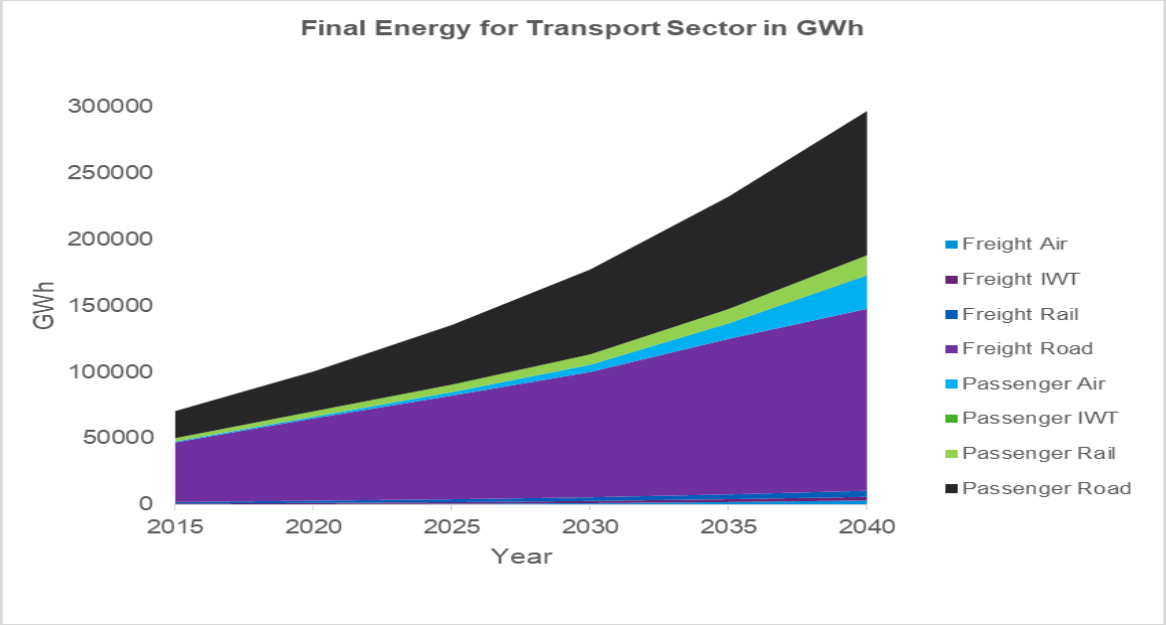


Figure 31: Final energy consumption by mode of transport

Oil (diesel and petrol) remains the dominant source of energy for passenger transport sector accounting for 83.8% of the total energy demand for transport sector. Energy demand from electricity in passenger transport segment increases by 10.4% CAGR between 2020 and 2040. In case of freight transport, the entire consumption is from diesel.

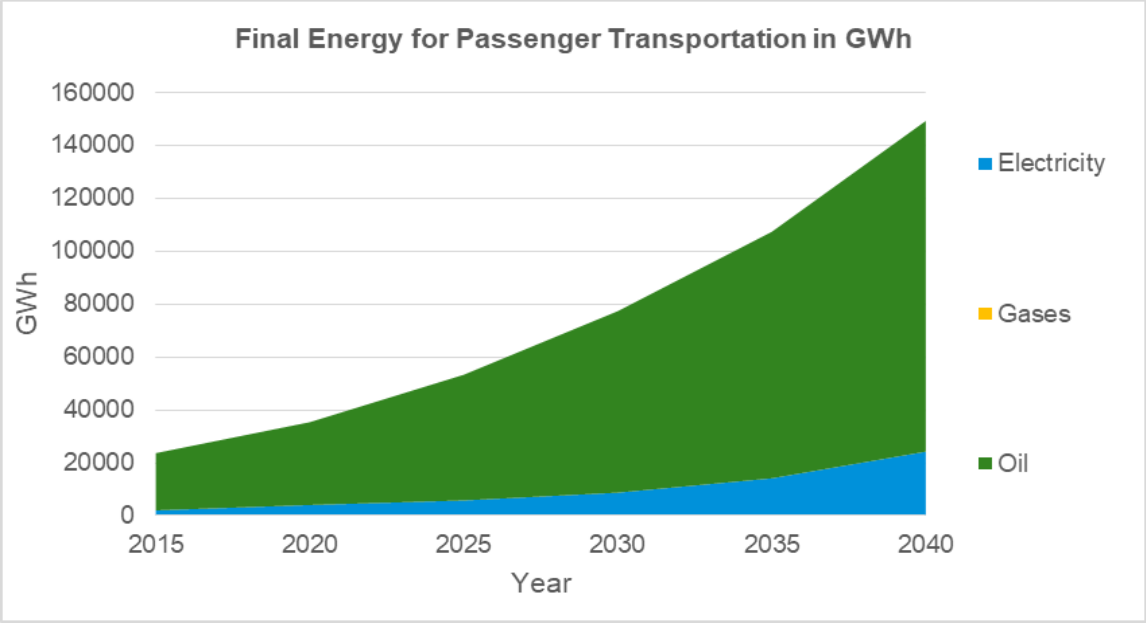


Figure 32: Energy demand by fuel type in passenger transport

While in terms of volume, majority of the oil is being consumed in road for both freight and passenger transport, air transport witnesses the maximum growth for both passenger and freight transport, followed by IWT.

C. Existing initiatives in the State

The state has undertaken multiple initiatives in the energy sphere for transport sector as given below:

1. EV charging infrastructure

New Town Kolkata Development Authority (NKDA), under the initiative by HIDCO, has set up 10 charging docks in all three action areas of the township (Clean Future, 2018). The charging stations have two types of universal charging points to enable any e-vehicle to get charged. Also, Indian Oil's COCO (Company Operated Company Owned) smart outlet at Action Area 3 also has electric vehicle charging units. There are also three heavy duty charging stations located at the bus terminal near Pride Hotel, Action Area 3 bus-stand near Sukhobristi and Eco Urban Village in Action Area 2, for running the electric buses.

2. Introduction of electric vehicles in public transport

Three electric buses have been introduced in New Town area of Kolkata (NKDA, 2018), which has reported more than 20000 passengers in the first 1.5 months of its operation. (Milleniumpost report, 2018). The buses are also able to regenerate 36% of the power from braking and use 0.8 electricity unit/km. (NKDA, 2018). Also 80 electric buses to be introduced in Kolkata Metropolitan region along 10 routes, utilizing the financial benefits provided under the FAME India (Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles) scheme of Department of Heavy Industries, Government of India. (Transport Dept GoWB 2018, 2018). 17 charging stations have been built along the routes of these buses which will be operated and maintained by the Transport Department, Government of West Bengal (Transport Department, 2019)

3. Promotion of e-rickshaw

The State Government, under the Swami Vivekananda Swanirbhar Karmasansthan Prakalpa (SVSKP) scheme has taken up a project to distribute e-rickshaws to unemployed youths in rural areas. (Uniindia report, 2018). The amount of assistance would be INR 37500 per person and the plan is to launch about 1 lakh e-rickshaws across the state, resulting in net investment of INR 375 crore.

4. Other initiatives

Going ahead in future, the state has a strong vision of increasing penetration of electric vehicles and promoting ride sharing as well. While announcement of the FAME scheme by Government of India has provided financial stimulus to uptake of electric vehicles, state level efforts shall also help reduce carbon footprint of transport sector as well as reduce dependency on imported fossil fuels. In order to streamline implementation EV charging infrastructure, the Department of Power, Government of India has published guidelines and standards for charging infrastructure for EVs in December 2018[18]. In February 2019, the Ministry of Housing and Urban Affairs (MoHUA), Government of India has made amendments in Model Building Bye-Laws (MBBL) 2016[19] and Urban Regional Development Plans Formulation and Implementation (URDPFI) Guidelines 2014[20] to make provisions for establishing Public Charging Stations (PCS) for EV charging.

[18] For further study: Charging Infrastructure for EVs - Guidelines and standards
[19] For further study: Amendments in MBBL-2016 for Electric Vehicle Charging Infrastructure
[20] For further study: Amendments in URDPFI-2014 for Electric Vehicle Charging Infrastructure

Also, development of IWT systems within the state is being taken up in tandem with the Central Government efforts. Use of IWT provides a cost effective and an environment friendly alternative to road transport, especially for freight movement in the state.

D. Comparative analysis of alternative pathways for transport sector

In the context of alternative pathway of development of transport sector in the State, the promotion of electric mobility and inland water transportation are focused as per existing interest of the department as well as underlying potential. As described before that the State is having two national water ways in the region and also bestowed with existing circular canals linked to river Hoogly, the basic hydrological requirement is fulfilled for promotion of IWT at passenger and freight sectors. Though State is already pursing the two mode of transportation, but its promotion and upliftment is important and desirable indeed. In the alternative scenarios, it is estimated that under the BGS scenario final energy consumption by the transport sector reduces by 3% by 2040 compared to the BAU scenario.

However, under ESS scenario energy use by the transport sector increases by over 20% in 2040 due to growth in gas based transportation. The scenario analysis further indicates that cleaning the transport sector with electricity and gas has mixed impact in terms of energy consumption. Energy content of liquid hydrocarbon is higher than gaseous hydrocarbon and electricity as well, and therefore, for same amount of transport demand sector needs higher volume of energy. Nevertheless, change in transport mode can also bring additional efficiency which can trade with additional energy demand for fuel shift. Thus the fuel shift and model shift both are important for alternative scenarios of the transport sector in the State. Based on optimization model the study finally brought out the balanced action plans for the sector which can take care of these issues. Figure below shows the comparison of total energy consumption by ESS and BGS scenario compared to the baseline and the right block shows the composition of modal share for BGS scenario consuming corresponding energy.

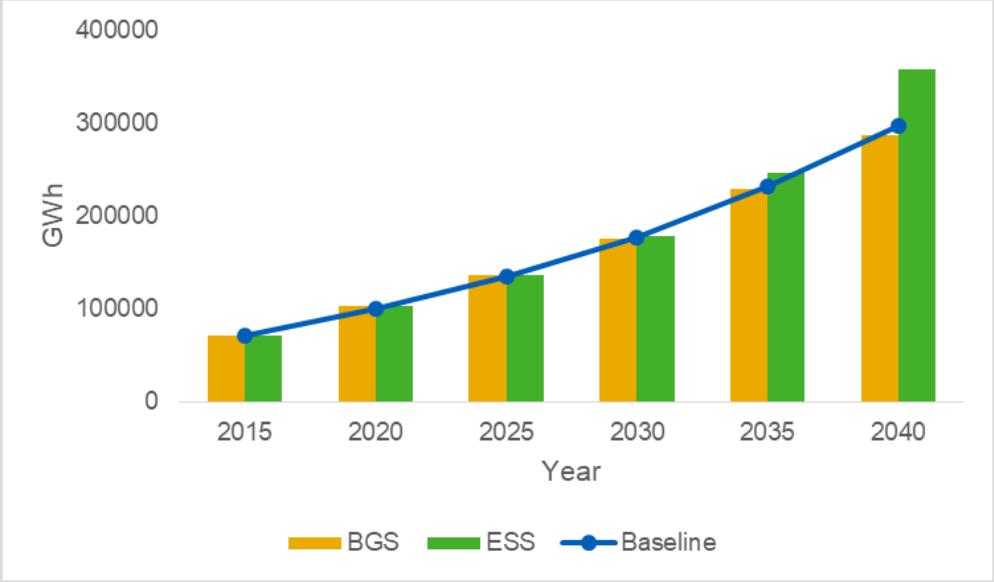


Figure 33: Comparison of energy consumption under various scenarios

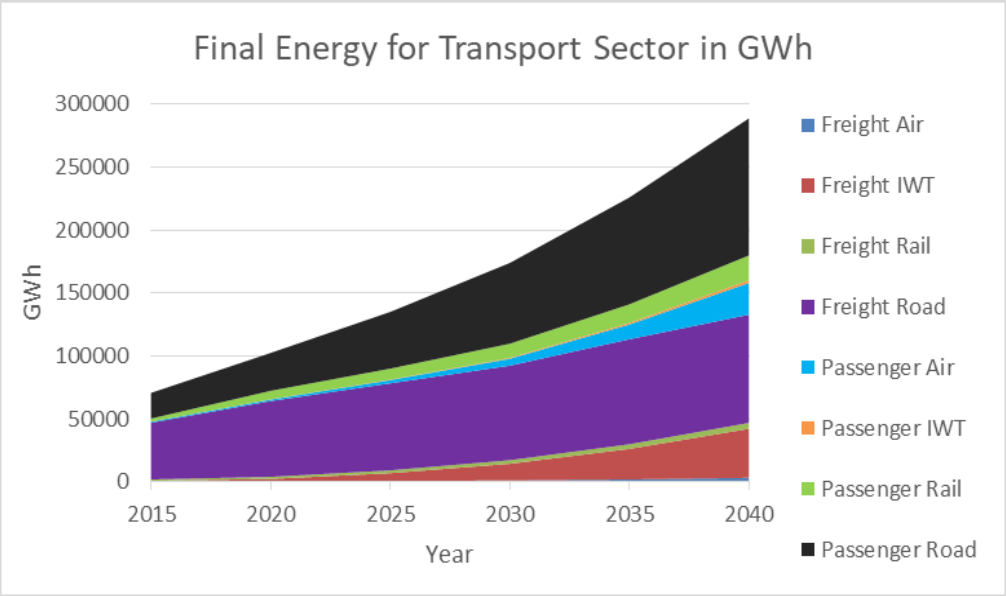


Figure 34: Final energy consumption for transport sector in BGS

Under the BGS scenario it is observed that the growth of air and IWT mode is expected to be much higher than other transport mode considering their reliability, fuel saving and time as compared to rail and road. Passenger air mode is expected to grow at 15% from 736 GWh in 2015 to 25150 GWh by 2040. IWT for Passenger transport is expected to grow at 14% from 91 GWh in 2015 to 2164 GWh by 2040 majorly taking the share from large vehicles in road transport. This is expected to happen through enhancement of freight movement in the Water Way-1 from Haldia to Varanasi where already freight movement stated. As a result in freight transport, IWT is expected to grow at 18% from 628 GWh in 2015 to 39055 GWh by 2040 since it is a most economical mode for freight movement as compared to heavy vehicles on road. Similarly, air for freight is expected to grow at 12% from 205 GWh in 2015 to 3159 GWh by 2040.

Interestingly, the total energy demand by the transport sector remains almost same except the ESS scenario where due to cheap gas supply in the market, gas based passenger transportation increases rapidly. It is also observed that under both the alternative scenarios the energy demand for the freight transportation reduces below the baseline case which indicates improvement in efficiency of transportation and fuel shift. Under all 3 scenarios, freight transport accounts for more than 45% of the total energy consumed in the sector and hence, reduction of energy consumption by freight will have a positive impact on the economy. Firstly, cost of transportation of goods will be lower which will affect the WPI and CPI and subsequently will help to reduce the market inflation by controlling price escalation. Transportation cost is one of the important factors in the pricing of goods and services. Secondly, this will also help to reduce the emissions from this sector of transport. Road freight transport is the single largest emitter in the sector and thus reduction in fuel consumption by this sector will help to reduce emissions from the sector overall. Figure below shows the comparison of energy consumption by different mode of transport over the period of time:

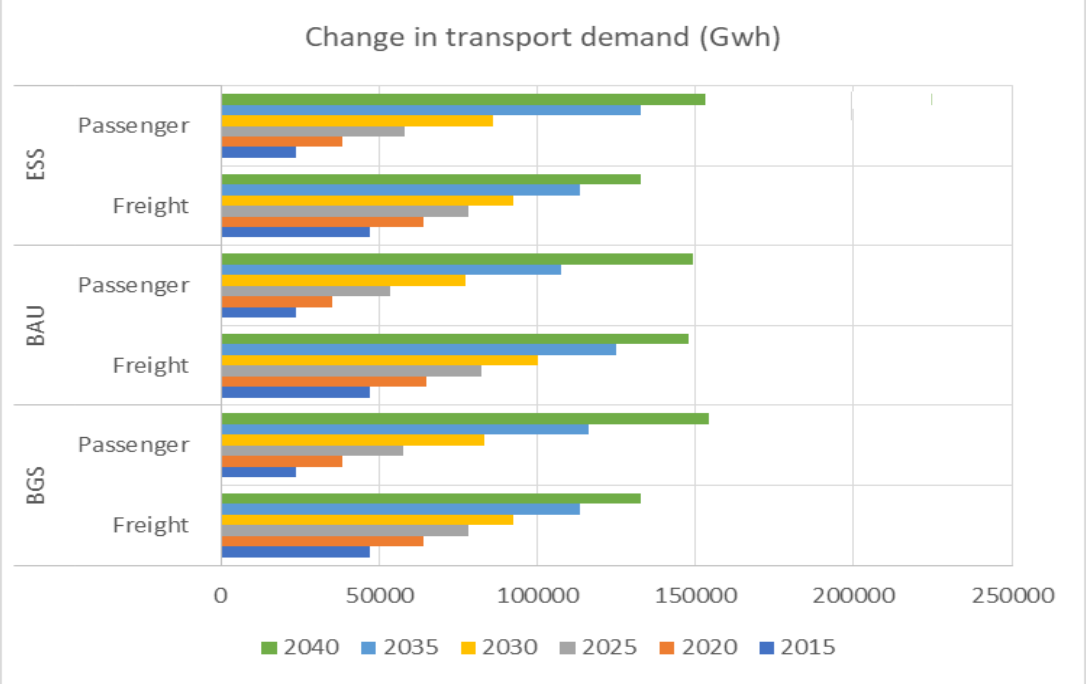


Figure 35: Comparison of energy consumption of passenger and freight transport

E. Sectoral Vision

In the baseline scenario, transport sector is the 2nd most energy intensive sector of West Bengal and it is set to be the most energy intensive sector by 2040, accounting for 44% of the total final energy consumption. The primary fuel source for the sector currently is petroleum and petroleum products, a majority of which is imported. This exposes the state (as well as India) to fluctuations in international fuel price subsequent impact on market price of goods and services. Dependence on imported liquid hydrocarbon is thus jeopardizing the energy security of the State and also making its fiscal health weak. On the other hand State is endowed with water transportation potential and having already existing basic infrastructure. Thus inland water transportation (IWT) can be viewed as a viable means of transport for the state considering the existing waterways and canals. Keeping three basic visions and goals in mind the transport sector's overall vision is set as follows:

Vision:

- State shall undertake de-carbonization of the state transport sector
- Increasing energy efficiency of transport sector

F. Action Plans for the Transport Sector

i) Passenger Transport

Objective: The State shall increase the penetration of electric vehicles to 50% by 2040.

Activity:

A.1: State shall provide adequate and effective financial incentives to motivate consumers to buy EVs.

A.2: State shall create an enabling environment to minimize cost of EV battery as well as undertake effective lifecycle management of the batteries.

A.3: State shall create adequate charging infrastructure in line with the EV growth in the state.

A.4: State shall undertake programmes for generating awareness on the benefits of EV, thereby increasing its uptake.

A.5: State shall facilitate development of adequate technical skills for maintenance of EVs as well as its charging infrastructure.

Objective: The State shall increase the modal share of IWT to 20% by 2040.

Activity:

B.1: State shall create adequate port and jetty infrastructure along with the requisite hinterland development for last mile connectivity.

B.2: State shall create adequate fleet of vessels to enable passenger transport.

Objective: The State shall increase the share of public transportation by 2040.

Activity:

C.1: State shall fast track expansion of metro rail system and explore alternate public transportation systems like BRT, trolley bus etc.

C.2: State shall promote public-private partnerships to develop public transportation methods

ii) Freight Transport

Objective: The State shall increase the modal share of IWT to 20% by 2040.

Activity:

E.1: State shall create adequate landside infrastructure for handling freight at the jetty

E.2: State shall undertake market development activities to generate awareness in commercial transportation space

E.3: State shall provide incentives to motivate modal shift from road/railways by commercial users.

Table below shows the summary of all activities and their corresponding sub-activities which are to be implemented over the period of time until 2040.

Table 5: Summary of action plans for transport sector

No.	Sector	Activity	Sub Activity	Time period	Type of Intervention	Responsible stakeholder
1.	Passenger Transport	Regulatory support	Development of EV policy	Short	Regulatory/Policy	Transport Dept.
2.		Increase of penetration of electric vehicles	Provide incentives to increase uptake of EV by retail consumers	Short to Long	Financial	Transport Dept.
3.			Introduction of electric trolley buses to utilize existing tram infrastructure	Short to Medium	Technical	Transport Dept.
4.			Increase private sector participation in increased penetration of EV in passenger transport	Short to Long	Market Development	Transport Dept.
5.			Engage with foreign organizations and specialized institutions for technical collaboration and partnerships	Medium to Long	Market Development	WBIDC
6.			Providing adequate charging infrastructure to support growth of EV	Short to Medium	Technical	DoP, UD&MA
7.			Capacity development in operation and maintenance of EV battery and charging infrastructure	Short to Medium	Capacity building	DoP, Transport Dept.
8.		Effective traffic management	Undertake modernization of traffic management system in the urban areas of the state	Medium to Long	Technical	Transport Dept
9.		Increase of modal share of IWT	Introduction of electric ferry services in the state	Short to Medium	Technical	Transport Dept.
10.	Freight Transport	Increase modal share of IWT to 20% by 2040	Provide infrastructure support required for operating RO-RO services	Short to Medium	Technical	Transport Dept, WBPWD
11.			Build awareness among commercial transportation companies to increase presence in IWT	Short to Medium	Awareness	Transport Dept.

G. Description of sub-activity

1. Electric Vehicle policy

While adoption of EV provides benefit in terms of low operational cost and low emission, the key roadblocks in mainstreaming EV penetration, specific to West Bengal are as follows:

a. Initiatives to increase penetration are mostly focussed on 3 or 4 wheeler segment. Considering the auto market of West Bengal (and India in general), sales of 2 wheelers is considerably higher than 4 wheelers. Also, considering the consumer behaviour of rural population regarding use of 2 wheelers, the barriers to entry for 2 wheelers would be low. Hence targeting 2 wheeler segment for increased penetration of EV would be a viable option.
b. Lack of availability of charging infrastructure: Currently there is limited infrastructure for charging and no future plan on the availability of charging infrastructure. This leads to considerable scepticism amongst institutional and retail consumers on acquiring and operating EVs.
c. Lack of clarity in regulations related to charging infrastructure: There is no clear directive on the regulatory requirement for setting up and operating charging units. The state's electricity act, needs to be suitably modified to allow entities other than licensed discoms to sell power for EV charging. .
d. Lack of technology standards: There are multiple technologies for the interface used to connect with the charging infrastructure and communication infrastructure being used in the various regions of the world a
e. Reliability of power supply: While all villages have been electrified, uninterrupted supply of power is yet to be realized. The power transmission and distribution systems need to be strengthened to ensure reliability of power supply to enable uptake of EV in rural areas.

The issues given above come from multiple stakeholders and while individual initiatives are being undertaken, there is no document providing the vision of the State government with regards to EV penetration and the initiatives proposed to address the issues mentioned above. The policy paper will also provide g in planning and designing future initiatives in the area of EV. Similar policies have been drafted by other states of India[21] .

The following areas need to be addressed by the policy:

a. Provide vision for EV penetration in West Bengal: It gives the policy vision, mission and specific targets for EV penetration in the state
b. Provide policy instruments to increase penetration of EV: The policy will provide the initiatives to be undertaken viz. EV and OEM manufacturing parks/clusters, developing EV charging network, promotion of adoption of EV across different consumer segments
c. Provide the initiatives to be undertaken for capacity building: The State should focus on research and development (R&D) and skill development in the different technical areas related to EV
d. Directives on EV charging infrastructure: Defining a distinction between vehicle charging services and sale of electricity would help overcome the regulatory barrier present in the Electricity Act and increase private sector participation in development of charging infrastructure. Also provision of mandatory inclusion of charging infrastructure in the building plan new residential/non-residential buildings.

[21] For reference:
a. Draft Policy on Electric Vehicles for state of Kerala, 2017
b. Delhi Electric Vehicle Policy, 2018

e. Institutional arrangement to ensure implementation: Propose creation of a high-level Inter departmental review committee under the purview of the policy to regularly review implementation of all provisions of the policy, suggest mid-course corrections. A 'working sub-committee' that will ensure that necessary facilitation is extended to investors should also be provisioned for to provide feedback to the high level committee on the progress at pre-defined intervals.
f. Incentives for developing EV ecosystem: The policy should contain attractive package of incentives and concessions to accelerate EV manufacturing, OEM manufacturing, battery manufacturing and battery charging/swapping infrastructure in the state. Special package of incentives/concessions will be offered to Anchor unit investors in the state in envisaged EV parks by having due consideration on Investment corpus, location of the project, potential for direct & indirect employment and, capacity to attract further investments through vendors, ancillary suppliers etc.

2. Provide incentives to increase uptake of EV by retail consumers

As discussed, the current penetration of EV in state is considerably low and financial incentive

Gatidhara is a scheme currently implemented by the Ministry of Employment and Labour to tackle the situation of unemployment in the state. Under this scheme, Gatidhara renders financial assistance in the form of loan to candidates meeting specific eligible candidates, which is sanctioned through all the Nationalized Banks, Co-operative Banks and Gramin Banks. The financial assistance can be used in the purchase of small and medium vehicle. The scheme can also be suitably modified to include EV in its purview and an extension of the scheme called "e-Gatidhara" can be introduced.

The following pattern of funding is being used currently (India Fillings, 2015):

a. The state Government financially supports the applicant by granting a subsidy of 30% of the cost of car provided that it confines to INR.100000.
b. The bank provides a term loan equal to 65% of the cost of car.
c. The remaining 5% of the cost of car needs to be provided by the applicant as margin money.

The recommended pattern of funding for e-Gatidhara is:

a. State government continues to provide subsidy of INR 100000 along with an additional subsidy equal to 10% of cost of car.
b. 5% of the cost of car needs to be provided by the applicant as margin money.
c. The bank provides a term loan equal to the remaining cost of car.

It is expected that 30% of the commercial 4 wheelers (Taxi and LCV) will be replaced in to EV by implementing this scheme. The incremental subsidy that the State Government has to bear as a result of e-Gatidhara is as follows:

Table 6: Details of e-Gatidhara Scheme

Term	Target Penetration	Total no. of vehicles	Total no. of EVs	Total cost (INR Crore)	Additional Subsidy (INR Crore)
Short (2020-25)	5%	6,43,765	32,188	2,575	258
Medium (2025-30)	15%	10,87,017	1,63,053	13,044	1,304
Long (2030-40)	30%	31,00,492	9,30,148	74,411	7,441
Total		**48,31,274**	**11,25,389**	**90,031**	**9,003**

Assumptions:

i. Total no. of vehicles (Taxi and LCV) taken from West Bengal EAP Model (West Bengal Energy Model Analysis , 2019)
ii. Cost of 4W EV taken as INR 8,00,000 (Plugin India, 2018)

3. Introduction of electric trolley bus

Trams in Kolkata have been present over 100 years and limited modernization being undertaken for trams has not only resulted in reduced speed, performance and but also increased congestion on the busy city roads. Passengers are moving away from trams to buses due to their inherent inefficiency. In order to utilize the existing infrastructure for trams and to meet growing demand for West Bengal transportation services, electric trolley buses present an alternate pathway towards improving ambient air-quality, energy security and economic opportunities. This can potentially increase use of public transport in Kolkata metro region.

The electric trolley buses will be procured, operated and managed by the West Bengal Transport Corporation. The buses can run on direct charge using the overhead 550V DC network which will be upgraded to run the trolley buses. The buses will be equipped with smaller battery units enabling the bus to run without direct power for 5-6 kms. The use of electric trolley provides distinct advantages over e-buses with no range limit, no battery and no down time for charging. The overhead power infrastructure can be owned and operated by the WBTC/CTC or CESC in Kolkata and WBSEDCL outside Kolkata. There will be greater scope of expansion of routes and services for Trolley buses over closed tram routes and other city localities where laying of track will not be required for dedicated movement.

The initial investment of procuring 20 electric trolley buses is estimated to be INR 30-40 crore (Trolley Project EU, 2013), along with additional cost on upgrading overhead DC network and upgrading charging infrastructure.

The initiative can be piloted over select routes and accordingly scaled up to exploit the wide network of ready infrastructure available for trams.

4. Increase private sector participation in increased penetration of EV in passenger transport

As discussed, the growing demand for transportation services in West Bengal provides a scope for battery powered electric vehicles (EVs) to create alternate pathway towards improving ambient air-quality, energy security and economic opportunities. In addition to the steps undertaken by the Government, private sector participation will further help increase penetration of EVs.

As a mode of mobilizing private sector investment for EVs, Transport Department can introduce PPP mode for introduction of e-buses in other routes. In such a case, the PPP can be structured in a way that Transport Department and the private player have equal share of the SPV, thereby sharing the procurement costs. Once buses are procured, the private player can take up operations of the bus, while Transport Department can take up maintenance. Considering that the Transport Department is already operating and maintaining e-bus routes across the city, there will already be technically qualified personnel available for any maintenance related work.

A pilot can be undertaken with 100 electric buses on multiple routes of Kolkata. The estimated cost for procurement of the buses and associated infrastructure is given below:

Table 7: Estimated cost for private sector participation in passenger transport

No.	Particulars	Unit Cost (INR)	No. of Units	Total Cost (INR)
1	Bus	75 lac	100	75 crore
2	Charging Station	8 lac	50	4 crore
Total				**79 crore**

Assumptions:

i. Cost of each unit of bus is INR 75 lac (Transport Department GoWB, 2019)
ii. Charging station considered is a DC Fast Charging Station of range 50-150kW (CARET AMU Aligarh, 2018)

The benefits derived from this engagement are as follows:

a. Diesel consumption will be entirely eliminated for 100 buses leading to reduction in fuel budget.
b. It is estimated that each electric bus will have the capacity to reduce 57,924 tonnes of CO_2 per year (Transport Department GoWB, 2019) compared to conventional diesel buses thereby being a significantly cleaner mode of transportation
c. The financial benefit derived from reduced operational cost can help either help to reduce the cost of travel to the passenger or can be used for upgrading the road transportation system.

Based on the performance of private sector participants and overall outcome of pilot, large scale projects can be undertaken which can help transform the public transport system in the state.

5. Providing adequate charging infrastructure to support growth of EV

For an average consumer the key decision drivers for considering an EV are cost of procurement and maintenance, the average distance covered in a single charge and the availability of EV charging station. While the cost component is being addressed by the preceding sub-activities and the distance covered is contingent on prevalent technology, the State can provide adequate support to increase growth of charging infrastructure. The growth of EV charging infrastructure can be undertaken in the following ways:

a. *Mandating installation of EV in public parking areas:* A directive can be issued by concerned urban local body (ULB) mandating the installation of EV charging infra in parking areas of malls, commercial and public buildings as well as public parking spaces by the building owners. The directive can be made voluntary in the 1st five years of this initiative, wherein technical support can be provided by Department of Power and Transport Department regarding installation. Financial support can also be provided in form of discount in land tax in the initial period to stimulate participation. After 5th year, the installation of such infrastructure can be made mandatory in new as well as existing buildings. Accordingly, the municipal bye-laws is required to be amended.

b. *PPP mode:* The State can enter in to a PPP agreement with private entities for installation and operation of EV charging station. The SPV can charge usage fee to recover the costs of installation as well as to generate profit. The State can also explore the option of forming an SPV with oil marketing companies (OMCs) to install EV charging stations in the existing or additional land available with oil retail outlets.

c. *State owned charging station:* The State can undertake installation of EV charging station through the state owned entity, WBSEDCL. WBSEDCL can undertake operation and maintenance of such charging units, while charging a nominal amount to users for utilization of the charging infrastructure.

In order to facilitate business operations by levying usage fees for EV charging station, the Department of Power should provide guidelines on the usage fees including maximum permissible fees. Accordingly any regulatory requirement should be taken in to consideration. Issuing such guidelines help provide a level field for market players, be it public or private and help stimulate the EV charging market.

Considering the recently released EV charging guidelines and standards released by Power Ministry, Government of India and the charging requirement considering penetration of EV in West Bengal, we get the following market potential for EV charging station in the state:

Table 8: Details of EV charging station

Time Period	Total No. of charging units	Cost of charging infrastructure (INR Crore)	Cost of supporting structure (INR Crore)	Total Cost (INR Crore)
Short Term (2020-25)	1300	110	42	152
Medium Term (2025-30)	5200	439	169	608
Long Term (2030-40)	6300	532	205	737

Assumptions:

i. CAGR of total road length in West Bengal between 2012 and 2015 is 2% (MOSPI, 2017)
ii. 3% of total road length in short term and 10% of total road length in medium and long term has been considered for assessment. Total road length includes national highways, state highways, other PWD roads, rural roads and urban roads
iii. EV charging station would be installed after every 3 km (Ministry of Power GoI, 2018)
iv. Charging station includes 3 charging units (including 1 fast charging unit) (India Smart Grid Forum, 2018)
v. Supporting structure includes new electricity connection, civil works, EVSE management software, CCTV camera system (India Smart Grid Forum, 2018)

6. Engage with foreign organizations and specialized institutions for technical collaboration and partnerships

The State has been organizing its investment promotion event Bengal Global Business Summit (BGBS) for the past five years to attract investment opportunities which can lead to job creation in the state. The potential growth of EV in the state can provide multiple opportunities which can be showcased to potential investors and technology partners:

a. Assembly and manufacturing of EV components
b. Installation and maintenance of EV charging stations
c. Expertise for technical assessment of sites for EV charging
d. Service providers for vehicle repairing facilities
e. Research and development on improved manufacturing techniques for EV/EV components

In order to tap this potential market there are multiple activities that the State can undertake to attract investment/partnership. This includes conducting investment missions to potential countries, advertising in foreign business media, attending national/international trade fairs and conference. The activities can be merged with the activities of BGBS and adequate market collaterals can be prepared by WBIDC in collaboration with Transport Department and Department of Power for the purpose of the IP activities.

7. Capacity development in operation and maintenance of EV battery and charging infrastructure

Adoption of EVs and the promotion of local manufacturing will create demand for new type of professional skills and capability at various levels such as automobile engineers, technicians, repairing and maintenance personnel, financiers etc. Collaborating with the industry for up-skilling the workforce to augment the human capital need for the EV industry as well as promoting investments in R&D of EV and its components through continuous cooperation, at both national and international level, between industry and academia can lead to creation of substantial number of jobs in the state.

The initiatives that can be undertaken with regards to capacity development in the state are as follows:

a. Research and Development
    i. Strategic deployment of public and private charging infrastructure necessary to support the transition to EVs;
    ii. Developing a low cost, high energy density, high performance battery module development to enable a larger market penetration of EVs;
    iii. Transformational research projects on energy storage technologies like metal-air, lithium-sulphur, magnesium-ion, advanced lithium-ion and solid state batteries;
    iv. Development of Vehicle-to-Grid (V2G) technologies which can push back surplus power from EV to grid during idle time;
    v. Deploy projects that can help accelerate the commercialization of advanced low- emission mass transportation technologies in mass transportation; and
    vi. Promote start-ups in the space of drive technologies, battery technologies, charging infrastructure, network integration, demand side management of Smart Grid, automotive design and other related fields.

b. Skill Development
    i. Introduce curricula and courses suited to the EV industry in professional institutes, polytechnics, vocational education institutes;
    ii. Formulate certified courses for skilled and semi-skilled repair and maintenance personnel by technical education department in collaboration with Transport department
    iii. Promote technical and semi-managerial training in EV manufacturing and related technologies in the state by offering suitable stipend.

8. Undertake modernization of traffic management system in urban areas

Based on the assessment of the BG scenario of state, the transport sector is the largest producer of CO_2 emission in the state in the demand side 94.2 MT CO_2/yr by 2040. This is after considering a 50% penetration of EV in passenger vehicles segment. While use of fossil fuel will have definite emissions, it can be reduced through efficient fuel usage. Also, considering the traffic congestion in the urban and peri-urban areas, fuel consumption due to vehicle idling has increased and is expected to further increase as number of vehicles increase.

In order to tackle the problem of fuel consumption due to traffic congestion, IT system based traffic management systems can be used. There are a number of ITS-based Traffic Management System solutions can help mitigate congestion (National Center for Sustainable Transportation, 2015):

a. Traffic Monitoring Systems are improving with better sensor technology, more reliable communication channels, and more advanced information processing capability. In addition to providing transportation managers with better real-time information, new data processing techniques are being developed to estimate traffic flow, density, and speed, as well as other microscopic traffic parameters. This real-time traffic information can be used for better traffic

system management and for individual drivers choosing alternative routes, resulting in reduced congestion.

b. Traffic Incident Management techniques are important tools for early detection and rapid removal of incidents (i.e., accidents, disabled vehicles, etc.), so that normal traffic operations recover as quickly as possible.
c. Integrated Corridor Management techniques, such as innovative ramp metering for freeway access ramps, and advanced signal timing algorithms on arterial networks, work together to help keep traffic flowing as smoothly as possible through the corridor, greatly reducing the amount of idling.
d. Travel Demand Management is another critical element of traffic management. By reducing the number of vehicles on a congested roadway or spreading out the peak of traffic volume through pricing and other techniques, traffic flow will improve, resulting in lower GHG emissions.

The overarching goal of traffic management is to take full advantage of capacities of existing roadway infrastructure, thus keeping traffic flowing smoothly at moderate speeds. As such, this will have a large impact in reducing energy consumption and GHG emissions. Traffic management system strategies go even further by reducing the number of vehicles in the transportation system, thereby reducing the total contributions of GHG emissions.

The state can look at development of such traffic management systems in the medium to long term. The roadmap for implementation can include development of pilot projects in Kolkata or other urban areas and close monitoring of the projects, in terms of improvement in average travel time and reduction in emission. Based on the assessment, the implementation can be further scaled up as required.

9. Introducing battery operated electric ferry to replace existing diesel operated ferry

West Bengal's stretch of navigable waterways is 2,293 kms in length (which includes 560 Km of developed stretch of NW1), at 15.81% share of total stretch this is the maximum navigable stretch available in a state. There is a vibrant network of passenger and/or vehicular ferries across the Hooghly River that runs through the Howrah-Central Kolkata area where daily passenger count varies from 6300 - 7000 persons with each passenger ferry typically accommodating 400 passengers. Most of the ferries plying these routes are over 25 years old with over 50 ferries operating on a daily basis consuming over 7000 litres of diesel per day.

Taking into consideration the volume of traffic experienced between Howrah and Kolkata, a pilot project of 2 battery operated electric ferries can be introduced. The salient features of the pilot project is as follows:

- Ferries will be procured, operated and managed by the West Bengal Transport Corporation.
- Ferries will have passenger capacity of up to 300 passengers and a nominal fare will be charged for each journey.
- Charging infrastructure will be available at the destination **points**

Based on preliminary estimates, one diesel ferry uses approximately 13 liters of diesel per hour, which at current price of INR 68 per liter of diesel, results in a budgetary outlay for fuel of up to INR 39 lakh per year. In case the ferries are manufactured in India, the cost for 2 ferries can be INR 6 crore along with a charging infrastructure cost of 44 lakh. This leads to a simple payback period of about 8 years. With limited fuel costs after payback period, the introduction of electric ferry can be

potential game changer in inland water transport in the state. It is estimated each electric ferry will have the capacity to reduce 95% of CO_2 emissions and 60-80% of costs per year as compared to conventional diesel ferries (Electrek, 2018). Based on the success of the pilot the same can be implemented in other ferries across the state.

10. **Provide infrastructure support required for operating RO-RO services**

Inland Water Transport (IWT) mode is widely recognized as an environment friendly and cost effective mode of transport. A brief comparison of the various modes of transport is provided below (Press Information Bureau, 2017):

Table 9: Comparison of various modes of transport

No.	Mode	Pre-tax freight (INR/tonne-km)	Fuel Efficiency (tonne-km)
1.	Railways	1.36	95
2.	Roadways	2.5	24
3.	IWT	1.06	215

The use of inland waterways for movement is very contextual in case of West Bengal, since the state has 17 of 111 national waterways notified as per The National Waterways Act, 2016 with a total length exceeding 3500km (Ministry of Law and Justice GOI, 2016).

Even though the IWT and even rail provides a clear advantage over roadways, roadways is still the most preferred mode of transporting freight in the country as well as state. A key influencing factor for the popularity of roadways is last mile connectivity. Roadway is the basic building block of transportation system which can provide door-to-door connectivity. Use of railways and IWT can only be possible if there is adequate road infrastructure connecting the source to the boarding location and final destination to the un-boarding location.

The state can address this issue by providing last mile connectivity to the jetty locations within the state along the national waterways. In order to plan for the last mile connectivity requirements, Transport Department can liaise with IWAI to understand the land-side infrastructure requirements. Accordingly, reference to the Origin-Destination (OD) studies already conducted by IWAI, can be referred. The Transport Department can utilize the expertise of state public works department to identify and develop infrastructure requirement for last mile connectivity to these jetties.

11. **Building awareness among commercial transportation companies to increase freight movement through IWT**

While the previous step ensures the development of infrastructure required for movement of freight, increasing awareness of actual users of IWT should be undertaken simultaneously to stimulate the market for freight.

The key benefits of using IWT over other modes of transport can be highlighted in the stakeholder outreach programs. The state can also provide financial incentives in the short to medium term in terms of rebate on tonne per kilometre basis to incentivize the use of inland water transport.

H. Investment required

The total investment required for implementing the activities mentioned in the Action Plan is provided in this section. The investment includes cost of acquiring a specific infrastructure/equipment. The table provides the average cost of each infrastructure/vehicle/vessel type along with the targets for 2040:

Table 10: Investment required for Transport Sector

No.	Particulars	Average cost per unit (INR)	No. of units in 2040	Total Cost (Cr. INR)
1.	EV (4W)	4,80,000 - 8,00,000	~50,00,000	2,40,000 - 4,00,000
2.	EV (2W)	42,000 - 60,000	~22,00,000	9,200 - 13,200
3.	EV charging unit	8,20,000 - 11,70,000	6300	520 - 740
4.	IWT passenger vessel (solar)	2,50,00,000	24000	60,000
5.	IWT freight (Barges)	6,00,00,000	14000	84,000

Note: In order to calculate the above figures the following aspects were considered:

1. The number of units for each type of infrastructure/vessels/vehicle were derived from the energy demand results provided from the modelling exercise and using assumptions to calculate average utilization of each infrastructure/vessel/vehicle
2. Cost of an average 4 wheeler and 2 wheeler EV available in Indian market is INR 8,00,000 and INR 60,000 (Plugin India, 2018)
3. The cost of an average EV charging unit takes into account the capital expenditure required for setting up an AC charging equipment compliant with Bharat EV Charger AC-001 standards (India Smart Grid Forum, 2018)
4. The cost of IWT passenger takes into account the cost of acquiring a 75 seater passenger solar boat. (Mydigitalfc, 2017). A larger passenger-cum-cargo vessel i.e. Roll-On-Roll-Off (RO-RO) vessel which can carry 8 trucks and 100 passengers (Cochin Shipyard, 2018) can be possible in feasible waterways and can cost INR 10 crore.
5. Barges with a capacity of up to 2000 tonne dead weight has been considered, for which cost of acquisition in INR 6 crore. (Times of India, 2017).
6. Cost of EV and EV charging units is expected to reduce considerably in the near future due to market maturity and technological advancements. A thumb rule of 40% reduction in prices of EV (4W) and a 30% reduction in EV charging units and EV (2W) has been assumed by 2040. Based on the assumptions, a range of investment is provided in the total cost.

7.2 Industries Sector

A. Brief Description of Sector

The Industries sector of West Bengal contributes 25% (Centre for Budget and Governance Accountability, India, 2018) to the state GDP. The sector, which comprises for both large industries and Micro Small and Medium Enterprises (MSMEs), accounts for a gross value added (GVA) of INR 30 lakh crore (MOSPI, Govt. of India, 2016).

The major industries of West Bengal in terms of GVA is basic iron and steel, basic chemicals, food processing, textiles and metal casting, refined petroleum products. Major industrial areas of West Bengal are Haldia, Kolkata, Asansol-Durgapur region and Kharagpur. As of July 2018, West Bengal had 21 SEZs; of which, 7 are operational, 5 are notified, 7 are formally approved and 2 have in-principle approval (IBEF, 2018). West Bengal is the 1st State in the country to achieve 100% implementation of Business Reforms Action Plan 2017 recommended by DIPP, GoI. (Department of Information & Cultural Affairs, GoWB, 2018)

In West Bengal, there are close to 52.7 lakh MSME establishments, the highest in the country. Nearly 1.1 crore people are employed in the MSME sector in 430 MSME clusters. These clusters have witnessed nearly 9 times growth in the last 7 years. (Department of MSME & Textiles, GoWB, 2018). 28,008 units on an average registered per year between 2011-18, compared to 12,192 units between 2004 and 2011. Around 2.1 lakh people have been employed in registered MSME sector per year, between 2011 and 2018. In comparison, 1.3 lakh people had been employed in the sector between 2004 and 2011. (Department of Information & Cultural Affairs, GoWB, 2018).

B. Energy Consumption of Sector

In BAU scenario, a major portion of the energy consumption of the industrial sector comes from coal and the share is expected to remain constant. The use of oil (especially diesel) is also expected to remain an important source of energy. Gas use in the sector is very limited mainly due to lack of availability in the market as well as limited work in expanding gas usage for industries. Hence proportion of gas in the total energy mix of the sector is almost remains same between 2015 and 2040 in BAU scenario.

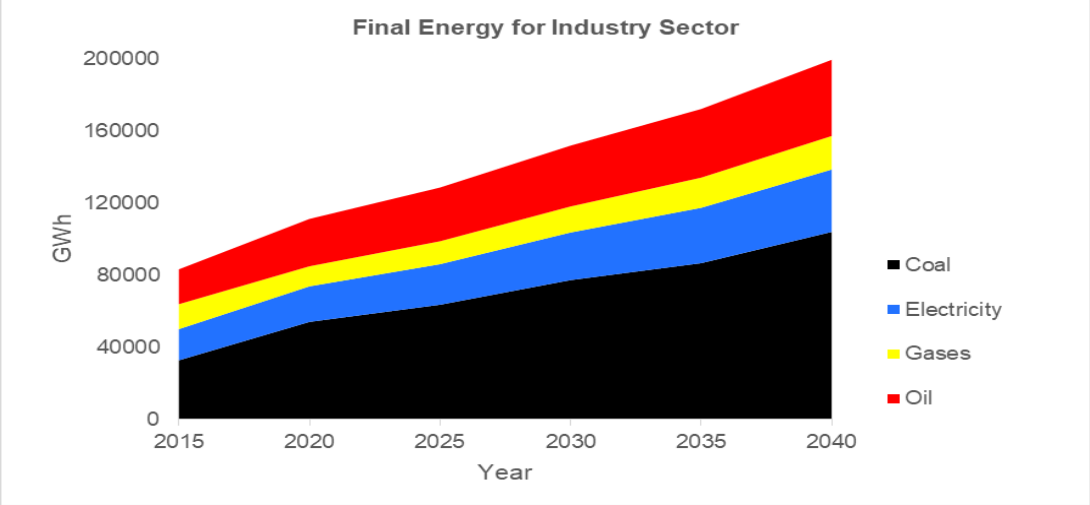


Figure 36: Final energy consumption in industry sector

The continued preference for coal and oil for energy consumption in the sector can be attributed to multiple of factors. While there is widespread availability of these fuel sources, a number of industrial units (especially in MSME segment) have limited financial and technical capacities to utilize other fuel sources, despite the long term benefit associated with their use. Most of the units have traditional equipment and lack financial capability to modify/change the equipment to account for new fuel source as well as the technical knowhow to operate and maintain such equipment. Figure 37 below shows the energy mix of the industry sector in the State between 2020 and 2040. This indicates though there is an increase in energy consumption in volume but the share of fuel use is not changing much.

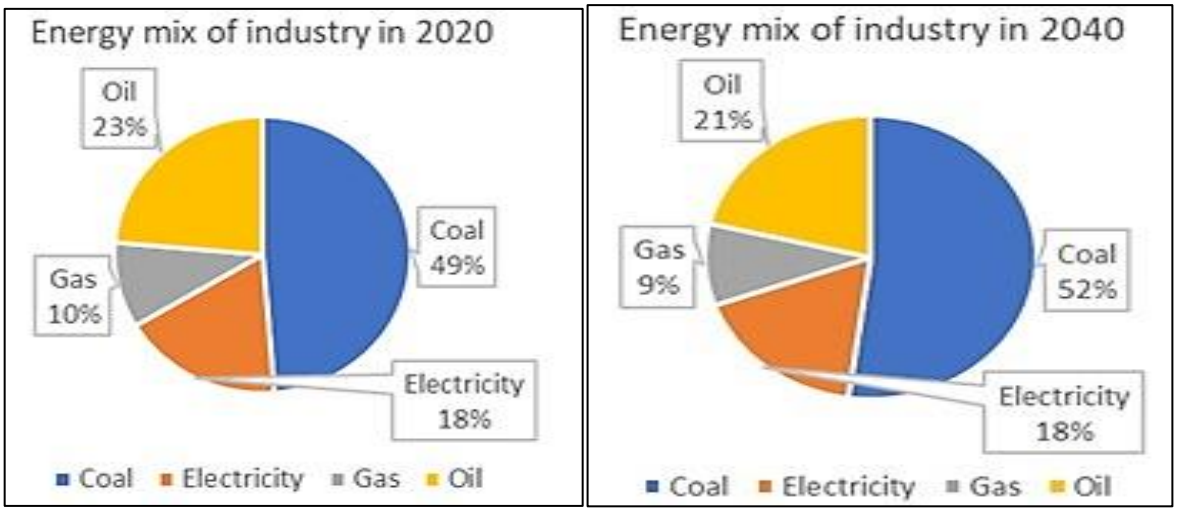


Figure 37: Energy mix of industry sector

C. Existing initiative in the state

Under the current scenario there are two national level schemes on energy efficiency in industrial sector, administered by Bureau of Energy Efficiency (BEE), which are operational in the state:

1. **Perform, Achieve, Trade (PAT) Scheme**

Perform Achieve and Trade Scheme (PAT) is an innovative market based mechanism which has been developed to enhance the energy efficiency in energy intensive industries through issuance of tradable energy saving certificates. In the scheme the notified energy intensive industrial units or designated consumers (DCs), are required to undertake energy efficiency measures to reduce energy consumption or face penalties. The scheme is spread across 14 sectors, off which 10 sectors are involved in production viz. cement, aluminium, chlor alkali, pulp & paper, iron & steel, textile, fertilizer, refinery, railways, petrochemical. For the state of West Bengal the following designated consumers have been notified under the 4 PAT cycles amongst the 10 production sectors:

Table 11: List of Designated Consumers in West Bengal

No.	Sector	Total no. of DCs	PAT I (2014-15)	PAT II (2016-19)	PAT III (2017-20)	PAT IV (2018-21)
1.	Pulp & Paper	1	1			
2.	Iron & Steel	14	3	3	2	6
3.	Textile	1			1	
4.	Railway Production	1		1		
5.	Petrochemical	1				1
TOTAL		**18**	**4**	**4**	**3**	**7**

2. **BEE SME Programme**

The BEE SME programme is the 1st national level initiative to be carried out for energy efficiency in the SME sector and includes extensive study for specific sectors. Apart from bringing in energy savings in the highly fragmented and informal SME sector, the programme will also help generate energy related data for the sector which is otherwise mostly unavailable. Under this programme, 25 clusters were selected from a group of 35 clusters across India where adoption of Energy Efficiency (EE) technologies and practices will be undertaken through knowledge sharing, capacity building and development of innovative financing mechanisms. Of these 25 clusters, 1 cluster from West Bengal viz. Howrah wire drawing and galvanizing cluster has been selected for further action. Currently, a cluster manual containing energy use and technology analysis of the clusters has been prepared and investment in implementation of energy efficient opportunities is expected to commence in the near future.

The state government, through its industrial policies, has provided energy related incentives to increase investment in industries as well as promote energy efficiency:

1. **MSME Policy incentive**

Under MSME policy 2013-18, there is provision for waiver of electricity duty and subsidy on power costs for specified period (Department of MSME, Govt. of West Bengal, 2013). The policy also has provisions to provide 50% reimbursement of the cost of energy audit undertaken by a certified agency and 25% reimbursement of the cost of installations for energy conservation as per energy audit, subject to a ceiling of INR 2 Lakh for micro and small enterprises.

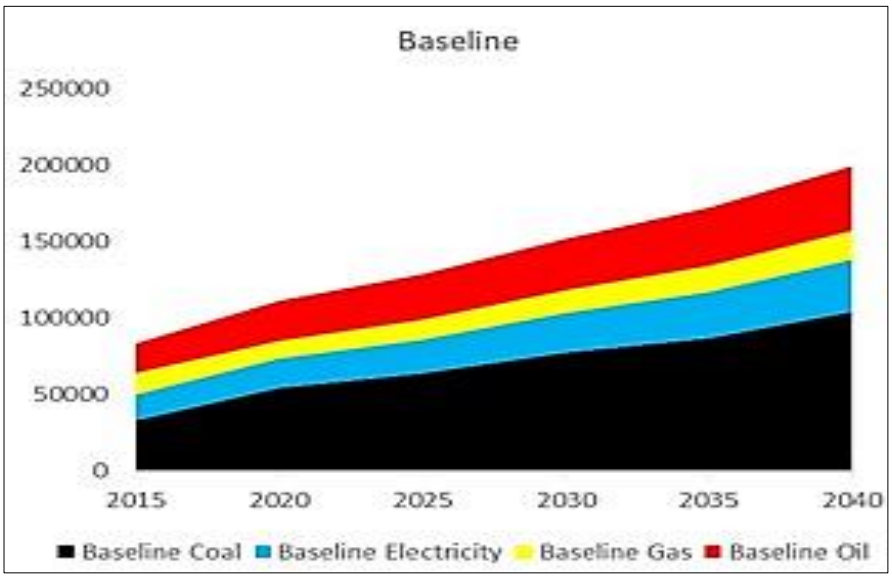
2. **West Bengal State Support for Industries Scheme (WBSSIS), 2013**

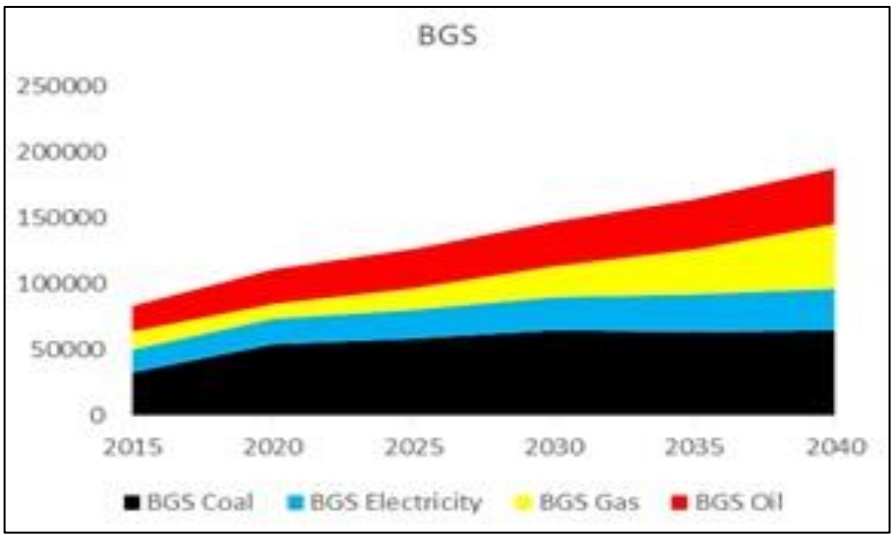
The policy, as part of providing incentives to attract investment in industrial sectors, provides waiver of electricity duty to particular industrial units, as specified in the policy document. (WBIDC, 2014)

It is expected that in the near future, use of natural gas will increase in the industrial sector, as exploration and extraction of shale gas from Raniganj block increases. Also use of technology and appropriate data analytics techniques that help monitor and optimize energy use in various industrial processes will gradually increase.

D. Comparative analysis of alternative pathways

Industrial energy demand is divided into its thermal and electricity requirement. In the figure given below, it is observed that the final energy demand for Industry sector is expected to increase at a growth rate of 3.3% CAGR from 83460 GWh in 2015 to 187595 by 2040. However, under both the Balance Growth and Energy Secured Scenario the total energy consumption by the industry sector reduces by around 6-7% by 2040 compared to the baseline situation. This also impacts on the GHG emissions from the sector as well. Figure below shows the comparison of energy consumption by the industry sector over the period of time.





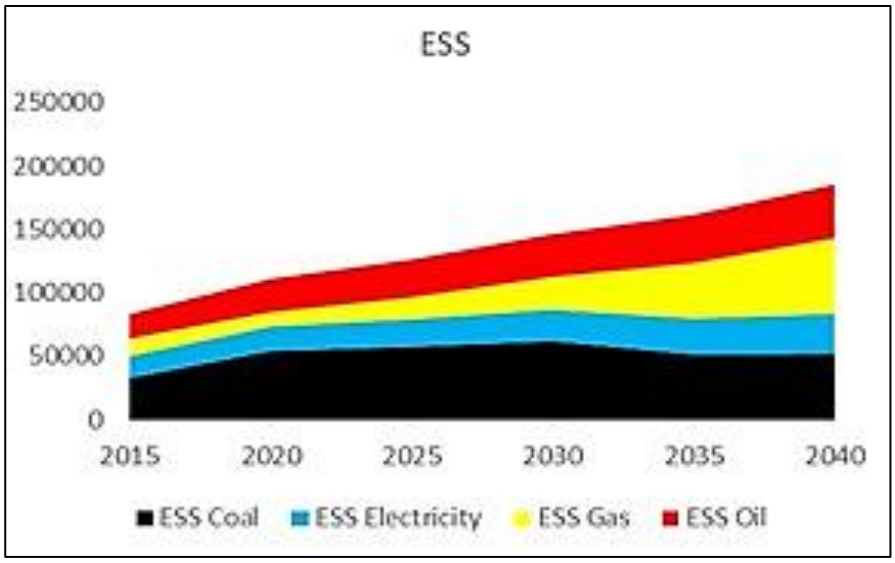


Figure 38 Final Energy consumption by Industry Sector by scenarios

It is further observed that thermal energy need is the largest component of the total industrial energy consumption in the State. This energy is required for process activities in the production line which is mostly boiler and furnace use, steam generators, heating facilities etc. More than 90% of the thermal energy need is met through solid and liquid hydrocarbons like coal and oil and in some case with gases. However, under the Balanced Growth and Energy Security scenarios it is observed that due to change in technology, standard of efficiency and moreover, availability of natural gas, the share of fuel mix is changing significantly. Under the BAU scenario the gas share was around 10% by 2040 while in BGS and ESS scenario the gas share increases upto 26% and 32% respectively. Coal consumption can reduces to 28% for ESS case and to 35% for BGS case compared to 50% in the BAU scenario. Figure 39 below shows the new fuel mix by 2040 under two different scenarios:

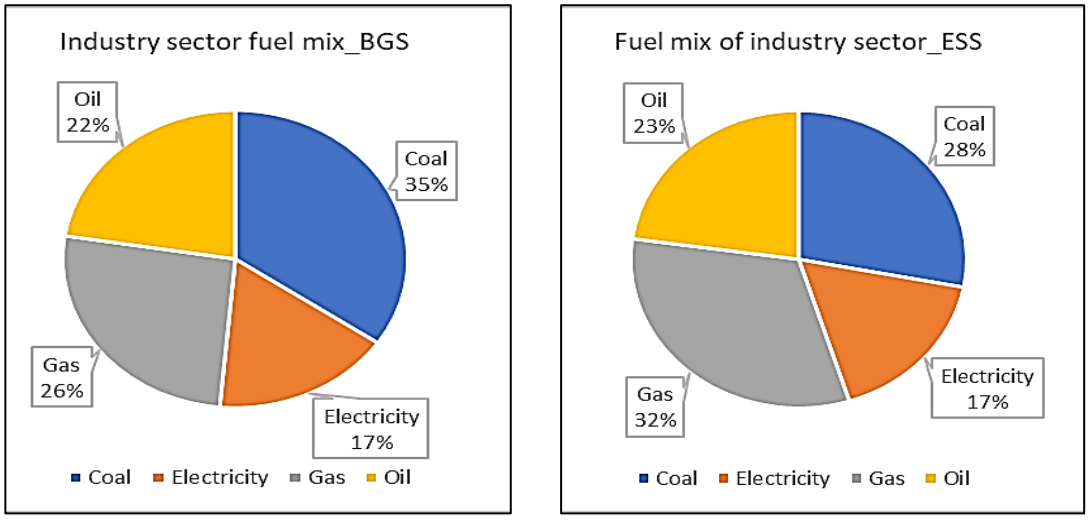


Figure 39: Energy mix of industry sector by 2040

In summary two things are very important for the industry sector in this context: one, to reduce the consumption of energy through efficiency improvement so that losses can be managed and cost of production can be minimized (as energy is an expensive factor input for industrial outputs) and two,

switching the fuels from coal and oil to cleaner sources like natural gas and electricity. It is observed that under BGS and ESS both the scenarios, industry sector can reduce their overall energy consumption as well as can do fuel shift to cleaner sources.

E. Sectoral Vision

Industrial sector is the 2nd most energy intensive sector of West Bengal, accounting for 30% of the net energy consumption. A major source of energy for the sector is low-grade domestic coal which has considerably lower calorific value. This leads to increased cost of fuel, higher emissions and decrease in boiler/furnace efficiency. Also there is limited information available regarding energy consumption for entire sector due to limited awareness of the benefits of energy efficiency. This further limits the application of energy efficiency in the sector.

- Vision:
    - State shall undertake de-carbonization of the state industrial sector
    - Reduction of specific energy consumption of industrial sector
    - State shall have an energy profile of the industrial sector

F. Action Plan

a) **Objective:** The State shall enable the reduction in specific energy consumption by 5% by 2040.

Activity:

A.1: State shall create energy profile database containing fuel mix, production data and machinery inventory

A.2: State shall undertake stakeholder outreach to create awareness of benefits of energy efficiency

A.3: State shall develop knowledge base to provide requisite technical support to market players in adopting energy efficient technologies and processes.

A.4: State shall incentivize adoption of energy efficient technologies and processes as well as development of energy efficiency services market

b) **Objective:** The State shall replace 50% of the energy demand for coal by natural gas by 2040.

B.1: State shall develop anchor consumers in industrial sector

G. Implementation of action plans

According to the PAT scheme, designated consumers are present across 8 sectors in West Bengal, off which 5 sectors i.e. paper & pulp, iron & steel, textile, railways are associated with industrial production units. As per the energy projections, Iron & steel and paper & pulp comprises for nearly 85% and 4% of the total energy consumption of the industries sector respectively. Accordingly, the initiatives for large industries have been identified to reduce energy consumption in these 2 sectors in the short to medium term. Also taking into consideration the number of cement units coming up in the state, initiatives specific to cement sector has also been included.

Since energy profile of various MSME sectors are not available, it is hard to provide specific action plans to implement. Nevertheless, keeping the overall objectives of 10% final energy consumption reduction at the industry level within the State, technology specific plans are developed. Implementation strategies for the proposed action plans are divided to two categories: i) overarching general plan of action which are visionary in nature and ii) technology specific action plans which are business case oriented. However, upon further investigation and preparation of an industrial sector specific energy profile, specific initiatives can be explored.

i) Industry specific technical improvements

Figure below shows the list of energy efficiency and conservation activities which could be performed across the industry categories in the State and their corresponding energy savings potential. The following set of implementation plans have been drawn from the sectoral energy audit report recommendations and can be replicated in the respective sectors.

Table 12: List of energy conservation and efficiency improvement measures

Industry Category	Energy Efficiency & Conservation Measures	Savings Potential
Iron & Steel (NEDO, 2014)	Power generation & coal drying through waste heat utilization from flue gas. Sources of heat: gases from coke ovens, blast furnaces, basic oxygen furnaces, and electric arc furnaces	6%
Cement (Grinding and packaging only) (OCL Bengal Cement Works, 2017)	• Optimization of Vertical Roller Mills (VRM) • Reduction of Compressor power consumption • Power factor improvement • Installation of variable frequency drive (VFD)	15-18%
Pulp & Paper Industry (Shakti Sustainable Energy Foundation, 2013)	• Oxyfuel burning in lime kiln & black liquor boiler. • Use of shoe press • Optimize energy dispersion as per requirement • Installation of extended delignification of system for cooking of wood	10-15%
Textile (Y Dhayaneswaran, 2013)	• Blowroom efficiency • Ring spinning activities • Humidification • Compressor efficiency	8-10%
Foundry (TERI, 2016)	• Replacement of existing conventional cupola with divided blast cupola • Replacement of inefficient blower with appropriately designed blower • Replacement of rewound motors with energy efficient motors • Retrofitting air compressor with variable frequency drive • Compressor efficiency improvement	15-20%

ii) Equipment specific technical improvements

As observed in the table above a majority of the energy efficiency initiatives provided is linked to three primary industrial equipment viz. furnace, compressor and motors. These equipment are widely used across industrial sub-sectors and as observed from sector experts, consume substantial amount of energy of any production unit. Apart from the above, a specific technology pertinent to brick industry has also been pointed by sector experts as an area which needs to be explored.

Table 13: Equipment specific technical improvements

Equipment/ Technology	Energy Efficiency measure	Reference Equipment	Energy Savings Potential	Monetary Savings Achieved	Investment required
Furnaces (BEE-GEF-	Conversion of fuel for forging and heat treatment furnace	Medium scale Forging unit	15%-25%	INR 300/Ton of production for heat treatment	INR 4-10 lac depending on capacity

Equipment/ Technology	Energy Efficiency measure	Reference Equipment	Energy Savings Potential	Monetary Savings Achieved	Investment required
World Bank, 2015)	from furnace oil to natural gas			furnace and INR 667/Ton of production for Forging Furnace	
	Preheating feed water by using waste heat	Steam System with 3,000 operating hours per year	20%-25%	INR 102,200/year	INR 24,500
Compressor system (BEE-GEF-World Bank, 2015)	Installation of energy efficient compressors	Compressor with 3000 operating hours per year	10-15%	INR 1260/cubic feet minute of compressed air generated	INR 2 lac for compressor with 1000cfm rating
	Installation of leakage proof compressed air pipelines		3-5%	INR 220/cubic feet minute of compressed air generated	Negligible
Motors (SIDBI, 2014)	Installation of variable frequency drive (VFD) on air compressor motor, blowers, centrifugal pumps	Motor with 3600 hrs of operation	50-60%	INR 600000/yr per motor	INR 330000/motor
	Installation of energy efficient motors	Motor with 8000 hrs of operation and efficiency improvement form 88% to 93%	5-6%	INR 5000/yr per motor	INR40000/ motor
Zig-Zag Technology (Sector Experts from GIZ , 2019)	Replacement of traditional fixed chimney bull trench kilns (FCTBK) with natural draft zig-zag type kilns	Kiln with annual production capacity of 4 million bricks	20-25%	INR 875/per 1000 bricks produced	INR 20.6 lac

In order to bring in energy efficiency in industrial sector, a roadmap for implementation for the short, medium and long term:

Table 14: Action Plan for Industries Sector

No.	Sector	Activity	Sub Activity	Time period	Type of Intervention	Responsible stakeholder
1.	Large Industries & MSMEs	Energy benchmarking of large industries & MSMEs in the state	Undertake detailed energy (and water) audit of sampled large industries and MSME clusters across the state	Short	Regulatory	IC&E, MSME
2.			Prepare energy benchmark for industrial sub-sectors utilizing database prepared from energy profile and existing best practices	Short to Medium	Technical	WBSEDCL, IC&E, MSME
3.			Development of online resource for dissemination of database and best practices in energy efficiency and conservation for the industrial sector	Short to Long	Awareness	IC&E, MSME
4.		Incentivize implementation of energy efficiency measures	Continue providing financial support to increase undertaking of energy audits and implementation of energy audit recommendations	Short to Long	Financial	IC&E, MSME
5.		Pilot project implementation	Develop linkages with technology providers, aggregators, R&D labs, technical institutions to provide relevant technical inputs to beneficiaries	Short to Medium	Market Development	IC&E, MSME, DoP
6.		Facilitation activities to increase uptake of energy efficiency measures	Undertake demonstration projects and subsequently pilot projects across sub-sectors	Short to Medium	Technical	IC&E, MSME, DoP
7.			Extend financial support to increase loan disbursement through banks	Short to Medium	Financial	IC&E, MSME
8.			Develop business model to implement energy efficiency measures	Short to Medium	Market Development	IC&E, MSME, DoP
9.			Develop partnership with technology and service providers	Medium to Long	Market Development	IC&E, MSME, WBIDC
10.			Providing training on operating and maintaining energy efficient technologies	Short to Medium Term	Capacity building	IC&E, MSME, DoP

G. Description of sub-activities

While the action plan for industries include both large industries and MSMEs, the action plan primarily focusses on penetration of energy efficiency and conservation methods in the MSME sector. This is primarily due to the fact that MSMEs function with lower working capital and have limited asset base to access funds from banks. Hence, MSMEs have greater reluctance to investment in energy efficiency measures than large industries. Also, MSMEs have limited access to technical inputs required for undertaking energy efficiency projects as well as to continue operations required henceforth. Thus, the barriers to adoption of energy efficiency by MSMEs is higher than large industries. Hence, the state government should provide special focus to MSMEs.

Accordingly, the sub-activities given in the action plan have been developed and are elaborated below:

1. ***Undertake detailed energy audit of sampled large industries and MSME clusters across the state***

   A critical data point required for developing the state energy database is the fuel mix of various industrial sub-sectors. While the current database has been developed by taking national level proxies, it is expected that the fuel mix at the state level will vary, especially in MSME sector. In order to understand the actual state level energy profile, separate studies need to be conducted for each industrial sub-sectors.

   The State can undertake the audit for sample industrial units, with a focus on MSME sector. This would require a two-stage selection process wherein the sub-sector needs to be selected and thereafter the specific unit. The key determinant in determining the sub-sector as well as sample unit can be based on the value of output at the sub-sector and unit level.

   A key impediment to implementation for MSME sector is limited availability of data regarding the units present in the state. In this case, the MSME department can undertake the selection process from the registered MSME units.

2. ***Prepare energy benchmark for industrial sub-sectors utilizing database prepared from energy profile and existing best practices***

   Based on the data obtained from the energy audits and studying the industry best practices, a benchmark for each sub-sector can be prepared. For this purpose, the IC&E and MSME department can take the assistance of the SDA for energy efficiency, WBSEDCL. WBSEDCL can further seek support from BEE to compile industry best practices, which can be used to prepare energy benchmark.

3. ***Development of online resource for dissemination of energy benchmark and best practices in energy efficiency and conservation for the industrial sector***

   As an outcome of preparing the energy benchmark for the industrial sector, the State can identify possible energy savings technology/process changes for each industrial sub-sector, the benchmark savings obtained by such interventions, the corresponding investment required and the payback period.

   The information can be consolidated in an online resource which can be accessed by users. This can be useful tool to generate awareness among industry sector participants. The online resource can be promoted through industrial associations to reach the end users of the technology.

In order to provide up-to-date information to end users which incorporates the new technology improvements, the database will also need to be updated periodically.

4. ***Continue providing financial support to increase undertaking of energy audits and implementation of energy audit recommendations, especially in MSME sector***

   The State should continue providing financial support as outlined in the MSME Policy 2013-18 to increase undertaking of energy audits and implementation of energy audit recommendations by MSMEs. The MSME department, through industrial associations and through other stakeholder outreach programs, can increase awareness on the incentive among MSMEs.

5. ***Develop linkages with technology providers, aggregators, R&D labs, technical institutions to provide relevant technical inputs to beneficiaries***

   The online resource suggested above provides a preliminary technical input to evoke interest in the target users. However, in order to take investment decision, the user would require technical inputs like retrofitting requirement for existing equipment, specifications of the energy efficient equipment or type of fuel that can be used etc. In order to resolve such queries as well as to develop adequate capacity in the target users to assess various technology options available for investment consideration, the state needs to connect the technology providers, aggregators, R&D labs, technical institutions to the beneficiaries.

   In his regard, the various industrial associations can be mobilized to disseminate relevant information and act as the bridge to connect the end users with the aforementioned stakeholders. The association members can be apprised of the energy conservation and efficiency measures available in the market and the relevant stakeholders who can be approached to gather the necessary information through conferences. Exhibitions can also be arranged where various technology and service providers will demonstrate/disseminate information on their energy efficiency offerings to participants i.e. association members.

6. ***Undertake demonstration projects and subsequently pilot projects across sub-sectors***

   In order to stimulate interest in energy efficiency and conservation in the industries sector, demonstration projects undertaken in the state can help showcase the viability of particular measures. In this regard, the state can undertake sub-sector wise demonstration project, wherein all possible energy efficient technology and process applicable for a particular unit will be implemented. The results of the project can be used in the awareness generation programs to disseminate the benefits of energy efficiency and conservation.

   Based on the success of the demonstration project (i.e. level of energy savings achieved, investment required and payback period), pilot projects can be undertaken to plan for a state-wide programme to implement such technology and processes.

7. ***Extend financial support to increase loan disbursement through banks***

   The banks can be motivated to increase disbursement of loans to MSME sector for the purpose of undertaking energy efficient initiatives, by providing partial risk sharing facilities by the State. Under this arrangement, the State will provide guarantee to cover a part of the loan amount, in case the borrower is unable to pay the loan amount. This will help reduce the financial risk of the banks in providing loans to MSMEs.

8. ***Develop model for implementation of energy efficiency measures***

In order to facilitate the growth of energy efficient measures in industrial sector, a self-sufficient energy services market needs to be developed. Establishing a working business model will be beneficial in kick-starting such a market.

Considering the relatively lower level of investment requirement, energy services company (ESCO) model can be applicable for MSME sectors. Accordingly support can be provided from the proposed Clean Energy Fund Clean Energy Fund (elaborated under Cross-Sectoral Initiatives) to the ESCO in form of loans to provide impetus to the market in West Bengal.

The MSME department, with support from DoP can empanel ESCOs to implement energy efficiency measures in the state. Considering the wide range of technologies that can be applicable for each sub-sector, an equipment/technology based approach to be followed wherein the empanelled ESCOs should specialize in providing energy efficiency services related to a particular equipment/technology. In the initial stage, the ESCOs can focus on the four common equipment/technology identified in the previous sector i.e. furnaces, compressors, motors, zig-zag. The ambit of the ESCOs can scaled up based on the market reception.

The MSME department can help identify the clusters where potential intervention by ESCOs can be undertaken. Thereafter, market outreach programs can be undertaken to connect the ESCOs with the interested MSMEs within the cluster. It is recommended that performance contracting based on mutually agreed terms between ESCO and MSME be undertaken. The performance contract can be either of the following:

a. *Shared Savings:* Under this model, the ESCO finances the project either through its own funds or by borrowing from a third party. The ESCO takes on the performance risk of the project. The cost savings are divided between the ESCO and customer at a prearranged percentage for an agreed length of time.

b. *Guaranteed Savings:* In this case, the customer finances the design and installation of the project by borrowing funds from a third party such as a bank or through leasing the equipment. The ESCO has no contractual arrangement with the bank but does assume the project risk and guarantees the energy savings made. If the savings do not reach agreed minimums the ESCO covers the difference; if they are exceeded then the customer agrees to share the savings with the ESCO.

c. *Lease Rental Model:* The supplier installs the equipment and may maintain it. The lease payments are financed by verified savings and the ownership is generally transferred at the end of a lease period. The client (lessee) makes payments of principal and interest; the frequency of payments depends on the contract. The stream of income from the cost savings covers the lease payment.

d. *Build-Own-Operate-Transfer (BOOT) Model:* It involves an ESCO designing, building, financing, owning and operating the equipment for a defined period of time and then transferring ownership over to the client. Clients enter into long term supply contracts with the BOOT operator and are charged according to the service delivered. The service charge includes capital and operating cost recovery and project profit. BOOT models are becoming an increasingly popular means of ESCO business in India.

Based on the arrangement, the ESCO and MSME can undertake a contract to the same effect. In order to provide guidance, Shakti Sustainable Energy Foundation has developed a Model ESCO

Performance contract specifically for industrial sector[22]. Thereafter the activities as defined by the contract can be undertaken by the ESCO.

9. Develop partnership with technology and service providers

The state can collaborate with international and national level market players who are engaged in manufacturing energy efficient technology/systems for industrial sector or provide related services (i.e. energy audit, installation and maintenance of technology/systems).

The collaboration can be in the form of technology collaboration (partner will provide access to innovative technology and solutions to their counterparts in the state), investment partnership (State provides the partner with opportunity to invest in setting up manufacturing facilities), knowledge partnership (State provides opportunity to universities/technical institutes to collaborate with state educational/technical training institutes to develop and impart technical courses to build capacity in the state in a particular area or to undertake R&D activities) and access to markets (State provides partners undertaking supply of services and equipment related to clean technology and processes, the access to local market to setup up their business).

10. Providing training on operating and maintaining energy efficient technologies

The state can facilitate development of courses and training modules to develop capacity of actual users in operating and maintaining energy efficient technologies. For this purpose of development and dissemination of the training modules, the state can collaborate with vocational training institutes as well as technology providers.

H. Investment required

The industrial sector of West Bengal contains a wide array of sub-sectors, each of which provide multiple potential energy savings opportunities. Mapping the entire investment potential of such activities requires industry sub-sector specific studies. Given the breadth of the current study and the paucity of a consolidated energy related data of the sector in West Bengal, only a set of energy intensive sub-sectors have been considered and their representative investment cost has been calculated. These sub-sectors have been selected from the DCs notified in the PAT scheme for the state which have the highest energy consumption.

The DCs in West Bengal represent 5 sub-sectors i.e. paper & pulp, iron & steel, textile, railways, which are associated with industrial production. As per the energy projections, Iron & steel and paper & pulp comprises nearly 85% and 4% of the total energy consumption of the industries sector respectively. Accordingly, implementable initiatives for large industries have been identified to reduce energy consumption in these two sectors. Since cement is identified in the PAT scheme as an energy intensive sector and the sector is expected to grow in the near future in the state, initiatives specific to cement sector has also been included in the calculation.

Table 15: Investment requirement for Industrial sector

No.	Sub-sector	Investment area	Cost (INR Cr)
1.	Iron & steel plant	Waste heat recovery (WHR) in sinter plant	227.61
2.	Cement plant	Installation of variable frequency drive (VFD), plant logistic automation system, optimizing	9.94

[22] For reference: Developing model ESCO Performance Contracts for Industrial Projects (SSEF, June 2014)

No.	Sub-sector	Investment area	Cost (INR Cr)
		power consumption of compressor in packing plant etc.	
3.	Paper & pulp plant	Optimizing energy dispersion system in deinking plant, use of shoe press, installation of extended delignification system	1022.25

Assumptions:

1. Cost of setting waste heat recovery unit in sinter plant per unit installed production capacity is taken INR 52.93 crore per MTPA (NEDO, 2014) and two integrated steel plants of West Bengal viz. IISCO Burnpur and SAIL Durgapur has been considered where such system can be installed.
2. Total installed capacity of cement plants in West Bengal is 20 mtpa (Financial Express, 2018) and reference for investment requirement for specified energy conservation methods taken from initatives undertaken by OCL Bengal Cement Works (OCL Bengal Cement Works, 2017)
3. Share of West Bengal in India's total paper production capacity is taken as 6% (Smriti Chand, n.d.) and the investment cost of energy efficiency activities for a reference plant with a production capacity of 200 tonne per day has been considered (Shakti Sustainable Energy Foundation, 2013)

7.3 Buildings Sector

A. Brief Description of Sector

For the purpose of the study, buildings sector comprise all residential, commercial and institutional buildings across the state of West Bengal, both in rural and urban areas. Energy consumption in buildings is due to usage of lighting, household appliances and commercial heating, ventilation and air conditioning (HVAC) systems and primary source of energy is in the form of electricity. Diesel and kerosene are the 2 other sources of energy in this sector. Diesel generating sets are used as an alternative to electricity in case of power outage, while kerosene is the primarily used for lighting purposes in rural households without electrical connection. More so, the detrimental environmental effect of diesel and kerosene on the ambient air quality, coupled with rising fuel prices will further lead to reduction in consumption of diesel and kerosene for household consumption.

Within residential segment, the rural consumers account for nearly 38% of the total consumption (Power for all - West Bengal, 2016). Since the state has achieved 100% household electrification in 2018 (Prod to plug power losses, 2018), it is expected that share of rural consumption will grow further and as per Government estimates, the share of consumption from rural consumers is expected to reach 44% in FY19 (Power for all - West Bengal, 2016).

B. Energy Consumption of Sector

In the building sector, residential and commercial energy consumption steadily increases and the proportion of consumption remains steady between 2015 and 2040. Share of residential is 69% in 2015 which marginally decreases to 68% in 2040 in the business-as-usual scenario.

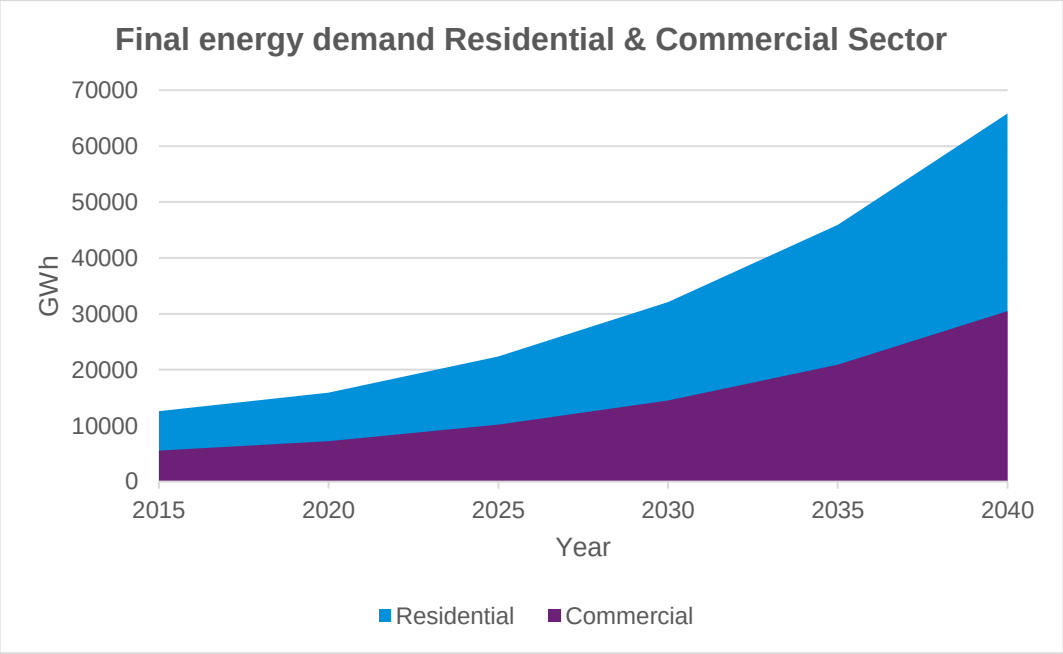
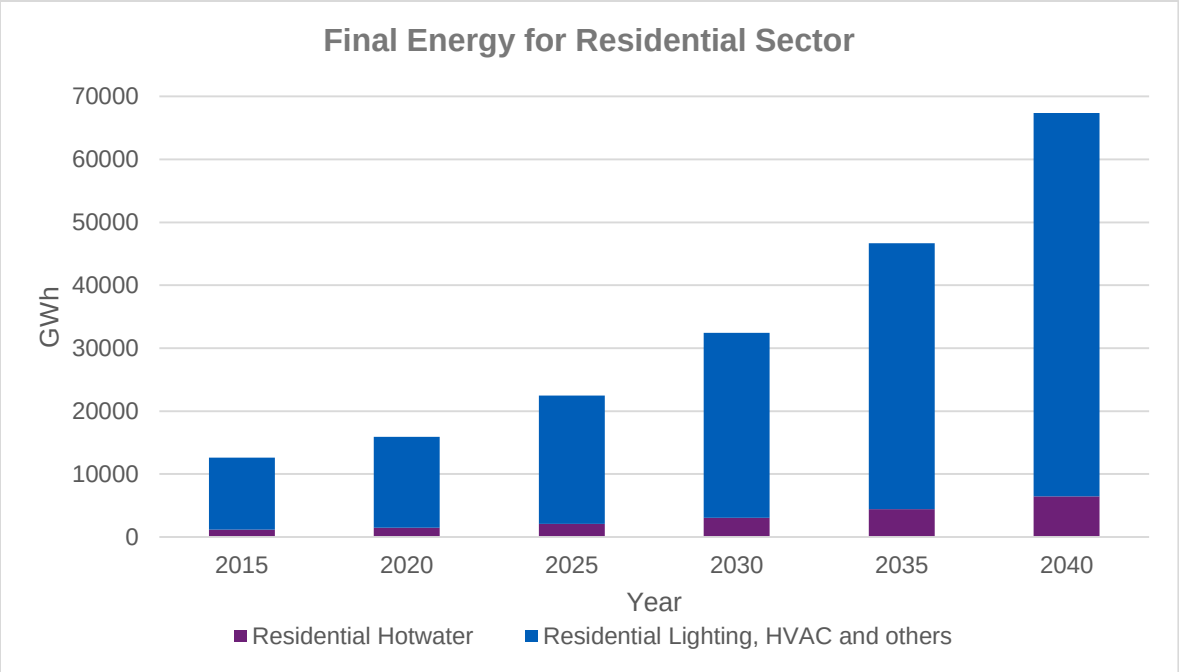


Figure 40: Final energy consumption in buildings sector

The energy consumption for residential sector includes consumption from household appliances including lighting and water heating appliances. Lighting, cooling and other appliances (except water

heating) account for 91% of the total energy consumption in residential sector, the remaining consumption coming from water heating. In case of commercial sector, HVAC, lighting and other appliances (except water heating) accounts for nearly 92% of energy consumption, the remaining 8% being utilized for water heating purposes.



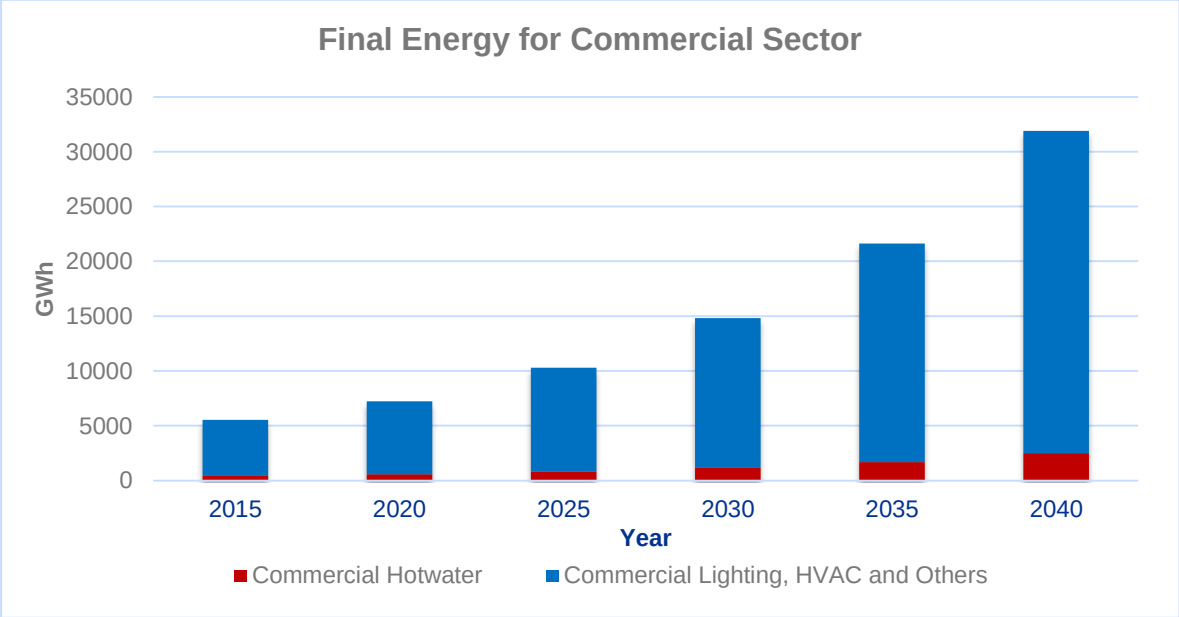


Figure 41: Energy consumption pattern for residential & commercial buildings

C. Existing initiatives undertaken in the state

There are multiple initiatives which are being undertaken in the energy sphere for building sector in the state as given below:

1. ***Energy Conservation Buildings Standards*** (Department of Power & NES, Govt. of West Bengal, 2016). The Government of West Bengal has laid down the West Bengal Energy Conservation Building Code (WB-ECBC), 2016 has laid down the technical standards that need to be adhered to the new and existing commercial buildings or building complexes that have a connected load of 100kW or greater or a contract demand of 120 kVA or greater. The code has been adopted from Energy Conservation Building Code, 2007, National Building Code 2005.

   However, since ECBC-C 2017 has already been notified, a renewed effort is being undertaken to update the WB-ECBC to these standards. It is expected that the amended WB-ECBC would be notified within 2019. Also, efforts are being undertaken to incorporate the amended Building Standards in the Municipal by-laws through discussions with Kolkata Municipal Corporation and Urban Development and Municipal Affairs Department. Based on the output of discussions, it is expected that these standards would be suitably incorporated once the new standards are notified.

2. ***Unnat Jyoti by Affordable LEDs for All (UJALA) Scheme.*** UJALA, launched in 2015, is a Central Government scheme which aims to increase uptake of energy efficient appliances by households. It started with the distribution of the LED bulbs and has now expanded to LED tube light and energy efficient fans. The current status of the programme in West Bengal is given in the table below (National Ujala Dashboard, EESL, 2019):

Table 16: Details of UJALA scheme in West Bengal

No.	Appliance	No. Distributed	Annual Energy Savings (MWh)	Annual CO_2 emission reduction (tCO_2)
1.	LED Bulb	92.3 lakh	12.0 lakh	9.7 lakh
2.	LED Tubelight	6.7 lakh	0.29 lakh	0.24 lakh
3.	Energy Efficient Fans	0.6 lakh	0.05 lakh	0.04 lakh

   The aim of the programme is to distribute 77 crore LEDs by March 2019 in 100 cities across the country.

3. ***Green City Mission (UD&MA Dept., Govt. of West Bengal, 2017)***
   The Green City Mission is a flagship project by the Government of West Bengal, launched in 2017 to meet the growing challenge of rapid urbanization by building environment friendly, sustainable, liveable, energy positive, IT friendly and safe city with a focus on creation of jobs and building affordable housing for poor. In 2 years of its operation (Times of India Article, 2017), (Housing.com article, 2018) projects with a value of over INR 2000 crore has been sanctioned. The project is executed as a State Government sponsored project wherein there are multiple components under which activities will be implemented by concerned ULBs (125 nos.) and Development Authorities (20 nos.) with Urban Development & Municipal Affairs Department acting as Nodal Department.

It contains a component on 'Energy Positive' cities, which focusses on the following aspects related to energy:

a. Installation of solar panels with net metering facilities at important buildings
b. Use of LED for street lights and encouraging use of LED lights for residential consumers
c. Encouraging new buildings to be green certified and
d. Encouraging electric mobility including e-rickshaw

The projects which have been sanctioned in the last 3 financial years have the following energy related components (UD&MA Dept., Govt. of West Bengal, 2019):

a. Replacement of existing street lights with LED lights
b. Installation of LED lights in new street
c. Installation of high mast LED lights

4. Other National Level Initiatives

HVAC systems consume significant amount of energy (around 65% consumption of commercial building is from HVAC). In order to effectively manage the energy consumption in cooling, the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India has published draft India Cooling Action Plan in September 2018[23] which provides recommendations to optimize energy consumption for cooling under multiple sectors including buildings.

India has also participated in District Energy in Cities Intitative of United Nations Environment Programme (UNEP) which aims to develop modern district energy systems, utilizing renewables, waste heat, thermal storage, power grids, thermal grids and heat pumps, which can provide heating and cooling requirements of buildings across a neighbourhood or entire city. Amravati is the 1st city in India which will receive funding for installation a district cooling system under the UNEP initiative. A district cooling system is already operational in Gujarat International Finance Tec-City (GIFT City) since April 2015 (REHVA, 2017) and the greenfield smart city Raiya in Gujarat will witness deployment of such a system under India's Smart City Mission (Smart Cities Council - India, 2017).

D. Description of Balanced Growth Scenario for sector

The energy demand for residential and commercial sector as shown in Figure 42. The treatment for residential sector excludes energy required for cooking. It is observed that growth rate of energy demand in residential sector is expected to increase at 6.8% while commercial sector's energy demand is expected to increase at a rate of 7%.

[23] For further study: India Cooling Action Plan - Draft

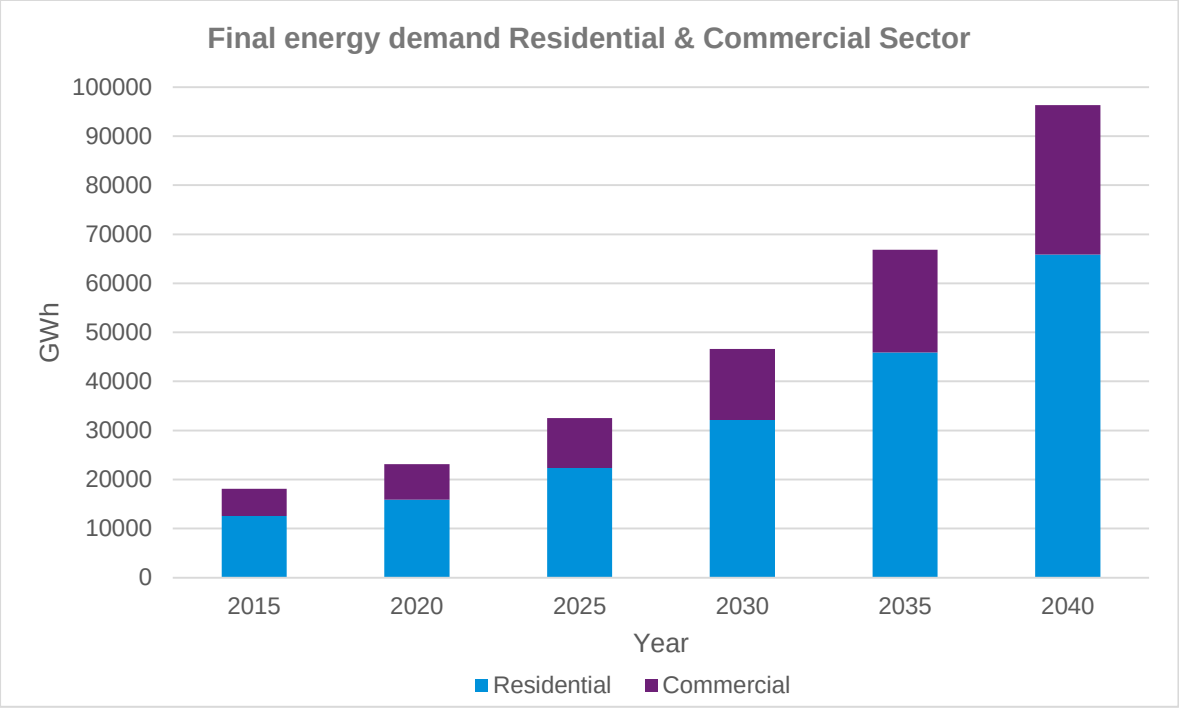


Figure 42 Final Energy Demand in Residential & Commercial Sector in GWh

In the residential sector that includes cooking energy use, it is observed from Figure 43 that in spite of all energy efficiency measure the demand from lighting, HVAC and others is expected to grow at a good rate of 6.9% from 11420 GWh in 2015 to 60935 GWh by 2040. Final energy demand for residential hot water is expected to increase from 11420 GWh in 2015 to 60935 GWh by 2040.

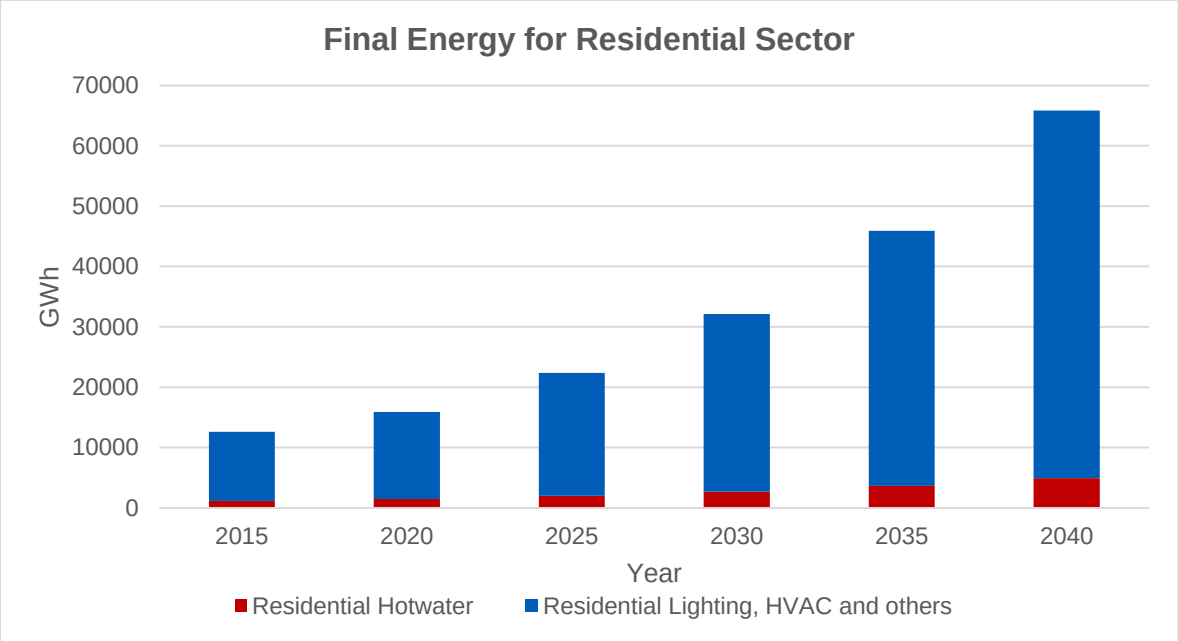


Figure 43 Residential Energy Split

In the fuel mix of the final energy of residential sector, it is observed that electricity demand is expected to increase from 14337 GWh in 2015 to 79864 GWh by 2040. Biomass as a fuel has major share in the total fuel mix which stands at 86251 GWh in 2015 and expected to reach 6178 GWh by 2040 due to inter fuel switching.

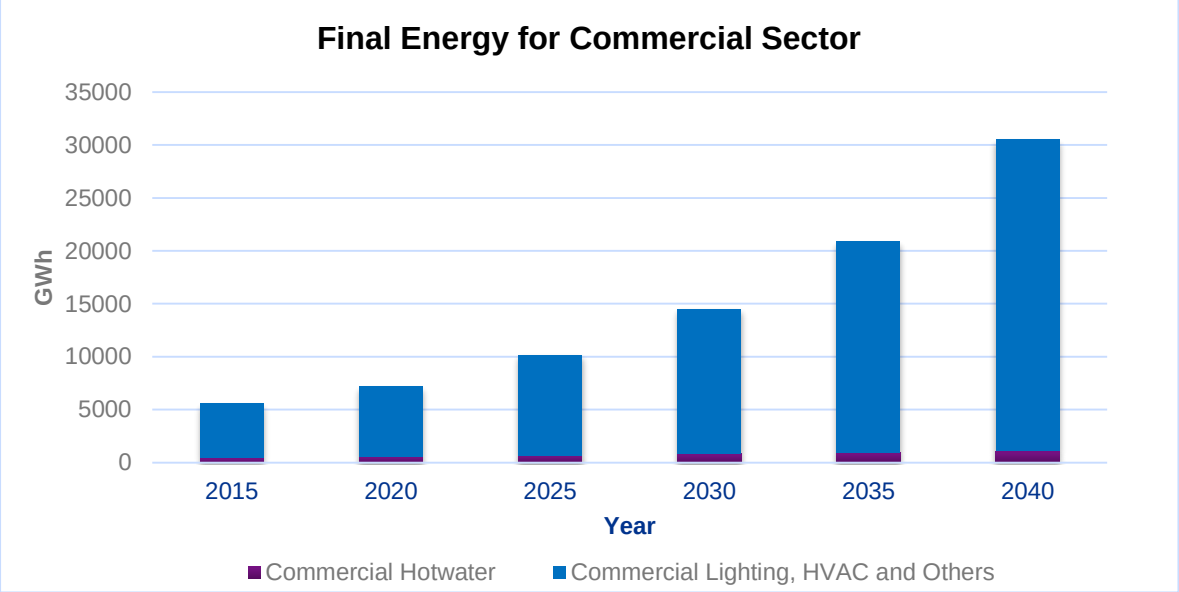


Figure 44 Final Energy for Commercial Sector in GWh

In the commercial sector, electricity consumption will increase from 5101 GWh in 2015 to 29396 GWh by 2040 as given in figure above. Similarly, final energy demand for commercial hot water use is expected to steadily increase from 433 GWh in 2015 to 1089 GWh by 2040.

E. Sectoral Vision

Residential and commercial sector combined accounts for nearly 15% of the total energy consumption of the state and is the 3rd most energy intensive sector. Penetration of ECBC compliant buildings is low since updated code is to be released as well as the institutional structure for implementation yet to be defined. Uptake of energy efficient appliances and solar water heating is voluntary and there is limited awareness of their benefits among consumers.

Vision:

State will achieve improvement in energy performance of buildings through focus on energy efficiency and increased use of renewables

F. Action Plan

Residential Sector

a) **Objective:** State shall increase penetration of energy efficient appliances and solar water heaters

Activity:

A.1: State shall provide incentives to retail consumers for increasing uptake of energy efficient household appliances

A.2: State shall provide financial incentives for increased uptake of solar powered water heater

b) **Objective:** State shall increase penetration of energy efficient residential buildings

Activity:

B.1: State shall proactively prepare ECBC for residential sector and provide adequate institutional, regulatory and infrastructural support to ensure strict implementation

B.2: State shall generate awareness about energy conservation in building construction among relevant stakeholders

Commercial Sector

a) Objective: State shall increase penetration of energy efficient appliances and solar water heating

Activity:

A.1: State shall create market mechanism to increase retrofitting of existing inefficient equipment with energy efficient variants and existing electrical water heating arrangement with solar powered heaters.

A.2: State shall undertake outreach programs for relevant stakeholders to increase awareness of benefits of energy efficient appliances and solar water heater

b) Objective: State shall increase penetration of energy efficient buildings

Activity:

B.1: State shall design and implement robust institutional, regulatory framework along with adequate infrastructure support to ensure implementation of codes

B.2: State shall ensure adequate market capacity is present to ensure increased implementation of ECBC.

B.3: State shall increase awareness of relevant stakeholders on the benefits of adopting ECBC as well as prevalent regulatory requirements for compliance to ECBC.

Table 17: Action Plan for Buildings Sector

No.	Sector	Activity	Sub Activity	Time period	Type of Intervention	Responsible stakeholder
1.	Commercial Buildings	Implementation of ECBC-C	Develop model regulation for ECBC implementation in state and ensure incorporation of regulation in municipal bye-laws of relevant municipal authorities	Short	Regulatory/ Policy	DoP, UD&MA
2.			Develop ECBC implementation roadmap along with requisite supporting infrastructure	Short	Institutional	UD&MA
3.		Market development to facilitate implementation of ECBC-C	Undertake awareness programs on building energy conservation and efficiency as well as building labelling systems	Short to Medium	Awareness/ Capacity	WBSEDCL
4.			Provide support to businesses institutional and regulatory support to businesses providing ECBC compliant building material and BEMS	Short to Medium	Market Development	UD&MA
5.			Undertake the energy conservation buildings awards to incentivize uptake of energy efficiency and energy conservation	Short to Long	Financial	WBSEDCL
6.		Increase uptake of energy efficiency and energy conservation measures	Undertake retrofitting of existing equipment with energy efficient variants along with implementation of energy conservation options for building envelope in public buildings	Short to Medium	Technical	DoP, WBSEDCL
7.	Residential Buildings	Increase uptake of energy efficient appliances	Develop and implement loyalty program for building efficiency	Short	Financial	UD&MA
8.			Develop awareness of retail buyers on the benefits of energy efficiency for buildings and building labelling program	Short to Medium	Technical	WBSEDCL
9.		Demand response system	Develop implementation roadmap for demand response system	Medium to Long	Technical	DoP, UD&MA
10.		Implementation of ECBC-R	Develop implementation roadmap of ECBC for residential buildings	Short to Long	Institutional	UD&MA, WBSEDCL
11.		Increase penetration of solar water heater	Provide financial incentives to increase uptake of solar water heaters	Short to Long	Financial	DoP

G. Description of sub-activities

1. Develop model regulation for ECBC implementation for incorporation in municipal bye-laws of relevant municipal authorities

According to the ECBC notification of 2016 developed by DoP and in line with the national code, the code was notified to be mandatory to all eligible buildings. However, unless the code is incorporated in the municipal bye-laws of respective municipal authorities across West Bengal, the adoption would be low and there be would no way to enforce the code. Since the state is in the process of revising the state ECBC based on national ECBC 2017, steps for incorporation in municipal bye-laws can be actively pursued.

In order to facilitate the development of model regulation for the State, the Ministry of Urban Development, Government of India has prepared "Model Building Bye-Laws 2016"[24]. Guidance for a developing a regulation more attuned to the regional considerations of West Bengal can be taken from the document and appropriate changes can be made in consultation with sectoral experts, UD&MA and the ECBC Implementation Cell of the WBSEDCL.

2. Development of implementation roadmap for ECBC adoption

In order to facilitate a seamless implementation of the ECBC guidelines, once it is incorporated in the municipal bye-laws, an implementation roadmap needs to be developed. In this regard, the Greater Hyderabad Municipal Corporation has been the first municipality in India to incorporate and implement the ECBC guidelines (Mercom India, 2018). Based on the Hyderabad model, a building approval process that can be developed for West Bengal is given below:

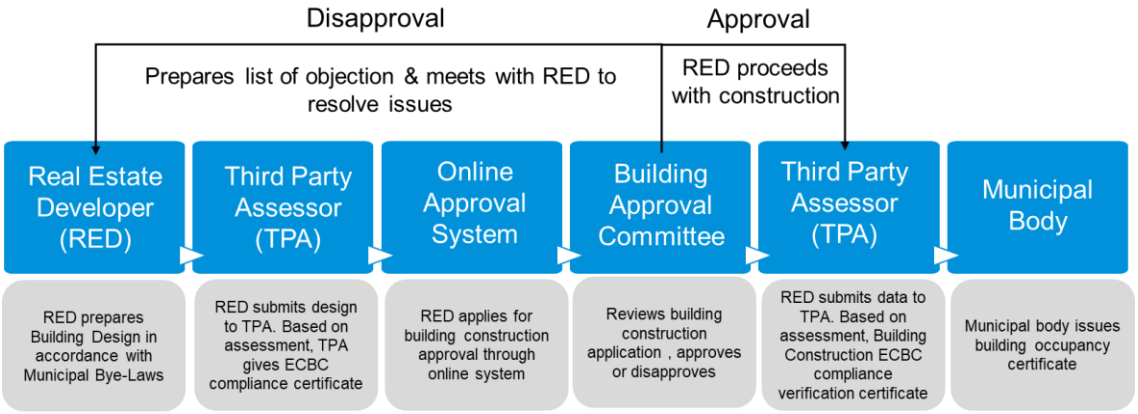


Figure 45: Flow-chart for model ECBC approval system

With reference to the figure above, the role of the various stakeholders is given as follows:

a. Real Estate Developer (RED): Prepares design in consultation with architect and MEP (Mechanical, Electrical and Plumbing) consultants which are compliant with the requirements laid down in the Municipal by-laws.

b. Third Party Assessor (TPA): A firm consisting of the Certified Energy Auditor certified under Bureau of Energy Efficiency (Certification Procedures for Energy Auditors and Energy Managers) Regulations, 2010 and individual Certified Energy Auditors (Building). During design phase, a

[24] For further details: Model Building ECBC Bye-Laws 2017 (India Environment Portal, 2017)

TPA would be responsible for assessing the building design submitted by RED and provide ECBC compliance certificate, if the design is found complying with Municipal by-laws. Also, during the construction phase, assess the data provided by RED i.e. materials used, certificates etc. to conclude whether ECBC design standards are being implemented. Based on this assessment, the TPA will issue a Building Construction ECBC compliance verification certificate, which will form the basis of issuing Building Occupancy Certificate by the Municipal body.

c. Building Approval Committee: A statutory committee within the Municipal body which would include personnel from the body along with independent experts who are certified Energy Auditors (Building). The committee would be responsible for reviewing submitted building plans and ensure compliance of the plans with ECBC requirements, providing response to ECBC requirements and process as well as tracking and reporting progress.

In order to ensure that the implementation mechanism will function smoothly, the follows preparatory steps need to be undertaken:

a. Development of adequate number of third party assessors for ECBC:
   Since the ECBC code will be mandatory, adequate number of TPA should be available in the market to review the building plans. Bureau of Energy Efficiency is in the process of setting up an examination program to build competent professionals who can verify the compliance of ECBC in buildings. (Bureau of Energy Efficiency, 2018). In order to stimulate the market for Certified Energy Auditors (Building), the following activities can be undertaken:
   i. Upon successful completion, provide part reimbursement of the fees borne by a candidate in acquiring energy auditor certification
   ii. Conduct awareness sessions in organizations employing architects and engineers who can meet the eligibility criteria for Energy Auditor (Buildings) (Bureau of Energy Efficiency, 2019)

   The TPA need to be empanelled with the Municipal Body in order to assess any building design plan.

b. Equip Municipal bodies with ECBC compliance:
   The Municipal bodies, specifically, the personnel involved in approval of building plan, need to be made aware of the ECBC codes and its significance. In this regard, the ECBC cell constituted in the state can form a Technical Committee at ULB level for capacity building of the personnel. A Technical Committee can support a single municipal body or a collection of multiple municipal bodies based upon the requirement, as determined by the ECBC cell. The Technical Committee can comprise a group of experts empanelled by the Department of Power & NES.

c. Online Approval System:
   In order to increase clarity of the process of certification involved in sanctioning the building plan, increase transparency of the approval system as well as decrease the manpower requirement from Municipal body an online approval system needs to be established. A pre-requisite for setting up the system is identifying the process flow and the corresponding documentation requirement for each activity of the process. The online system should provide the operational guidelines and the forms required in the approval process.

d. Constituting Building Approval Committee:

In order to approve the building plans being submitted for approval, a dedicated committee needs to be setup comprising technical personnel with a combined knowledge of the state ECBC guidelines as well as state municipal bye-laws. The committee members should preferably be from Department of Power & NES and the Urban Development & Municipal Affairs Department.

3. Undertake awareness programs on building energy conservation and efficiency as well as building labelling systems

Adopting ECBC at the local level is the first step in successful implementation. The next step is to motivate the terminal level stakeholders/actual users i.e. citizens, project developers, commercial property owners conform to the code by helping them understand the financial, environmental and health benefits received by adopting the code. End-user buy-in is pivotal for successful implementation of ECBC and realizing the objectives of the code.

In order to gain stakeholder support and build general capacity, stakeholder outreach programmes need to be organized with the aforementioned target stakeholder group. Apart from the on-ground planning involved in organizing such events, certain back end activities need to be undertaken to prepare the material for the events. Such back end activities, along with the reference material to be referred for completing the specific activity, is given in the table below (US Dept of Energy's PNNL, 2016):

Table 18: Summary of recommended awareness generation activities

No.	Activity	Stakeholders to be referred	Description/Reference material
1.	Agenda templates for stakeholder meetings	Local government	a. PNNL[25] has organized state- and local-level stakeholder meetings to introduce ECBC and gain stakeholders' support. Agenda template from these meetings are provided in the PNNL's Toolkit for ECBC Implementation[26]
2.	Training materials for conceptual understanding	Local government Building owners Building developers Architects and engineers Building industry professionals	a. USAID and BEE developed ECBC training materials to introduce ECBC basics. b. Training modules introducing ECBC requirements are provided[27]. c. PNNL developed training material for local code officials, which provides a brief overview of ECBC and its benefits[28]
3.	ECBC benefit analysis	Local government Building owners Building developers	a. PNNL conducted a benefit analysis for ECBC in Gujarat to show the potential for energy and economic savings in comparison with other building energy programs[29]

[25] PNNL is Pacific Northwest National Laboratory, one of the United States Department of Energy national laboratories, managed by the Department of Energy's (DOE) Office of Science. PNNL scientists conduct basic and applied research and development in multiple fields including increasing the U.S. energy capacity, reducing dependence on imported oil and reducing the effects of human activity on the environment.
[26] For further information, refer: Implementing the Energy Conservation Building Code: Toolkit for Smart Cities
[27] For details: ECBC Training Modules 1 to 8 (BEE Website, 2016)
[28] For details: Energy Conservation Building Directive – 2018 (PNNL, 2018)
[29] For details: Potential Benefits of ECBC in Gujarat (PNNL-2015)

No.	Activity	Stakeholders to be referred	Description/Reference material
4.	Pilot building case studies	Local government Building owners Building developers Architects and engineers Building industry professionals	a. Malaviya National Institute of Technology wrote a case study of its on-campus ECBC pilot building[30] b. PNNL developed a brochure on the pilot building[31].
5.	City-level case studies	Local government	a. City-level case studies could help local governments have a big-picture view of how ECBC takes effect and interacts with other dimensions of the city. b. Natural Resources Defense Council's report Analyzes and offers recommendations for the Hyderabad buildings sector[32]. **c.** A state-level ECBC progress report for Rajasthan by PNNL is also available[33]

The group of stakeholders given for each activity need to be consulted/interviewed to suitably modify the reference material and make them more relevant to the context of commercial buildings in West Bengal.

WBSEDCL can collaborate with industry associations like Confederation of Real Estate Developers Association of India (CREDAI) to undertake conferences and workshops to develop conceptual understanding of ECBC and spread awareness of benefit of ECBC using building and city level studies developed above.

4. **Provide support to businesses institutional and regulatory support to businesses providing ECBC compliant building material and BEMS**

With the notification of the new ECBC for the state and subsequent incorporation in the municipal bye-laws, compliance with ECBC will become mandatory for construction of new commercial coming under the ambit of the code. This will lead to demand for ECBC compliant building materials, solar water heating equipment, comfort systems and controls, specialized experts for designing and constructing ECBC compliant buildings. In the absence of market players providing aforementioned equipment or services, the implementation of ECBC will fail to achieve its desired results. Hence, there is a need to ensure presence of such market players in West Bengal is a pre-requisite to implementation of ECBC in the state.

In order to undertake the market development activities, DoP/WBSEDCL can undertake studies to establish the market potential arising out of implementation of ECBC in the short to medium term. The market studies can provide vital information in developing collaterals to reach out to market players providing equipment and services related to ECBC. WBSEDCL can act the anchor agency

[30] For details: ECBC Compliance and beyond – A Pilot Study (Malaviya National Institute of Technology, 2017)
[31] For details: Pilot ECBC-Compliant Building in Jaipur (PNNL, 2016)
[32] For details: Analysis and Recommendations for the Buildings Sector from the Hyderabad Experience (NRDC website, 2011)
[33] For details: Capturing Energy-Saving Opportunities: Improving Building Efficiency in Rajasthan through Energy Code Implementation (PNNL, 2016)

which will co-ordinate and organize the events (roadshows, conferences etc.) for reaching out to the market players for developing their businesses in West Bengal in the following areas:

a. Developing training institutes/conducting certification courses in the state to develop capacities in designing ECBC compliant buildings and assessing compliance of building design with ECBC
b. Establish manufacturing units/development centres for manufacturing and developing ECBC compliant equipment, material and control systems.
c. Establish testing centres and develop capacity in the state for testing compliance of material and control systems with the state ECBC.

5. State Energy Conservation Awards for Buildings

For promotion & awareness of ECBC and energy conservation in general, a State Energy Conservation Award can be given to those consumers of industrial, commercial, government buildings, educational institutions, hospitals, municipal committees / corporations and individuals who have excelled in adopting the various energy conservation measures in their buildings / units to save electricity / other fuels. A breakup of the various categories and the corresponding prize money that can be considered for the state is given below:

Table 19: Details of state energy conservation awards for buildings

No.	Category of Consumers	Prize Money
1.	Any type Commercial Buildings (Shopping Malls/ Plazas / Hotel/ Hospitals/Corporate/ Resorts etc.) including ECBC compliant buildings: i. Connected Load 1 MW and above ii. Connected Load below 1 MW	i. First prize Rs.2.0 lac and certificate & Shield ii. Second Prize Rs.1.0 lac and certificate & Shield i. First prize Rs.1.0 lac and certificate & Shield ii. Second Prize Rs.0.50 lac and certificate & Shield
2.	Govt. Buildings/ Offices with covered area of min. 5000 sq. feet. including LEED/green Building, GRIHA rated or ECBC Compliant building: i. having connected load above 500 kW ii. having connected load below 500 kW	i. First Prize Rs.2.0 lac and certificate & Shield ii. 2nd Prize Rs.1.0 lac and certificate & Shield i. First Prize Rs.1.0 lac and certificate & Shield ii. 2nd Prize Rs 0.50 lac and certificate & Shield
3.	Institutions & Organizations (Pvt. Schools/ Universities, Colleges educational, Govt./ Govt. aided Schools/Universities/ Colleges, Organizations: i. Having connected load more than 30kW ii. Having load more than 10kW	i. First Prize Rs.2.0 lac and certificate & Shield ii. 2nd Prize Rs.1.0 lac and certificate & Shield i. Rs. 0.50 lac and certificate & Shield
4.	Innovation/ New Technologies / R&D Projects including innovative promotional Projects, Research & Innovation in energy conservation, energy efficiency, Waste to Energy and Renewable Energy Area	i. First Prize Rs.2.0 lac and certificate & Shield ii. 2nd Prize Rs.1.0 lac and certificate & Shield

In order to evaluate the respective entry an evaluation criteria needs to be developed. A set of model evaluation criteria that can be considered are as follows:

Table 20: Evaluation Criteria for State Energy Conservation Awards

<table>
<tr><th>No.</th><th>Parameters</th><th>Max. marks Allotted</th></tr>
<tr><td>1.</td><td>Detailed Energy Audit conducted once in last three years by:
a. BEE Accredited Energy Auditor firms (copy of the detailed energy audit needs to be enclosed with the application). (Maximum Marks 30) or
b. BEE Certified Energy Auditor Firms (Third Party) having minimum Three Year Working Experience with desired measuring equipment (Maximum Marks 20)
b. BEE Certified Internal Energy Auditor (Maximum Marks 10)</td><td>30</td></tr>
<tr><td>2.</td><td>Energy Savings due to Implementation of Energy conservation measures
(Mark shall be given equal to the percentage of energy saving in comparison to last year with maximum 30 marks if the energy saved is 25% or more (e.g. if the energy saved is 10% compare to the last year, 10 marks shall be given). (if Operational)</td><td>30</td></tr>
<tr><td>3.</td><td>Investment made by the firm for implementation of recommendations mentioned in the detailed energy audit report.
<table>
<tr><td>Investment implemented for energy audit report recommendations</td><td colspan="3">Marks for each category</td></tr>
<tr><td></td><td>BEE Accredited Energy Auditor</td><td>BEE Certified Energy Auditor</td><td>BEE Internal Energy Auditor</td></tr>
<tr><td>>50%</td><td>25</td><td>20</td><td>15</td></tr>
<tr><td>>35-50%</td><td>20</td><td>15</td><td>10</td></tr>
<tr><td>>25-35%</td><td>15</td><td>10</td><td>5</td></tr>
</table></td><td>30</td></tr>
<tr><td>4.</td><td>Whether any awareness campaign / training regarding EC measures organized by the industry (proof of campaign/training specifying number of participants)</td><td>10</td></tr>
<tr><td colspan="2">TOTAL</td><td>100</td></tr>
</table>

Nominations from these categories shall be invited through local newspapers and consumer associations. A committee for the purpose of assessing the applications needs to be setup containing members of Department of Power & NES, UD&MA along with the technical consultant empanelled by the Department of Power & NES. The entire process of inviting and assessing applications and presenting the awards through a public ceremony should be undertaken by the SDA for West Bengal i.e. WBSEDCL.

The awards should be supplemented by activities which increase the awareness of real estate developers through stakeholder outreach programmes as elaborated in Sub-activity 3 above.

6. Energy Efficiency in Public Buildings

The State government can replace existing appliances and lighting in commercial buildings with energy efficient variants and recover the costs for replacement through cost savings achieved through the implementation. In the short term, the public buildings (i.e. buildings owned by State Government and its agencies) can be targeted and WBSEDCL being the SDA can be the modal agency for implementing the process

Subsequently the initiative can be extended to other commercial buildings. The implementation of the replacement for public buildings can be completed by the individual departments, with initial funding provided by the State Government. Subsequently departments can payback the cost of replacement to the State Government based on the energy savings achieved.

Table 21: Details of energy efficiency initiative in public buildings

No.	Appliance	Net Power savings at State for commercial consumers (MU)	Net Power savings through initiative (MU)	Net cost savings/yr (INR Cr)	No. of Units	Net Cost (INR Crore)	Payback period (yr)
1	Fans	2789	279	666	3745684	1348	2.03
2	HVAC (Central AC system)	558	56	6656	74914	1498	0.23
3	HVAC (Standalone AC)	2231	223	14303	139444	641	0.04
4	LED Tubelight	3100	310	277	6672329	367	1.32
TOTAL		**8677**	**868**	**21901**	**21901**	**3855**	**0.18**

Assumptions:

1. Average hours of operation/day = 8 hrs
   No. of working days per month = 22
   No. of working days/yr = 22*12 = 264;
   No. of working days where fans & HVAC are operational = 22*9 = 198
2. Per unit power cost = INR 8.94 (WBSEDCL, 2017)
3. Net power savings at state level in 2040 for commercial consumers from WB Energy Model Analysis (West Bengal Energy Model Analysis , 2019)
4. 10% of commercial buildings' consumption is considered from public buildings
5. Cost & rating of super-efficient fan is INR3600 and 28W respectively (Online shopping site [Amazon India], 2019)
6. Cost & rating of LED tubelight is INR 550 and 18W respectively (Onlie Shopping Site [Amazon india], 2019)
7. Savings between 1.5 T 5star & 0 star rated is 1010W (Lloyd, 2018) & price of 5star AC is INR 57,000 (Online Shopping Site [Amazon India], 2019)
8. 50% of savings HVAC due to introduction of EE ceiling fans, 40% from energy efficient standalone ACs & 10% from energy efficient HVAC system
9. Cost of central ac system is INR 2,00,000 (Online shopping site [Indiamart], 2019)
10. Retrofitting in existing public buildings are completed between 2020-30 & since ECBC is expected to be implemented within 2025, all new construction is expected to be energy-efficient

7. Loyalty program for private buildings

In order to provide incentive to users to increase uptake of energy efficient appliances and generate awareness regarding about energy efficient domestic appliance, an Energy Efficient (EE) Point scheme can be undertaken.

Under this program, each consumer will receive EE points for buying energy efficient appliances & lighting. EE points can only be gained by purchasing products with four or more stars as per BEE appliance rating standards and labelling. The number of loyalty points will increase on the basis of the start rating of appliance being bought – a higher star rating translating in to higher loyalty points.

The points can be exchanged for three types of goods: coupons and prepaid cards, energy-efficient products or products that promote regional economies. More points can be gained for a small fee by handing over old products for upcycling to a new appliance.

A similar program can be undertaken for building construction, where BEE also has star labelling. Here EE points are given to people who build a green home or undertake energy-efficient remodelling and undertake the BEE labelling program. The eco-points can be exchanged for eco-friendly products or gift certificates or used for additional renovations.

8. Develop awareness of retail buyers on the benefits of energy efficiency for buildings and building labelling program

In order to spread awareness among retail consumers on energy efficient appliances, a webtool has been developed as part of the Action Plan. This webtool can be hosted in the website/mobile phone application of Department of Power/WBSEDCL and can be adequately modified for other discoms as well. The webtool can provide the consumers with detailed analysis on the impact of using energy efficient application on power consumption charges as well as discounted payback period for the investment made on the appliance. Details on the webtool is provided in the section on cross-sectoral activities.

The web-tool can later on be expanded to serve as the means of developing awareness around energy labelling for residential buildings, which was introduced by BEE in February 2019.

9. Develop implementation roadmap for demand response system

Demand response (DR) is a strategy used by electric utility companies to reduce or shift energy consumption from peak hours of the day, when the demand for electricity is the highest to leaner demand periods. It involves allowing customers to choose non-essential loads, which can be shed by the customers themselves or by the utility, at peak times. It is a pre-arranged agreement between the Utility or intermediate agencies like aggregators with the consumer with specific conditions of load, price and time intervals.

The key benefits of implementing a demand response system are as follows (Schneider Electric, 2014):

a. Grid integration of renewables: The intermittent nature of renewable sources, as well as their growing contribution, can potentially lead to grid instability if not balanced. Since such variations is conditional and sometimes unpredictable, utilities need flexible tools that can respond to accommodate such variation. DR is often the most economical tool utilities can use to balance their portfolios. For example, in order to adjust for power overproduction due to renewables, utilities can incentivize some customers to over-consume by reducing power prices.

b. Grid planning: Since power plants and transmission systems are designed to respond to the highest potential demand, lowering peak demand during demand intensive times of the day helps utilities reduce overall installation costs, operating costs and mitigate potential grid failures.

c. Reduced energy consumption costs: Through effective management of power demand, utilities can reduce their cost of power procurement which is transferred to the consumer through dynamic pricing strategies.

The key infrastructural building blocks for implementation of DR System is given below (ISGF, 2015):

a. *End-User Interfaces*: Utilities send signals to the participants of the DR program using a variety of channels, including email, phone, and web portals. In-home or business display devices are another way that utilities can communicate with consumers about an event, including information about energy usage and pricing with smart grid. Consumers need to acknowledge their participation in the program. HAN can be used to connect displays, load control devices and ultimately "smart appliances" seamlessly into the overall smart metering system.

b. *Load Control Devices*: Utilities use a number of different tools to actually cycle systems like heating and cooling on and off during demand response events. Load control switches enable direct remote control over AC units or heating systems. Smart thermostats allow utilities to adjust temperature settings remotely.

c. *Advanced Metering Infrastructure (AMI):* AMI is the collective term to describe the whole infrastructure from Smart Meter to two way-communication network to control center equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time. AMI is increasingly being used with DR, because it enables both utilities and end-users to have more robust data about loads, energy usage and electricity pricing.

Apart from the infrastructural requirements, a demand response strategy should also be in place. There are two common demand response strategies used by utilities globally (ISGF, 2015):

a. *Direct Load Control*: It involves remote interruption of customers' energy usage, in which power distributors cycle loads like heating, cooling, elevators, washing etc. on and off at varying time intervals during peak hours of the day.

b. *Dynamic Pricing*: It involves variable electricity rates to encourage customers' voluntary curtailment during demand response events. Utilities use a variety of pricing schemes including peak time rebates, critical peak pricing, and time of use rates to curtail usage.

While implementation of DRS can provide substantial benefits to the discom, there are a set of prerequisites for setting up such a system. Since development of the system is dependent on the installation of elements of smart grid, it is recommended that DRS be taken up in medium to long term for the state.

10. Develop implementation roadmap of ECBC for residential buildings

Ministry of Power has launched the ECO Niwas Samhita 2018, an Energy Conservation Building Code for Residential Buildings (ECBC-R) in December 2018 (Press Bureau of India, 2018). Initially, Part-I of the Code has been launched which prescribes minimum standards for building envelope designs with the purpose of designing energy efficient residential buildings. It is expected the other Parts will be released in one-two years. Once released, the State has to undertake the similar activities undertaken for implementation of ECBC for commercial buildings. For guidance, the responsibilities for adoption and enforcement tasks to mainstream ECBC are captured in the following matrix:

Table 22: Summary of activities required to implement ECBC

Tasks related to mainstream ECBC	Responsibilities		
	Central Government	State Government	Local Government
ECBC Adoption			

Tasks related to mainstream ECBC	Responsibilities		
	Central Government	State Government	Local Government
Set-up ECBC committee to implement code		SDA	
Review the ECBC and customization of code to suit regional and climatic conditions		SDA	
Define criteria of applicable building types		SDA	
Make legal notification in the state gazette for mandatory implementation of code		SDA/ UDD	
Develop enabling mechanisms and processes for mainstreaming ECBC	BEE	SDA and UDD	ULBs
Revision of Schedule of Rates (SoR)	CPWD	PWD	
Revision of State General Development Control Rules/ ULB's Building Bye-Laws		SDA and UDD	ULBs
Develop ECBC implementation Rules e.g. Third Party Assessor (TPA) Model	BEE	SDA and UDD	ULBs
Use public online tools/ endorse third party simulation software to show compliance	BEE	SDA	ULBs
Develop technical capacity of building sector stakeholders	BEE	SDA	ULBs
ECBC Enforcement			
Institutionalize mechanisms for enforcement and compliance checking in ULBs & Electrical Inspectorate		SDA	ULBs
Set-up of robust Monitoring and Verification (M&V) system	BEE	SDA	ULBs

Further guidance on fast tracking adoption and implementation of ECBC at urban and local level is available as a report conceived by NITI Aayog and available with BEE[34].

11. Provide financial incentives to increase uptake of solar water heaters

Water heating requirements consume considerable amount of energy. An alternative of reducing energy costs for heating water can be achieved by installing solar water heater. In order to promote the solar heaters in commercial and residential sectors, interest free loans can be provided to beneficiaries. Based on the assessment of the energy requirements for the state, the following figures have been obtained:

Table 23: Details of financial incentive provided for solar water heaters

Time period	Total No. of water heaters	Cost of acquisition (INR Cr)	Cost savings (INR Cr)	Payback period (yr)
Short	14,63,147	2195	1024.2	2.14
Medium	27,05,969	4059	1894.2	2.14
Long	49,11,184	7367	3437.8	2.14

[34] For further information: Roadmap to fast track adoption and implementation of ECBC at urban and local level (AEEE website, 2017)

Assumptions:

i. Cost of solar heater capacity 100lpd is INR 15000 (Intersolar Systems, 2017)
ii. Energy savings of average household in eastern India using solar water heating system is 1000 units (Bijli Bachao, 2016)
iii. Average tariff for household consumers is INR 7/unit (WBSEDCL, 2017)
iv. Interest-free loan provided on cost price of solar heater

H. Investment Required

Investment required in buildings sector for achieving the State Energy Vision, is primarily related to initiatives that lead to increased penetration energy efficient appliances, BEMS, solar water heater and increased construction of buildings compliant with ECBC. In order to calculate investments related to these initiatives, the existing volume of the market is required viz. number of appliances being used, floor area of commercial buildings in the state. Due to the lack of these data points and reliable proxy data to derive the market volume, calculation of investment can be possible only in case of solar water heaters.

Accordingly the investment required to increase penetration of solar water heater is provided below:

Table 24: Investment required for Buildings sector

No.	Particulars	Average cost per unit (INR)	No. of units in 2040	Total Cost (INR)
1.	Solar Water Heater	15,000	49,00,000	~7400 Cr

The following assumptions were considered to calculate the figures above:

1. An average household in West Bengal will require an Evacuated Tube Collector Solar Water Heating system with a capacity of 100 liters per day (Intersolar Systems, 2017)
2. Energy consumption of an average household in eastern India using solar water heating system for 200 days in 1000 units (Bijli Bachao, 2016)

Table 25: Investment planning for Buildings sector

No.	Particulars	Short Term	Medium Term	Long Term
1.	Solar Water Heater	INR 1500/ Cr	INR 2200 Cr	INR 3700 Cr

7.4 Agriculture & Fisheries Sector

A. Brief Description of Sector

The agriculture sector is a major area of economic activity in West Bengal and accounts for 18.33% of the state GSDP and 59% (5.2 million hectares) of state geographical area is under agriculture. The cropping intensity i.e. raising of a number of crops from the same field during one agriculture year, for West Bengal is 184%, while the national average is 142%. The state is the largest producer of paddy, jute, pineapple, brinjal, cabbage and the 2nd largest producer of potato, tea and fish. (Dept. of Agriculture, Govt. of West Bengal, 2019)

The sector is a focus area for the state considering the fact that it employs 57% of the state's workforce under various core and allied activities and 96% of Bengal's farmers are classified as small or marginal farmers. In order to improve the economic condition of workforce in agriculture sector, the state's has increased its expenditure in agriculture and allied activities by more than 6 times from INR 3029 Cr in 2010-11 to INR 20323 Cr in 2017-18. (Dept. of Agriculture, Govt. of West Bengal, 2019).

The major consumption of energy in agriculture sector in general is due to irrigation pumps, tractors, other farm mechanization equipment and post harvesting equipment. Penetration of farm mechanization equipment in West Bengal is low, as exemplified by the mechanization index for major crops in West Bengal given in the chart below (V.K. Tewari, 2012):

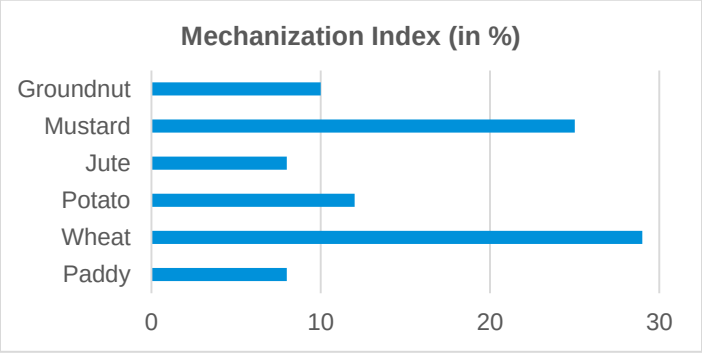


Figure 46: Mechanization level for various crop in West Bengal

The fact that the quantum of Bengal's farmers (as discussed above) are small or marginal i.e. having land holdings less than 2 hectares, justifies the low penetration of mechanized farm equipment in West Bengal. Procuring as well as operating and maintaining mechanized farming equipment requires considerable capital investment, which is mostly not available with the large number of small and marginal farmers.

Within the agriculture sector, fisheries has been considered as a sunrise sector by the State Government. Although West Bengal contains only 7.45% of the total land resources available in the country for fishery, it stands in 2nd place, after Andhra Pradesh, in terms of state wise fish production as on 2014-15 (Fisheries Department, Govt of West Bengal, 2016). The fish production has increased by a CAGR of 3.2% from 1.443 million tonnes in 2010-11 to 1.742 million tonnes in 2017-18. It is estimated that fish production in 2018-19 will reach 1.772 million tonnes. (Department of Fisheries, Govt. of West Bengal, 2019). The fish seed production is led by West Bengal in India and production in 2017-18 stood at 20.177 billion seeds fulfilling 40% of the country's fish seed demand. (Fisheries Dept, Govt. of West Bengal, 2019).

The fish produced in the state is consumed at national level as well as exported beyond to multiple countries viz. USA, Japan, Vietnam, UAE and EU. Major export items include Frozen Shrimp, Frozen Fish, Frozen Squid, Dried Items, Live Items and Chilled Items. Off the 0.17 million tonnes of fish exported to other states and overseas, shrimp exports (totalling to about 70000 tonnes) alone gives the state an annual income of around INR 8000 crore. (Economic Times report, 2018)

Inland fishing has been contributing to nearly 87% of total fish production in West Bengal between 2001 and 2015 (Planning & Statistics Dept, Govt. of West Bengal, 2015). In case of inland fishing, mostly non-mechanized boats are used which contains mostly batchari boats and chot boats (Vikaspedia Article, n.d.). For marine fishing, there are about 7419 mechanized and 4986 non-mechanized boats operating in West Bengal (Dept. of Fisheries, Govt. of West Bengal, 2015). The mechanized boats for inland and marine fishing boats mostly run on diesel and except for trawlers, most of the boats and their drive train are developed by local mechanics with limited technical knowhow on fuel efficiency.

Most of the energy consumption in agriculture sector of West Bengal is in irrigation pumps and tractors. The state has 154182 registered tractors and trailers engaged in the agriculture sector and all of these tractors and trailers run exclusively on diesel. In case of pumps, as on 2014-15, nearly 70% are diesel based, 29.5% are grid power based and 0.05% are solar power based. Even though the share of diesel pumps is high in 2014-15, the number has decreased from 2006-07, when it accounted for nearly 77% of total number of pumps.

For the purpose of the report, agriculture mentioned henceforth would imply agriculture sector including fisheries sector.

B. Energy Consumption of Sector

The energy demand for agriculture sector is primarily from irrigation pumps, tractors and fishing vessels. The state has 1.54 lakh registered tractors and trailers in the state engaged in the agriculture sector and all of these tractors and trailers run exclusively on diesel. As on 2014-15, nearly 70% of pumps were diesel based, 29.5% were grid power based and 0.05% were solar power based. As compared to 2006-07 there has been a gradual shift in fuel mix for pumps from diesel to electric.

For the purpose of the study, consumption by fisheries has been included in transport sector for agriculture. In the baseline year (2014-15), the share of agriculture pumping is 47% which increases to 52% in 2040, on account of increased irrigation requirements in the state.

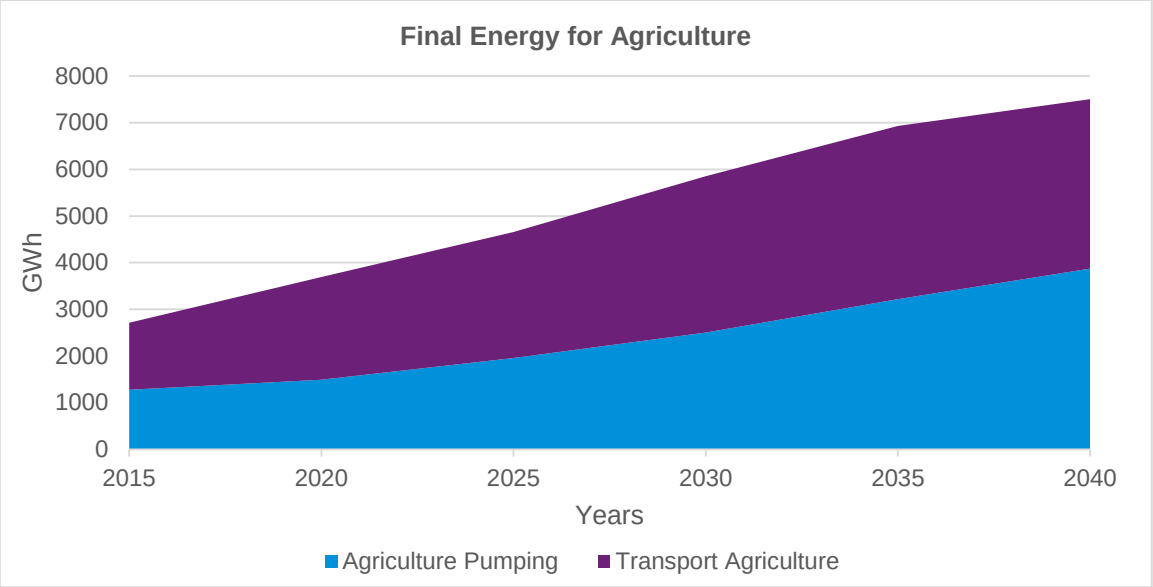


Figure 47: Final energy consumption for Agriculture sector

C. Existing initiatives undertaken in the state

There are multiple interventions being undertaken in the state which have an impact in optimizing the energy consumption in the sector:

1. **West Bengal Accelerated Development of Minor Irrigation Project (WBADMIP):**

   WBADMIP is a project supported by World Bank which commenced in January 2012 and is scheduled to close in December 2019. The project aims to enhance agricultural production of small and marginal farmers in the project area by creation of minor irrigation (MI) schemes involving community-based institutions known as Water Users Associations (WUAs), which includes distribution of solar pumps. Proposed number of beneficiaries under the project is 100000 and proposed irrigated area is 75000 Ha spread across 19 districts of the state (World Bank, 2019).

2. **Pradhan Mantri Krishi Sinchai Yojana (PMKSY):**

   PMKSY is a scheme developed by the Government of India to enhance the physical access of water on the farm and expand cultivable area under assured irrigation, improve farm water use efficiency to reduce wastage and increase availability both in duration and extent, enhance the adoption of precision - irrigation and other water saving technologies (More crop per drop). PMKSY has 3 components off which “Per Drop More Crop” component is being implemented in West Bengal. Accordingly registration documentation has been prepared for bondafide manufacturers satisfying the eligibility criteria for ensuring supply, installation and training of handhold operations and other activities as specified by West Bengal State Watershed Development Agency (WBSWDA) for the scheme.

3. **Rainwater harvesting programme (Jal Dharo-Jal Bharo)**

In order to conserve both ground and surface water in the state, a rainwater harvesting programme named “Jal Dharo-Jal Bharo" was launched during 2011-12. Under this programme, programme rain water is harvested in all kinds of water bodies viz. tanks, ponds, reservoirs, canals as well as underground artificial recharge through rooftop rain water harvesting. The programme is being implemented by the Water Resources Investigation & Development Department (WRIDD) through construction and management of minor irrigation structures such as re-excavation of tanks, check dams, water harvesting tanks and surface flow minor irrigation schemes (WRIDD, GoWB, 2019).

Under this programme, 1,45,743 number water bodies/retention structures have been created/renovated out of which 40,893 equivalent pond have been created by WRIDD, 1,04,850 number water bodies have been created/renovated in convergence with P&RD Department and 311 number tanks have been created/renovated by WRI&DD under MGNREGA.

4. Renewable energy in fishing trawlers

An effort in utilizing renewables for fishing boats was undertaken through a workshop by WBREDA on RE Programme for Fishing Trawler in Deep Sea in 2011. (West Bengal Renewable Energy Development Agency, 2011). There was a discussion between WBREDA and Digha Fisherman and Fish Trawlers Association on solar PV installation for fishing launch, provision of electricity for refrigeration, battery charging arrangement. However, no pilot projects have been reported for the same.

D. Description of Balanced Growth Scenario for sector

The final energy demand for agriculture is expected to increase from 2712 GWh in 2015 to 7503 GWh by 2040 at a rate of 4.15% (See Figure 48). In the final energy demand for transport in agriculture, it is expected to grow at 3.78% from 1436 GWh in 2015 to 3631 GWh by 2040. Similarly, in case of agriculture pumping the growth is expected to be 4.54% from 1275 GWh in 2015 to reach 3872 GWh by 2040.

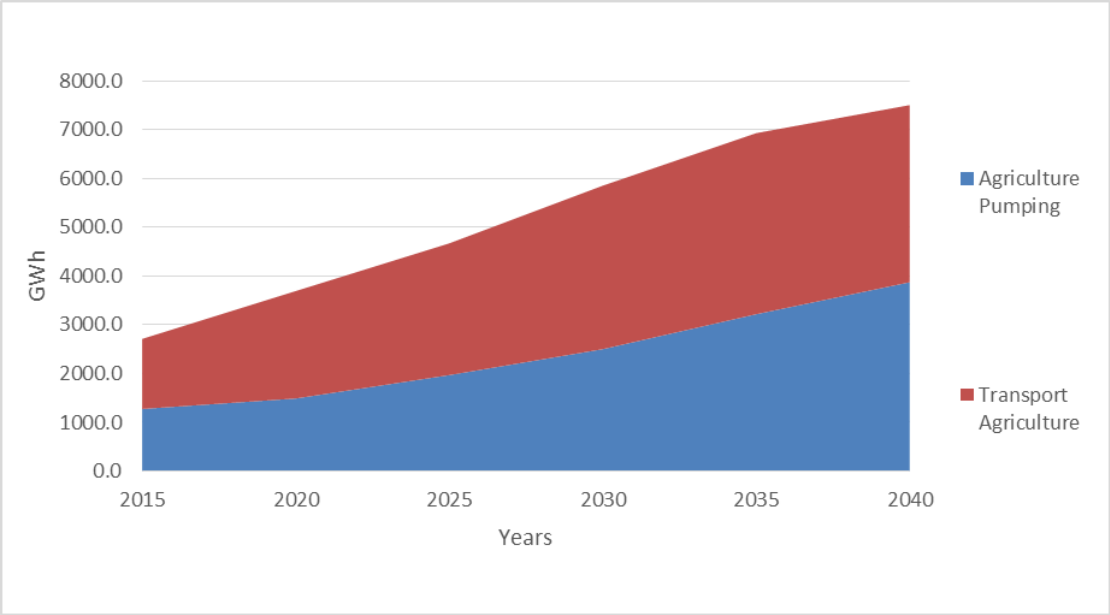


Figure 48 Final Energy for Agriculture in GWh

Due to de carbonisation in the agriculture pumps by removal/replacement of oil based pumps, it is expected that the energy demand of oil based pumps will decrease at a rate of 2% from 631 GWh in 2015 to 385 GWh by 2040. The growth of electric grid based pump is expected to increase by 8% from 484 GWh in 2015 to 3323 GWh by 2040. Similarly, penetration of solar based pump is expected to grow by 5.9% from 38 GWh in 2015 to 163 GWh by 2040.

E. Sectoral Vision

In the baseline scenario, agriculture (including fisheries) sector accounts for 1% of the total energy consumption of the state. Although agriculture sector witnesses a robust growth from 2015 to 2040, the energy intensity in the sector is low due to limited farm mechanization. However, there is a large scope for energy efficiency and enhancing energy conservation which can have a positive impact on enhancing farmers' income, improve farm productivity as well as lead to resource conservation. The existing policies and their corresponding targets can help achieve the intended energy goal for the state. Particular to fisheries sector, the consumption of diesel from trawlers can be reduced by maximizing use of renewables and increasing fuel efficiency leading to reduction of operational costs.

Vision:

State shall ensure positive impact on the livelihood of farming and fishing community and maximize utilization of resources by reducing the costs involved in fuel consumption

F. Action Plan

Agriculture Sector

a) **Objective:** State shall replace 85% of energy requirement for pumping from diesel to electricity, off which 4% of requirement shall come from solar power

Activity:

A.1: State shall increase penetration of solar pumps by developing adequate financing mechanisms

A.2: State shall create market mechanisms as well as generate awareness to increase uptake of energy efficient pumps

b) **Objective:** State shall improve energy efficiency and increase penetration of renewables in post-harvest activities

Activity:

B.1: State shall increase penetration of solar power micro cold storage

B.2: State shall increase private sector participation in establishing energy efficient post-harvest processes and infrastructure

Fishing Sector

a) **Objective:** State shall increase penetration of solar power and energy efficiency in fish harvesting processes

Activity:

A.1: State shall ensure a shift of fuel for fishing vessels from diesel to solar

A.2: State shall ensure fuel efficiency of marine and inland fishing vessel.

Table 26: Action plan for agriculture and fisheries sector

No.	Sector	Activity	Sub Activity	Time period	Type of Intervention	Responsible stakeholder
1.	Agriculture Sector	Increase penetration of energy efficiency and solar power in value chain	Distribution of energy efficient pumps to replace existing electric pumps	Short to Medium	Technical	WBSEDCL
2.			Develop co-operatives to provide financial support for procurement of solar pumps and energy efficient pumps by farmers	Short to Medium	Financial	WRID, Agri Dept.
3.			Assess potential for energy efficiency in cold chain and develop implementation roadmap	Short to Medium	Technical	WRID, Agri Dept.
4.			Undertake awareness programmes for disseminating benefits of energy efficient pumping and irrigation systems as well as solar powered pumps to farmers through co-operatives, gram panchayats etc.	Short to Medium	Awareness	WRID, Agri Dept.
5.	Fisheries Sector	Increase penetration of solar power and energy efficiency in value chain Increase energy efficiency in value chain	Develop and implement financial mechanisms to increase uptake of solar power options in fishing vessels	Short to Medium	Financial	Fisheries Dept.
6.			Undertake awareness programs to disseminate benefits of switching to solar power for fishing vessels	Short to Medium	Awareness	Fisheries Dept.
7.			Undertake stakeholder outreach programs to create awareness on the methods of increasing fuel efficiency of marine fishing vessels	Short to Medium	Awareness	Fisheries Dept.

G. Description of sub-activities

1. Distribution of energy efficient pumps

Bureau of Energy Efficiency (BEE) has undertaken the replacement of agricultural pumps in 8 states across 11 discoms, wherein inefficient agricultural pump sets is being replaced with BEE 5 star-rated energy efficient pump sets. Farmers are being offered a zero-cost energy efficient pump set (EEPS), and a long-term partnership with EESL under the ESCO model. The initial cost of installing pumps is undertaken by EESL and it recovers the EEPS cost over a mutually agreed period of time by monetizing energy savings. EESL also offers free repair maintenance during the 5-year project duration, further incentivizing farmers to adopt newer and more efficient models.

WBSEDCL can work with BEE to bring the program in West Bengal where it would on a similar model. Based on the information developed in the WB Energy model, the following investment potential is present in replacement of energy efficient pumps in West Bengal:

Table 27: Details of energy efficient pumps distribution scheme

Term	Total no. of Pump addition	Target Penetration	Nos.	Net Cost (INR Crore)	Power savings (MU/yr)	Cost savings/yr (INR Crore)	Payback period
Short	213384	10%	21338	42	16	6.37	6.65
Medium	148030	40%	59212	117	44	17.67	6.65
Long	399684	50%	199842	396	149	59.63	6.65

Assumptions:

i. Total no. of electric pumps added in each term taken from WB Energy Model (West Bengal Energy Model Analysis , 2019)
ii. Annual hours of usage of pumps is 1000 hours (NITI Aayog, 2016)
iii. Unit power cost for Agricultural consumers in INR 4/unit (WBSEDCL, 2017)
iv. Cost of energy efficient 4HP 5 star pump is INR 19800 (CRI Pumps, 2017)
v. Energy savings by operating energy efficient pumps for 1 hour is 0.746 unit

2. Develop co-operatives to provide financial support for procurement of solar pumps and energy efficient pumps by farmers

Penetration of solar pumps can be increased by providing loans at less-than-market rates through co-operatives and gram panchayats. The co-operatives shall be adequately supported by civil society organizations (CSOs) mobilized by the State Government. An annual interest rate of 2% will be charged for the loan. The CSOs shall be provided with technical knowhow to provide technical assistance to farmers willing to opt for solar pumps and educate them about the operational.

Based on the penetration of solar pumps obtained from West Bengal Energy Model, the following investment potential has been derived:

Table 28: Details of solar pumps distirbution scheme

Term	Target penetration	Target (in nos.)	Cost of solar pumps (INR Cr)	Annual interest (INR Cr)	Annual operating cost (INR Cr)	Annual diesel savings (INR crore)	Actual cost savings (INR crore)	Payback period (in yr)
Short	1%	1001	30	0.60	1.50	9.41	7.31	4.11
Medium	2%	2161	65	1.30	3.20	20.31	15.77	4.11
Long	4%	5610	168	3.40	8.40	52.72	40.94	4.11

Assumptions:

i. Cost of solar pumps is INR 100000/kW as per prevalent market standards
ii. Power rating of average solar pump is 3hp for equivalent diesel pump having 5hp rating (NITI Aayog, 2016)
iii. Unit power cost for Agricultural consumers in INR 4/unit (WBSEDCL, 2017)
iv. Annual hours of usage of pumps is 1000 hours (NITI Aayog, 2016)
v. Operating cost of solar pump is 5% of capital cost (NITI Aayog, 2016)
vi. Annual Fuel usage of 5hp diesel pump is 1150 kg
vii. Density of diesel is 0.832kg/L
viii. Annual Fuel usage for a diesel pumps is 1382L
ix. Cost of diesel is INR 68/L
x. Interest rate for loan is 2%

In case of any farmer wants to opt for energy efficient pumps, over and above the ones who are getting served by the energy efficient pump program described above, they can avail this loan as well. The modalities for disbursal will be same.

3. Increase construction of energy efficient cold storage working on solar power:

The state already has solar powered micro storage facilities in multiple locations. One of the facilities, established in 2014, is in Nadia (Switch-On, 2014) and the other cold storage, commissioned in 2018, is in Hooghly district (The Hindu, 2018). There is a need to commission more of such micro cold storages in future along with retrofitting existing cold storage units with solar power. While solar power in can suffice the power requirements for micro cold storages, larger cold storage units cannot be powered by solar power alone. In such a case, an on-grid solar system can be used to partially provide for the power requirements.

A conventional cold storage has a designed refrigeration load of 120-150 W/m^2. With the application of modern technology in energy efficiency for cold storage, this load can come down to 75 W/m^2 and in case of larger stores, a load of 50 W/m^2 is also achievable (ASHRAE India, 2018). In order to achieve energy efficiency in cold storages, some of the activities that can be undertaken are as follows:

a. Installation of variable speed fans for condensers and room fans. 50% speed equates to an 85% energy reduction
b. Improving insulation of cold storage by installing Polyisocyanurate (PIR) cold store panels
c. Vertical park dock levellers that do not penetrate the cold envelope when not in use
d. Hi-speed bi-parting coldstore doors eliminating need to duplicate door with high speed air curtain
e. Use of energy management systems
f. Energy saving light fittings i.e. installation of LED lights.

In order to promote the measures for increasing energy efficiency in cold storage, the cold storage associations can be mobilized.

4. **Undertake awareness programmes for disseminating benefits of energy efficient pumping and irrigation systems as well as solar powered pumps**

   As discussed under sub-activity 1 and 2, energy efficient pumps and solar pumps provide substantial energy savings and cost benefits. Users should be made aware of the benefit of using the pumps over existing electric/diesel pumps through targeted outreach program. The effective medium for reaching out to individual farmers is through farmers' co-operatives, where workshops can be arranged to disseminate the information.

5. Develop and implement financial mechanisms to increase uptake of solar power options in fishing vessels

   The power requirement of marine fishing vessels is about 100HP (New Indian Express Report, 2018), requiring solar panels which will take considerable area as well as increase the overall weight of the vessel. Alternately, solar power can be used to supply auxiliary power i.e. power required for various purposes e.g. cooking, charging mobile, signal light, selecting fish etc. In most cases, the electric power is supplied by a battery which is charged through a dynamo synchronized with trawler engine. These dynamos require diesel to serve electric power. Solar power can be used instead of using diesel to charge the batteries.

   In contrast to marine fishing vessels, inland fishing vessels have a lower power requirement of around 5-6HP (New Indian Express Report, 2018). Unlike a marine fishing boat where retrofitting of existing fishing vessels is undertaken, new vessels fitted with solar panels can be introduced in case of inland fishing vessel. An interest free loan can be provided to beneficiaries to stimulate adoption of solar option for fishing vessels.

   Pilot projects can be undertaken to introduce solar power in marine fishing vessels. In this case WBREDA can provide technical assistance**,** while financing can be provided by Department of Fisheries. The scheme, promoted through the arms of the Fisheries department directly involved with individual fishermen and marine fishing organizations/associations, should solicit voluntary participation. An initial assessment can be carried out by WBREDA, providing the technical requirements and liaise with independent agency to provide the quotation to the beneficiary. In case concurrence is received from the beneficiary, WBREDA can provide support to the beneficiary in securing finances required for undertaking the project.

   The financial assistance proposed can be divided in to 2 components as given below:

   a. Loans: 90% of the total installation cost can be provided to the beneficiary as interest free loan. The preferred organization for disbursal and monitoring of the loan should be through a co-operative like BENFISH, which has a greater scope of interface with individual fishermen than commercial banks.

   b. Beneficiary capital: 10% of the capital will be paid by beneficiary as a one-time payment. An alternate arrangement of part payments can be provided to the beneficiary provided financial credibility of the beneficiary has been established.

   Based on the assessment in West Bengal Energy Model the following figures have been obtained:

Table 29: Details of mechanism to increase penetration of solar power in inland fishing

Term	Nos. of vessels	Net Cost (INR Crore)	Diesel savings (INR Cr)	Payback period (in yrs)
Short	1000	9	4.8	1.88
Medium	2000	18	9.6	1.88
Long	10000	90	48	1.88

Assumptions:

i. Cost of solar boat is INR 100000 (New Indian Express report, 2019)
ii. Fuel savings if 240 days fishing considered is INR 48000 (ICAR, 2015)
iii. Indicative number of boats taken as targets for the programme. Actual number of inland fishing vessels unavailable for calculation.

Table 30: Details of mechanism to increase penetration of solar power in marine fishing

Term	Target (%)	Target no. of vessels	Net Cost (INR Cr)	Diesel savings (L/yr)	Energy Savings (in MU/yr)	Cost savings (INR Cr/yr)	Payback period
Short	5%	343	1.72	575988	7	4	0.44
Medium	20%	2089	10.45	877464	10	6	1.75
Long	60%	9549	47.75	1336860	15	9	5.25

Assumptions:

i. Cost of solar panel is INR 50/W (Bijli Bachao, 2015)
ii. Total solar power requirement for an average marine vessel is 1000W (IEEE, 2013)
iii. Electricity generated by 4*250W solar modules is 3.5 KWh in 1 day (Navgathi Marine, 2014)
iv. Entire electricity generated is consumed and no battery is installed
v. Power generated by 1L diesel is 10 kWh (DeepResource, 2012)
vi. No. of mechanized marine fishing boats in 2015-16 considering historic growth rate i.e 4.3% is 5794 (Dept. of Fisheries, Govt. of West Bengal, 2015)
vii. Cost of diesel is INR68/L
viii. GCV of diesel 11840 kcal/kg
ix. Density of diesel 0.8263kg/L

6. Undertake awareness programs to disseminate benefits of switching to solar power for fishing vessels

As discussed in sub-activity 5, the use of solar power for inland and marine vessels provide substantial cost savings for the user. The benefit of these alternatives can be disseminated by the respective beneficiaries (viz. trawler owners, 'bheri' owners, individual fishermen) through co-operatives like BENFISH. This ensures substantial outreach is achieved.

7. Undertake stakeholder outreach programs to create awareness on the methods of increasing fuel efficiency of marine fishing vessels

Trawling is one of the most energy intensive fishing activity. It consumes nearly 5 times more fuel compared to passive fishing methods such as longlining and gillnetting and over 11 times more fuel compared to purse seining for every kilogram of fish produced. Percentage of fuel cost in the operational expenditure of trawlers may vary between 45 and 75 %, depending on installed engine power and duration of voyage. Hence the largest potential for fuel conservation exist in trawling. There are multiple interventions that can be undertaken, without requirement of additional cost, to improve the efficiency of trawlers as given below:

Introduction of the measures can be undertaken:

a. Economic vessel speed (M.R.Boopendranath):
   Vessel speed is the single most important factor affecting fuel consumption of the vessel. The fuel consumption drastically increases as the vessel approaches maximum speeds, due to great increase in wave breaking resistance. It has been shown 35 to 61% savings in fuel is possible for a reduction of 10-20% speed.

b. Operating RPM range of engines (M.R.Boopendranath):
   Modern marine diesel engines will run most economically at a service speed of 80% of the maximum continuous rating of the engine. The propeller design and size should be so selected as to allow the engine to operate in the area of lowest specific fuel consumption. A 3% reduction in engine RPM is reported to reduce fuel consumption by 10% and 11% reduction in RPM reduce fuel consumption by 30%.

c. Hull design, displacement & maintenance (M.R.Boopendranath):
   Reduction in power requirements can be achieved by (i) increasing length of water line (LWL) and (ii) reducing displacement wherever possible at the design stage, and (iii) by taking measures for control of hull fouling. Though fuel consumption can reduce by 20-25% there is a capital cost involved in implementing these solutions.

The monetary benefits from the initiatives given above can be disseminated to the trawler operators and owners through awareness programmes. Agencies under the Fisheries Department which are associated with trawler owner/operator associations/individuals can undertake workshops/seminars/meetings to disseminate the benefits.

H. Investment Required

The following table provides the investment required in terms of unit cost of preferred equipment and the number of units requiring such equipment in 2040:

Table 31: Investment required for Agricultural & Fisheries sector

No.	Particulars	Average cost per unit (INR)	No. of units by 2040	Total Cost in INR
1.	Solar pump	2,60,000	7,61,098	20,000 Cr
2.	On-grid electric pump	20,000	62,805	125 Cr
3.	Auxiliary power consumption for marine fishing vessel	50,000	16,480	85 Cr

Assumptions:

1. Number of units derived from total energy consumption for energy projections in 2040.
2. Rating for solar pump and on-grid electric pump considered as 3hp and 5hp and average annual utilization is considered as 1000 hours.
3. The growth rate of mechanized marine fishing vessel between 2010-11 and 2015-16 is 4.3% (Dept. of Fisheries, Govt. of West Bengal, 2015)
4. The total solar power requirement for an average marine vessel is 1kW (IEEE, 2013)

Table 32: Investment planning for Agricultural & Fisheries sector

No.	Particulars	Short Term	Medium Term	Long Term
1.	Solar pump	INR 4,000 Cr	INR 6,000 Cr	INR 10,000 Cr

No.	Particulars	Short Term	Medium Term	Long Term
2.	On-grid electric pump	INR 25 Cr	INR 40 Cr	INR 60 Cr
3.	Auxiliary power consumption for marine fishing vessel	INR 20 Cr	INR 25 Cr	INR 40 Cr

7.5 Cooking Sector

A. Brief Description of Sector

For the scope of our study, cooking sector comprises the fuel used by the households for cooking purposes. Based on the India census data, the type of fuel being used for cooking in West Bengal is given as follows:

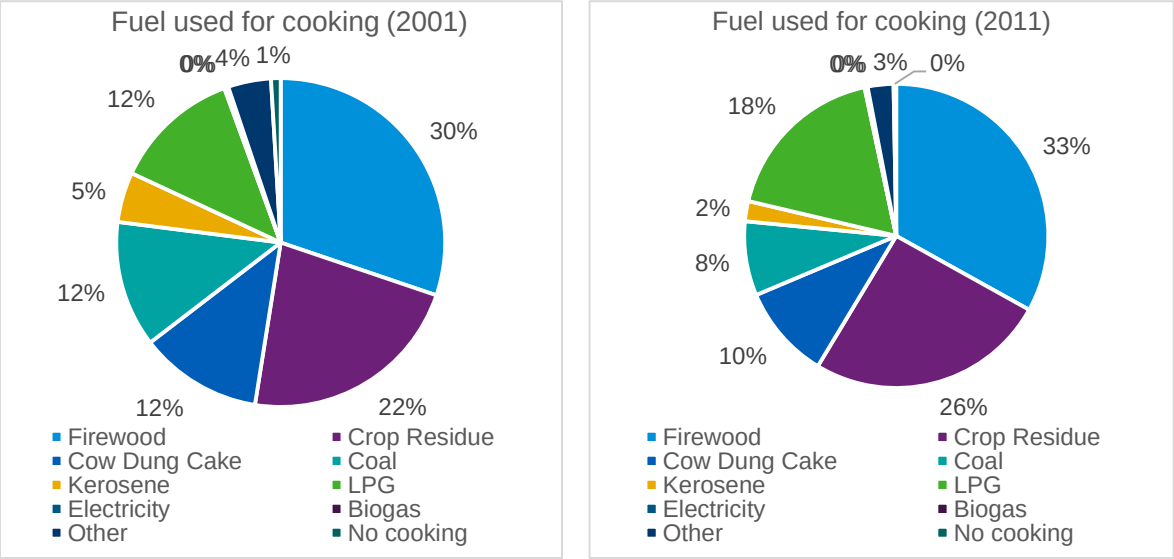


Figure 49: Fuel Mix for cooking

The share of firewood in the state has been increasing, mostly in rural parts. It has been noted (Lancet Medical Journal, 2018), that indoor air pollution caused due to use of wood/cow dung as cooking fuel has led to 1.24 lakh premature deaths in India. Also the inefficient cook stoves that people traditionally use have a thermal efficiency of only 8% to 10%. It is estimated that nearly 2-4 hours of labour is involved to collect firewood every day and it is mostly the women who undertake this job. (MyClimate Projects, 2019) Moreover, the use of fire wood also contributes to the depletion of forest cover. Hence there has been a focus on reducing usage of biomass for cooking purposes.

B. Energy Consumption of sector

In the baseline scenario, the energy consumption from biomass accounts for 91% of total energy demand in the sector in 2015, which reduces to 57% in 2040. This is due to the growing importance of gas which is reflected by the increase in its share of total energy – 7% in 2015 to 38% in 2040.

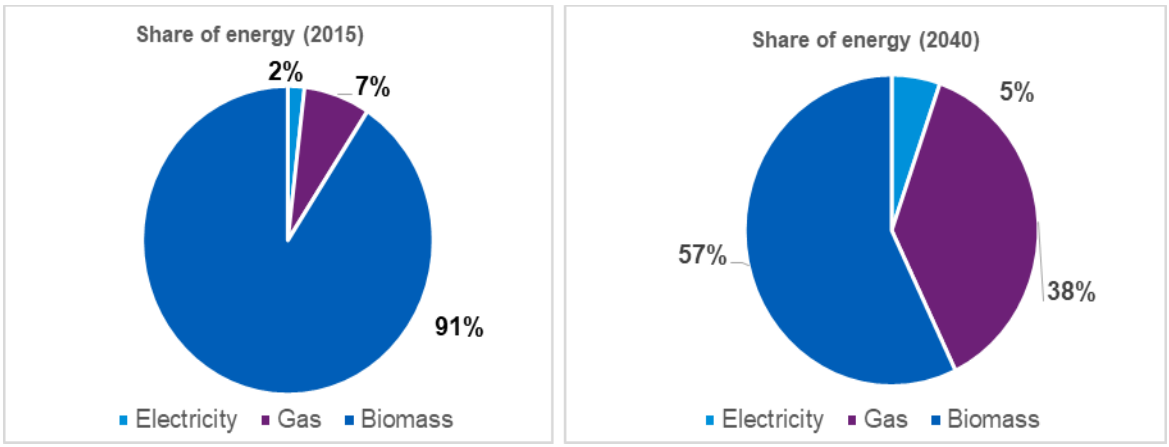


Figure 50: Cooking energy by fuel type by 2040

C. Existing initiatives undertaken in the state

The initiatives of state and central government that are currently being undertaken in relation to the cooking sector is as follows:

1. ***Pradhan Mantri Ujjwala Yojana (PMUY):***
   PMUY aims to safeguard the health of women & children by providing them with a clean cooking fuel – LPG, reducing the need to cook in smoky kitchens or wander in unsafe areas collecting firewood. Launched in 2016, 8 crore LPG connections is planned to be provided to BPL families with a support of Rs.1600 per connection in the subsequent 3 years. The scheme has been launched in West Bengal in 2016.

2. ***Gobardhan scheme***
   Implemented by Ministry of Drinking Water and Sanitation, GOBAR-DHAN or Galvanizing Organic Bio-Agro Resources Dhan is a scheme within Swachh Bharat Mission (Gramin). The scheme was announced in February 2018 with an aim to ensure cleanliness in villages and generate wealth and energy by converting cattle dung and solid agricultural waste into compost and biogas and improve the lives of villagers. GOBAR-DHAN scheme proposes to cover 700 projects across the country in 2018- 19. The scheme will be implemented in two phase i.e, 350 projects in first half of the year and rest in the second half (Ministry of Drinking Water and Sanitation, 2018). In West Bengal, there is no reported case of GOBAR-DHAN scheme implementation.

3. ***PNG pipeline***
   For the state, the construction of Jagadishpur-Haldia pipeline is expected to provide piped natural gas (PNG) to 14.2 lakh home in Kolkata and 5 adjacent districts - North 24-Parganas, South 24-Parganas, Howrah, Hooghly and Nadia (GCGSCL, 2018).

D. Description of Balanced Growth Scenario

In the Final energy for cooking, energy from biomass is expected to go down significantly from 86251 GWh in 2015 to 6178 GWh by 2040 at a rate of -10%. Similarly, with the increased penetration of electric cooking, it is expected to increase from 1746 GWh in 2015 to 14017 GWh by 2040 at a rate of 8.7%. Energy for Gas based cooking (LPG and PNG) is expected to increase at a rate of 4.6% from 7009 GWh in 2015 to 21323 GWh by 2040.

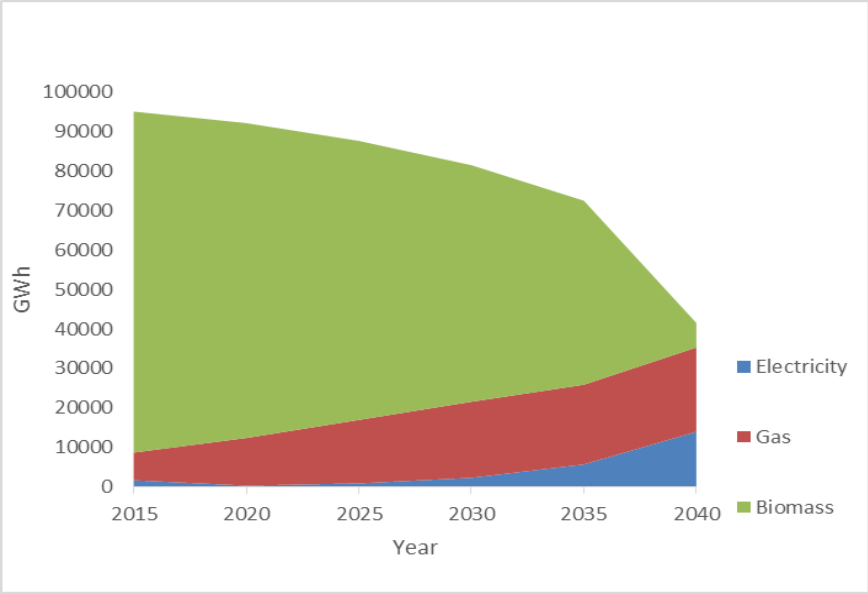


Figure 51 Final Energy for residential cooking in GWh

The share of gas and electric based cooking is expected to increase from 7% and 2% respectively in 2015 to 51% and 34% respectively by 2040.In case of biomass, the share is expected to decrease from 91% in 2015 to 15% by 2040.

E. Sectoral Vision

In the baseline scenario, cooking as a sector accounts for 35% of the total energy consumption of the state. This is primarily due to the widespread use of an inefficient form of fuel i.e. biomass (majorly firewood) for cooking purposes. More than 3 times more biomass is used to cook the same food as compared to LPG. While use of LPG is being promoted to reduce dependence on biomass, the development of gas pipeline infrastructure in Haldia-Jagadishpur pipeline project, provides new avenues for increasing growth of PNG in urban areas. It is expected to supply PNG to 14.2 lakh home in Kolkata and 5 adjacent districts - North 24-Parganas, South 24-Parganas, Howrah, Hooghly and Nadia (GCGSCL, 2018). Also, use of electricity as a means of cooking is gradually being perceived by consumers as a reliable and affordable to gas based cooking, especially in urban areas.

Vision:

State shall reduce exposure of its citizens to harmful health conditions due to use of emission intensive cooking fuel and inefficient cooking practices

F. Action Plan

Rural areas

Objective: State shall reduce the share of biomass in final usable energy in the sector to 15% in 2040 from 91% in 2015, through increased use of gas and electricity.

Activity:

A.1: State shall provide requisite infrastructure support to increase penetration of LPG

A.2: State shall increase awareness of rural consumers regarding benefits of using LPG and electricity over biomass for cooking.

Urban areas

Objective: State shall increase penetration of gas and electricity to increase their share in the final energy requirement for the state.

Activity:

A.1: State shall provide requisite technical and institutional support to increase uptake of piped natural gas (PNG)

A.2: State shall provide adequate financial support to increase penetration of electricity as cooking fuel

Table 33: Action Plan for Cooking Sector

No.	Sector	Activity	Sub Activity	Time period	Type of Intervention	Responsible stakeholder
1.	Rural	Increase penetration of LPG	Develop LPG distribution mechanism at co-operative/panchayat level to facilitate refilling of LPG cylinders by consumers	Short to Medium	Market Development	P&RD, OMCs
2.			Facilitate setting up of biogas plants through setting up co-operatives	Short to Medium	Financial	P&RD
3.			Undertake awareness programmes for disseminating benefits of switching from biomass to LPG.	Short to Medium	Awareness	P&RD
4.		Increase penetration of electricity	Assess power distribution infrastructure development required to support use of electricity in cooking and develop implementation roadmap	Medium to Long	Technical	DoP, Discoms
5.	Urban	Increase penetration of electricity as fuel	Provide financial support to end user to increase penetration of electric cooking equipment	Short to Medium	Financial	GCGSC
6.			Undertake stakeholder outreach programs through mass media channels to create awareness on benefits of using electricity for cooking	Short to Medium	Awareness	DoP, Discoms

G. Description of sub-activities

1. *Increase penetration of LPG in rural and urban households*

There are two key benefits of using biomass over LPG:

a. Health Benefits; For an average Indian household, traditional cooking using biomass emits 1.4 tonnes of CO_2 per annum and around 0.4 tonnes of CO_2 per annum (CEEW, 2015). This has substantial implication on health of user and according to World Health Organization sustained exposure to particulate matters and noxious gases such as carbon monoxide can even lead to death (Down to Earth, 2015).

b. Heat content of fuel: Most biomass sources have net calorific value (NCV) between 3500-4500 kcal/kg and in case of wood waste waste and barks, it can go down to 2500kcal/kg. LPG on the other hand has a NCV (IISC, 2015) of nearly 11000kcal/kg. Thus the time required for cooking substantially decreases by using LPG instead of biomass.

However, the prime issue in adoption of LPG is availability and price of gas cylinder. In order to reduce the use of firewood for cooking, the state can further leverage the central scheme PMUY to increase penetration of LPG. The other issue of availability is with regards to transportation of the new cylinder from the point of sales to the households. In order to address the issue of transportation, the State Government can facilitate introduction of LPG distribution centres at local co-operatives.

2. *Biogas plant through setting up co-operatives*

Biomass can provide an alternative to the forms of energy available for cooking. There are multiple examples of co-operative setting and running biogas plants in India. A similar model can be replicated in the case of West Bengal with the village co-operatives taking up the initiative of setting up and maintaining the biogas plant.

In such a case, the initial funds for setting up the plant can be provided by the State Government in the form of interest-free loan. The co-operative can recover the costs by charging usage fee on the biogas supplied. The co-operative can also sell the bio-digested slurry as manure, thereby providing for additional income. A part of the amount generated can be allocated to cover for operational costs.

Table 34: Details of Biogas Plant scheme

Time Period	Target Penetration	Target for period (No. of households)	No. of biogas plants	Total cost (INR Cr)	Monthly payment (INR Cr)
Short	0.30%	32566	163	13.855	0.16
Medium	0.60%	52371	262	22.27	0.27
Long	1.0%	75569	378	32.13	0.38

Assumptions:

i. Biogas plant cost INR 8500/m^3 (MNRE, Govt. of India, 2011)
ii. Average energy requirement for household 7 MJ/day (NITI Aayog, 2016)
iii. No. of rural households catered by unit capacity of biogas plant is 2 (DowntoEarth Report, 2015)
iv. No. of households to be catered by 1 co-operative biogas plant in West Bengal is 200
v. Capacity of 1 biogas plant proposed under initiative is 100m^3
vi. Payback period is 7yrs
vii. Monthly payment per household is INR 50.60

Apart from co-operatives installing and operating biogas plants, penetration of biogas can be pursued at the household level. A model can be adopted for West Bengal wherein grants or subsidy can be provided by the State Government. Else a loan can provided by the co-operatives at less-than-market rates. The loan will have flexible repayment schedules to ensure participation from households in this initiative.

3. ***Undertake awareness programmes for disseminating benefits of switching from biomass to LPG***

As discussed for sub-activity 1, LPG provides substantial health benefits over biomass as a fuel. Awareness can be generated regarding the benefits of LPG over biomass by organizing stakeholder outreach programs. P&RD Department, the anchor department for this sub-activity can mobilize the gram panchayats to spread awareness on the matter. Also, NGOs can be roped in for additional support on spreading awareness.

4. ***Assess power distribution infrastructure development required to support use of electricity in cooking in rural areas and develop implementation roadmap***

While penetration of LPG achieved in rural areas will successfully lead to a switch from relatively inefficient and polluting biomass, the ultimate aim would be to increase penetration of electric cooking equipment. This provides an immense opportunity for utilities to increase their revenue base.

However, tapping this revenue base would require strengthening the power distribution system as well as providing reliable and quality power supply. Undertaking this task would require technical studies to be conducted in the medium to long term to establish the requirement for distribution network in the designated area.

5. ***Provide financial support to end user to increase penetration of electric cooking equipment***

In case of urban, semi-urban and other rural areas where uninterrupted power supply is available, cooking from electrical sources can be pursued to reduce dependence on fossil fuel. Moreover electric and induction cooktops are more efficient than gas cooktops as given in the table below (US DOE, 2018)

In order to mainstream use of electrical cook stoves, public awareness needs to be developed. This should be directed in exhibiting the energy related benefits of electric cookstoves and the ease of actually using them. Since the use of electric cookstoves will help increase power demand, the promotion of the initiative provides incentive to state discoms. Also, the discoms can provide a one-time discount in the electricity bill to those consumers who will provide the invoice for acquisition of an induction cookstove/electric cooker.

Table 35: Details of mechanism to increase penetration of electric cooking

Term	Target Penetration	Target penetration (No. of households)	Net cost (INR Cr)	SGST (INR Cr)	Net subsidy (INR Cr)
Short	40%	3293858	240	18	9
Medium	70%	7004531	642	49	24
Long	74%	10803454	2120	162	81

Assumptions:

i. Electric induction cooker cost is INR 2800 (Online shopping site [Amazon India], 2019)
ii. No. of urban households taken from West Bengal energy model (West Bengal Energy Model Analysis , 2019)
iii. Power cost for domestic consumers INR 7/unit (WBSEDCL, 2017)
iv. SGST rate for induction cooker (CBIRC Ministry of Finance GOI, 2019)
v. Subsidy per unit is 50% of SGST
vi. Penetration level in 2020 is 1% of total no of urban Households (West Bengal Energy Model Analysis , 2019)

6. ***Undertake stakeholder outreach programs through mass media channels to create awareness on benefits of using electricity for cooking***

Electricity as a means of cooking is considerably efficient than gas and its efficiency further increases if it is used for direct induction cooking. Under test conditions, the efficiency for each type of cooking is as follows (ACEEEE, 2014):

Table 36: Efficiency for various type of cooking

Type of technology/fuel	Gas	Electricity	Induction
Efficiency	40%	74%	90%

Hence, the use of induction cooking can potentially reduce the energy requirement for cooking. However, considering the Indian scenario, there are multiple practical issues that is impeding the growth of induction cooking. Some of these factors are given below (CEEW, 2015):

a. Ability to Accommodate Variety of Utensils and Food Items
b. Ease of Control of Flame or Heat Intensity
c. Ability for quick start-stop operation

These factors make use of induction cooking in its present form largely unacceptable to the larger populace for cooking purpose. However, it can be a very convenient cooking technology for consumers with intermittent cooking pattern. Also, users do not have to order for separate LPG cylinders and can conveniently use their induction cooktop. Considering the type of use and availability of electricity, induction cooking can be promoted in urban areas.

In such a case, discoms can undertake awareness building programs both in online and offline methods targeting urban consumers and spreading awareness on the cost benefit of using induction cooking over LPG or other modes of cooking.

H. Investment Required

In case of cooking sector, investment is required in increasing penetration of induction cooking equipment in households.

Table 37: Investment Requirement for cooking sector

No.	Particulars	Average cost per unit (INR)	No. of units by 2040	Total Cost in INR
1.	Induction Cooking	2,800	1.54 crore	3,000 Cr.

The following assumptions were taken to reach the figures above:

1. An average household consumes 0.00102 GWh of power annually for cooking purposes. (NITI Aayog, 2016)
2. Each household uses an average of 1 electric cooking equipment i.e. induction cooktop.

Table 38: Investment planning for cooking sector

No.	Particulars	Short Term	Medium Term	Long Term
1.	Induction Cooking	INR 1000 Cr	INR 1000 Cr	INR 1000 Cr

7.6 Cross-sectoral initiatives

In order to implement the core activities provided under the Action Plan there are a number of supporting activities/initiatives that need to be undertaken which are cross-sectoral in nature. This section provides a brief description of such activities/initiatives.

A. Creation of Innovation cum Accelerator Cell

An Energy Innovation cum Accelerator cell shall be created within the DoP to provide a nodal body in the state for energy planning of the state and implementation of the Energy Action Plan.

The energy innovation cell shall be responsible for the following functions:

a. Supporting the state SDA i.e WBSEDCL in disposing its duties, as assigned by EC Act, 2001.
b. Act as owner of the energy database and provide support to other departments and external stakeholders in case of any data is required.
c. Provide technical support to various departments for market development activities.
d. Conduct data analysis to understand key metrics for measuring performance of the energy sector and identify initiatives that help in achieving the energy vision of the state. These initiatives should include those mentioned in the Energy Action Plan and also additional initiatives that maybe identified by the cell time to time, through its own independent analysis.
e. Periodically update the energy database for the state and amend the Energy Action Plan.
f. Serve as an incubation centre for startups of the state working in the field of energy. It will provide the startups with necessary technical and business knowhow to bring innovations in the field of energy to market. It will also organize networking events where startups can connect with potential clients and mentoring session with sector experts and industry stalwarts.
g. Provide laboratory testing facilities where startups can undertake product testing before taking their product to the market.

The Cell can be constituted by energy sector experts and representative from various departments viz. DoP, Transport, Agriculture, Fisheries, P&RD, IC&E, MSME. It is preferable, that representation form the departments are engaged on a full-time basis in the cell i.e. they are deputed to work in the cell.

B. Webtool to support assessment of power consumption of domestic consumers

In order to effectively plan and design any initiative targeting energy efficiency for households, a key data point required is the volume of each category of appliances currently operational in the state and power consumption of these appliances. Currently there is no consolidated data on the penetration of various appliances for the state of West Bengal. This was a key constraint in developing the energy database for the state while developing the EAP and the appliance wise energy requirement for households has been estimated using suitable national level proxies.

While a door-to-door survey can provide the requisite data, executing such a task for the entire state of West Bengal is expected to require considerable time and manpower for collection and collation of the data. Use of alternative means of reaching out to household consumers can cut down the time and cost for the exercise and at the same time increase reliability of the data generated. The phenomenal growth that internet telephony is witnessing in the state has the potential to serve as the alternative that can strengthen the data collection process - smartphone user base in the state is growing at a rate of 103% y-o-y, 3G connection growth is over 100% y-o-y and over 30% mobile users are data consumers in 2016 (Economic Times Report, 2016).

A web-based survey tool can provide an effective means of collecting household level appliance consumption data. Since the tool provides a direct communication with the end user, it can provide the user with curated information to generate interest in exploring energy efficient appliances. Also, by applying suitable data analytics techniques, the wealth of information provided by the survey can help not only in planning energy efficiency projects/initiatives but also in effective power distribution

planning. The data generated by the tool can be utilized in multiple areas including household appliance enhancement potential, planning for demand response system, generating awareness on benefits of energy efficiency, undertaking data analytics on connected load and development of database on household energy consumption in the state.

The webtool can be hosted in the website of DoP and can be integrated with the mobile app of WBSEDCL to further increase accessibility of the tool to household consumers. Users can be provided incentives for using the webtool in terms of discount in electricity bill. The data generated from the responses can be integrated with the consumer database of WBSEDCL and this data can be used for the advanced distribution planning.

C. Detailed sectoral studies on energy scenario

In order to supplement the updation of energy database, specific sectoral studies need to be undertaken thorough on-ground data collection. An indicative list of areas where studies can be undertaken are as follows:

Table 39: List of sectoral studies on energy scenario of state

No.	Sector	Area/Objective of study
1.	Buildings	A. Average household power consumption of appliances B. Number and type of appliances currently in residential buildings sector C. Scope of ECBC buildings in West Bengal and corresponding energy saving potential
2.	Transport	A. Energy consumption of public transport in West Bengal B. Energy consumption in private transport in West Bengal
3.	Cooking	A. Type and quantity of fuel used in household and commercial cooking in West Bengal
4.	Agriculture	A. Energy consumption of cold storages in West Bengal B. Energy consumption post-harvest activities in agriculture sector
5.	Fisheries	A. Energy consumption in post-harvest activities B. Energy consumed by inland and marine fishing boats operating in West Bengal
6.	Industries	A. Fuel mix of each sub-sector in large industries & MSMEs B. Energy consumption of large industries & MSMEs
7.	Energy Supply	A. Sector wise consumption of petroleum and petroleum products in the demand sectors of the state

The studies can be undertaken by the Cell or a specialist agency can be engaged to undertake these studies. The scope of work and project outcomes shall be determined by the Cell.

D. Raising awareness & capacity building of demand sectors in energy efficiency/conservation

While a wide range of energy conservation and energy efficiency initiatives are possible with compelling outcomes and impacts, the critical factor in all of these initiatives is the participation of the beneficiaries. Even though some options provide considerable financial benefits, apart from environmental and socio-economic benefits, these options are not actively taken up by the end-users viz. uptake of solar pumps in agriculture, energy efficiency methods in industry and MSME etc. In

each case there are unique issues which prevent the mainstreaming of energy efficient and energy conservation initiatives.

In order to understand the issues of the beneficiaries and to address these issues adequate awareness and capacity building measures need to be designed and implemented. Such measures have been elaborated under the sub-activities of each specific sector.

E. Prepare 'Green Procurement Guidelines' to promote procurement of technology/equipment/components that lead to energy efficiency.

Green procurement is a spending and investment process through which organizations meet their needs for goods, services, utilities and works not exclusively on a cost-benefit analysis but with a view of maximizing long term financial and economic benefits. Green products are often found to be costlier (first cost) than other products. Hence the organization has to incorporate extrinsic cost considerations into decisions alongside the conventional procurement criteria of price and quality.

The public sector is continually procuring various goods for sustaining its operations. Since a substantial amount of money is spent on these items so it adoption of energy efficient/cleaner alternatives can help reduce total cost of ownership of these items over a period of time. An effective method of reducing operational cost can be switching to purchase and increased usage of energy efficient items. Hence looking at life cycle cost or total cost of ownership (TCO) and selecting energy efficient products can bring down the GHG emission as well as reduce energy consumption. Hence, the State Government can adopt Green Procurement Guidelines which will on one hand reduce the carbon footprint of government entities and bring about energy savings, on the other hand it will help stimulate the market for green or environment friendly products in the state.

The procurement guidelines shall contain the following aspects:

- Setting the 'green procurement' criteria – subject matter of the proposed PO/ Contract.
- Technical specification of the product or works
- Selection criteria for bidders
- Contract award criteria
- Any other contract performance clauses

Establishing a state wide "Green Procurement Guidelines" across all departments of the State government would require consultation with sector experts as well as extensive consultation with individual departments to ensure a comprehensive guideline, relevant to all concerned stakeholders is prepared.

F. Collaboration with National/International Partners

The State can leverage the business promotion platforms e.g.: Bengal Global Business Summit to showcase the initiatives undertaken to improve energy conservation and efficiency and to seek funding or technical assistance for specific initiatives in the energy sector. This can potentially create investment options and help increase engagement with international partner countries or national organizations to enhance economic activity in the state as well as achieve better results in energy conservation efforts undertaken by the state.

There are four types of collaboration/partnerships that the state can undertake to help reach its energy vision as given below:

a. Technology collaboration: In this case the partner will provide access to innovative technology and solutions to their counterparts in the state.

b. Investment partnership: In this case, the state provides the partner with opportunity to invest in setting up manufacturing facilities in the state.

c. Knowledge partnership: The state in this case provides opportunity to universities/technical institutes to collaborate with state educational/technical training institutes to develop and impart technical courses to build capacity in the state in a particular area or to undertake R&D activities.

d. Access to markets: Here the state provide companies undertaking supply of services and equipment related to clean technology and processes, the access to local market to setup up their business.

The areas where the state can look for opportunity on collaboration is given below:

Table 40: Summary of collaboration opportunites for West Bengal in energy sector

No.	Sector	Area	Type of Collaboration
1.	Coal Mining	• Installing new infrastructure required for mining and extraction • GPS based Truck Dispatch System • Use of mine planning software like MINEX • Development of Decision Support System through enhancement in MIS of standard ERP solution • Implementation of automated mining system (like mine robotics, armchair mining) for enhancing worker safety and improving mine productivity. • Use of computerized system in underground mines	Technology collaboration
2.	CBM & Natural Gas	• Integration of CBM extraction technologies and systems	Technology collaboration
3.		• Supply, installation and maintenance of drilling equipment, fracking equipment, well-head natural gas processing equipment and control systems.	Access to markets
4.		• Development of infrastructure in efficient gas transportation • Exploration and development of shale gas	Investment partnership
5.	Solar	• Manufacturing of solar PV panels • Manufacturing/assembly of supporting power equipment required for solar rooftop viz. bi-directional meter, isolation transformers, inverters, protection devices	Investment partnership/ Technology collaboration
6.		• Supply of solar PV panels and supporting power equipment • ESCO services for installation and maintenance of rooftop solar systems • Stand-alone installation and maintenances services	Access to market
7.	Power Transmission & Distribution	• Manufacturing and installation of power transmission equipment viz. digital switch gear and smart substations • Manufacturing and installation of power distribution equipment viz. smart meters, smart controllers, Remote Terminal Units, SCADA systems, distribution	Investment partnership/ Technology collaboration

No.	Sector	Area	Type of Collaboration
		transformers, aerial bundled (AB) cable, meters with Low Power Radio Frequency (LPR) communication capabilities	
8.		• Grid and transmission line expansion to account for increased consumption of electricity	Access to market
9.		• Technical expertise for assessment of grid synchronization and smart grid installation	Technology partnership
10.	Electric Vehicles	• Assembly and manufacturing of EV components	Investment partnership
11.		• Installation and maintenance of EV charging stations • Service providers for vehicle repairing facilities	Access to market
12.		• Expertise for technical assessment of sites for EV charging • R&D on improved manufacturing techniques for EV/EV components	Knowledge partnership
13.	Inland Water Transport	• Operation and maintenance of dredging equipment and vessels • Installation, operation and maintenance of state-of-the-art land side infrastructure including material handling equipment	Access to markets
14.		• Fabrication of battery-operated or solar powered passenger vessels • Fabrication of diesel operated freight vessels	Technology partnership
15.		• Research and development for designing new vessels and economizing vessel modification to suit local conditions	Knowledge partnership
16.	Energy Services	• Designing energy efficient building • Technical expertise for developing energy optimization systems • Development and implementation of industrial energy management systems	Technology partnership/ Access to markets
17.		• Develop R&D centres specializing in developing supporting tools and software for efficient operation of equipment/systems	Knowledge partnership
18.	Equipment Manufacturing	• Technology transfer/technical assistance for setting up units manufacturing energy efficient household appliances • Setting up semiconductor fabrication plant that can supply components for manufacturing smart appliances and equipment.	Technology partnership

No.	Sector	Area	Type of Collaboration
19.		• R&D on designing and manufacturing energy efficient equipment • Development of State-of-the art testing laboratory for manufactured products.	Knowledge partnership

G. Clean Energy Fund

There are multiple scheme of the State and Central government which are aimed to promote clean technologies across some sectors as per departmental targets. However, a consolidated fund for financing clean technologies and related technical services across all energy demand and supply sectors will help create a focus on increased penetration of such technologies.

The fund will initially target small to medium scale projects with a value of INR 1 lac to 50 lac and will have an initial fund scope of INR 50 crore. This is expected to help mainstream the uptake of clean technology by the end users i.e. retail, industrial and institutional consumers as well as stimulate the growth of the energy services industry in the state. The fund can be scaled up in the future to fund projects with investment requirement of above INR 50 lac, based on the availability of funds and the utilization of the initial fund allocation.

The fund will focus on projects/initiatives implemented in residential and commercial buildings; agriculture and fisheries; public transport; SMEs etc. The list of priority projects that can be considered for funding are given below:

Table 41: Details of funding areas of Clean Energy Fund

No.	Sector	Examples of priority projects for funding	Potential scale of penetration	
			Short & Medium Term (2020-2030)	Long Term (2030-40)
1.	Energy Supply Sector	i. Installation of rooftop/ground mounted solar panels for commercial and industrial units. (up to capacity of 100kWp)	Total installed capacity of 3.1GW*	Total installed capacity of 5.7GW*
		ii. Installation of solar rooftop for households (up to capacity of 100kWp)		
2.	Agriculture & Fisheries	i. Installation of agricultural solar pumps	3,000 nos.*	6,000 nos.*
		ii. Installation of energy efficient pumps	65,000 nos.*	2,80,000 nos.*
		iii. Installation of energy efficient cold storage/retrofitting energy efficient equipment in cold storage	100 nos.*	300 nos.*
		iv. Procurement of solar powered inland fishing vessel	3,000 nos.*	10,000 nos.*
		v. Retrofitting marine fishing vessels with solar panels for auxiliary power consumption	2,300 nos.*	9.500 nos.*
3.	Transport	i. Installation of EV charging infrastructure	9,500 nos.*	14,000 nos.*
4.	Buildings	i. Implementation of building energy management system (BEMS)	20-30% of newly	100% of newly

No.	Sector	Examples of priority projects for funding	Potential scale of penetration	
			Short & Medium Term (2020-2030)	Long Term (2030-40)
			constructed buildings**	constructed buildings**
		ii. Replacement of existing appliances with energy efficient variants in commercial buildings/residential complexes	10% of existing buildings**	60-80% of existing buildings**
		iii. Procurement of building materials for ECBC compliant buildings in commercial sector	20-30% of newly constructed buildings**	100% of newly constructed buildings**
5.	SMEs	i. Installation of energy efficient machinery	High potential***	High potential***
		ii. Conducting investment grade energy audit (IGEA)		
		iii. Installation of equipment to enable conversion from diesel to electricity/natural gas in SMEs		

*Numbers estimated from projections made under WBEAP and based on state level data/appropriate national level proxies

**Indicative figures are provided since state level data not available. 100% of commercial buildings have been considered in the long term since it is expected that ECBC will be incorporated in the Municipal bye-laws in the short term i.e. by 20205. To provide data for this section, development of building sector database has been recommended in WBEAP.

***Currently there is limited penetration of the mentioned projects (as per inputs provided by industry stakeholders and concerned Government departments). However, scope of penetration can be finalized only after detailed scoping study is conducted for the state.

The fund will have a three tier structure, wherein the Steering committee will have over-arching jurisdiction on the fund functions and will be assisted by the Management committee, which will undertake the overall management and utilization of the Fund. The Management committee will be supported by the Technical committee on technical aspects of the proposals put forward for funding by the beneficiaries. The Secretariat would conduct preliminary screening of the proposals and other requisite back-end activities required for functioning of the fund. Empanelled banks will be the agents for receiving the applications from beneficiaries and based on the decision provided by the Steering Committee disburse the funds/communicate the rejection of application to beneficiaries.

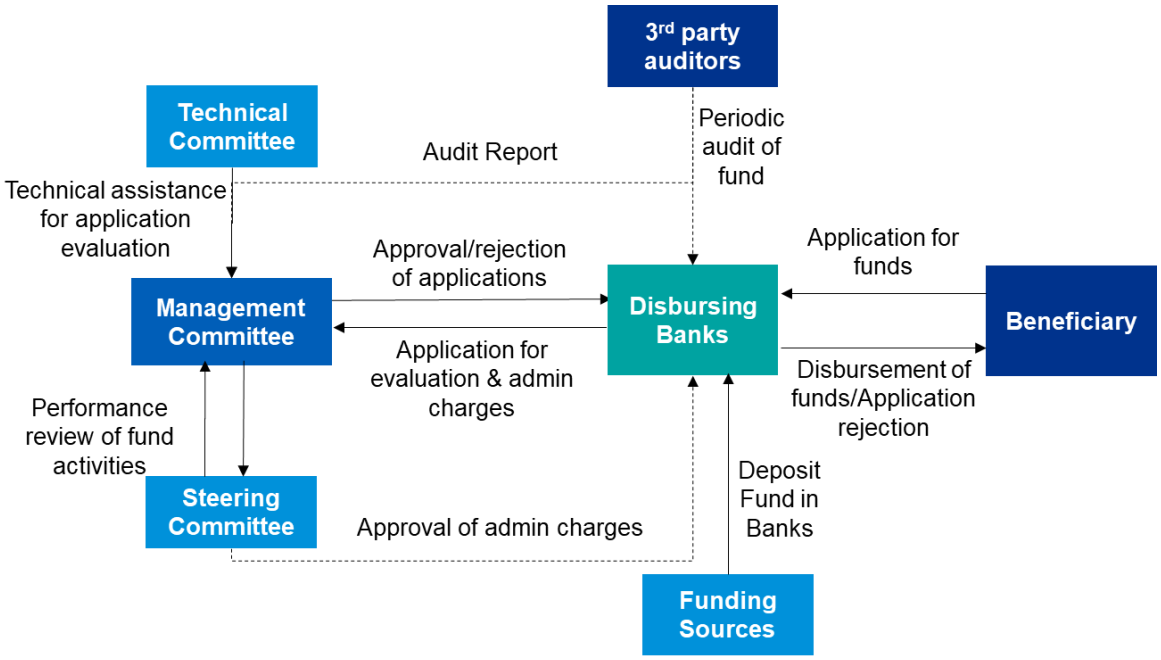


Figure 52: Proposed structure of Clean Energy Fund

In the short term, the source of fund will be through state budgetary allocation, proceeds from a proposed pollution tax, central government funding schemes or CSR spend of public/private entities.

In the long term, the fund can provide allocation from state government, state government owned entities (E.g.: WBPDCL, WBSEDCL etc.) and private sector entities (E.g.: CESC, Vikram Solar etc.) to provide seed funding for startups from the state operating in manufacturing activities or providing services related to the focus areas stated above. Based on the future prospects, the participants of the arm can further convert their seed funds in to equity in the start-ups. This can help increase private sector participation and help develop clean energy market in the state.

8. Decision Support Tool

The Web tool developed for West Bengal under Energy Action Plan has two parts. One part is maintained by the user to update the information and data related to various supply and demand sectors as per the pre-defined data templates. The user needs to update and maintain the energy model database on a regular basis. The figure below shows an illustration of the web tool comprising of DST (Linked to the interactive interface for analytical use).

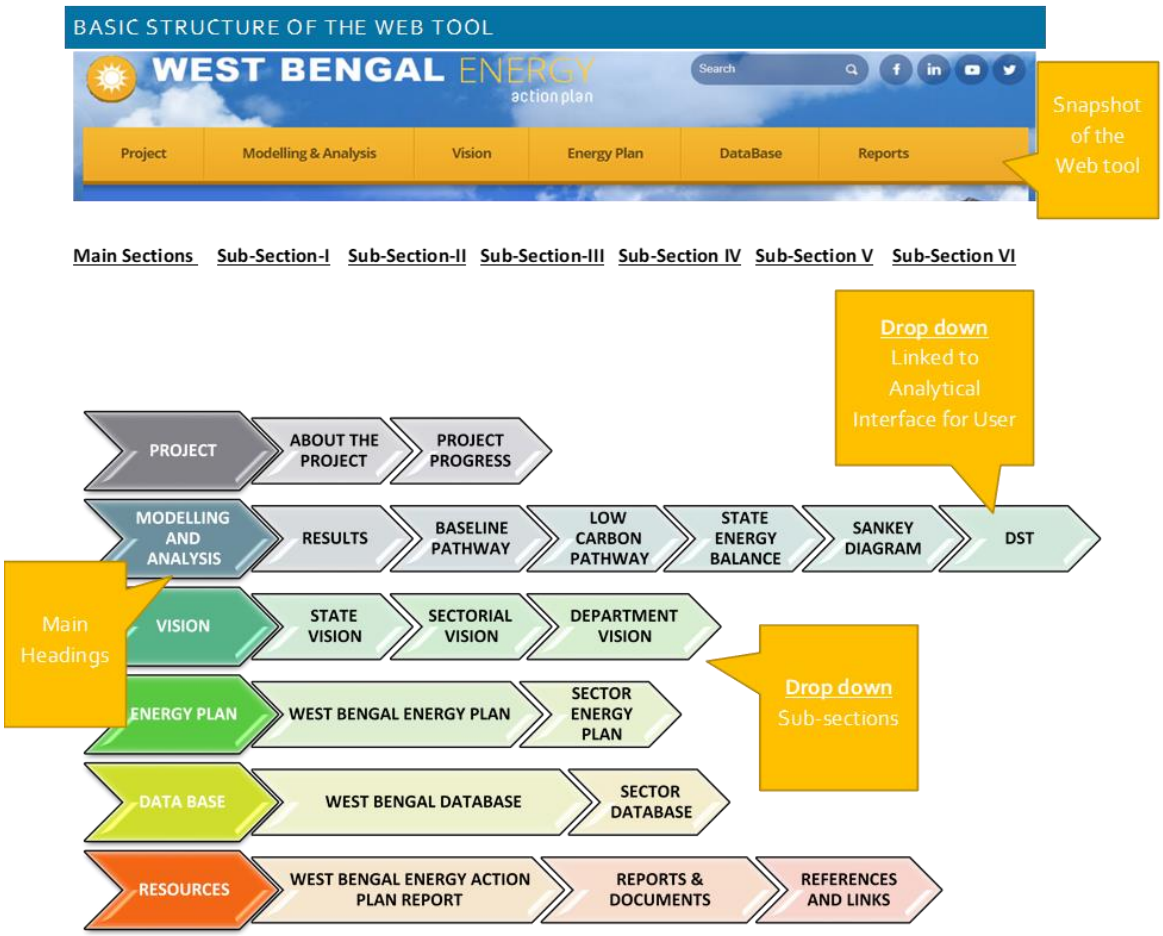


Figure 53: Basic Structure of DST

Second part of the web tool is the Decision support analytical tool (DST) with an attractive interface focused on result analysis using the output of the model. It is developed to support decision analysis and participatory processes. It comprises of a database, provided with a dedicated interface in order to be directly and more easily accessible by non-specialists (e.g. policy and decision makers). It has specific prediction capabilities but is also used as a vehicle of communication, training and experimentation. Principally, DST can facilitate dialogue and exchange of information thus providing insights to non-experts and support them in the exploration of policy options.

The DST assists the users to pull out the required information and interpret the resultant outputs in the form of plots in a stylized manner as per the user interest. DST also displays comparative plots depicting the baseline as well as the scenarios results together under same display chart. The plots beside demonstrates the performance comparison to baseline of policy interventions like electric

vehicle penetrations, electric cooking and other technologies use in the state. The DST has 3 sections as mentioned below:

1. **BAU Projections**
2. **Scenario Builder**
3. **General Statistics**

BAU Projection page comprises of plots of the BAU scenario and related information/results in the form of plots/charts. This BAU scenario is already generated in the model and fixed. If any update is needed to be done, one will have to again regenerate the BAU to update. This requires technical expertise of the model (which is being given to the department in the capacity building sessions) to update the input file of the model.

Scenario builder page comprises options for users to build their own future scenario based on the available interventions. The scenario builder provides an interface to let the user input numbers using sliders and check boxes to build their own scenario on top of the BAU scenario. The scenario, when executed, gives results in the form of supply mix of fuel, emissions, etc. in the state for different sectors in comparison against the BAU scenario and BGS Scenario.

The general statistics page comprises of statistics based on demographics of the state in terms of BAU and EAP scenario.

A. Display of results of existing scenarios

This comprises of 3 scenarios considered for the study in the development of Energy action plan.

a. BAU scenario tab
   This scenario is the baseline scenario which takes into account the existing policies and historical trend to arrive at future projections.

b. BGS scenario tab
   This scenario is one of the most recommended scenario taken in the study known as the balanced growth scenario. This comprises of various policy/ technology interventions.

c. ESS scenario tab
   This scenario is another recommended scenario taken in the study known as energy security scenario. This takes into account the utilisation of resources of the state optimally and reducing the dependency for imports into the state.

To begin with, the BGS and ESS scenarios are built over the BAU scenario by considering different levels of penetration for the clean technologies in each of the demand and supply sector. The user needs to first run the BAU scenario and see the subsequent results in the form of charts/plots and then he/she can give his/her own penetration rates to see the results.

The results from each of the above tab is in the form of plots/charts further drilled down into sub-categories like Energy, CO_2 emission, Investments and Sectorwise plots.

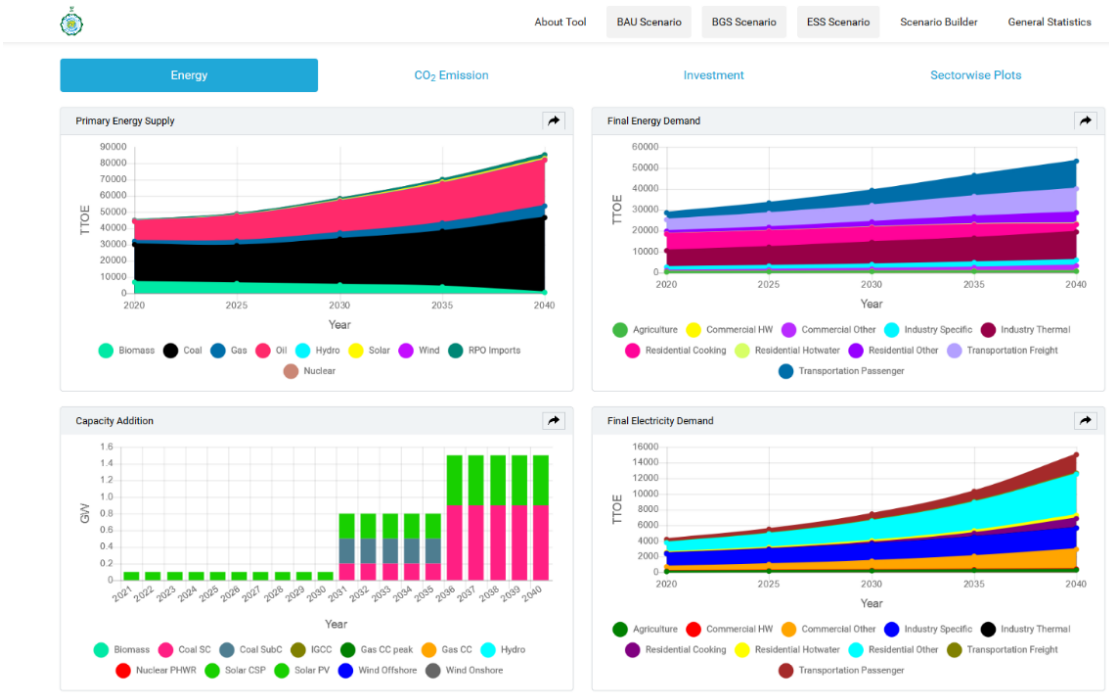


Figure 54: Screen-shot of DST outputs

In the sectorwise plots, user can see the results further drilling down into the breakup of fuels like electricity, coal, gas and oil.

Figure 55: Screenshot of Sector wise Results

B. Scenario Builder

This is the section, where the users can prove their own inputs from the list of interventions in the DST in this section. The user can select any number as penetration rate using the slider. Scenario builder page comprises options for users to build their own future scenario based on the available interventions list. The scenario builder provides an interface to let the user input numbers using sliders to build their own scenario on top of the BAU scenario. The scenario when executed gives results in the form of supply mix of fuel, emissions, etc. in the state for different sectors in comparison against the BAU scenario, BGS Scenario and ESS scenario.

Figure 56: Scenario Builder

The user can choose the penetration rates of each technology interventions and submit it by clicking on the "**SUBMIT**" button. Once the user clicks on the "**SUBMIT**" button, the Model begins to run and the results start getting populated.

C. General Statistics

This section of the DST displays the important information inferred from the baseline and other scenario simulations (BGS & ESS) which are important for decision making activities. Per capita consumption of energy, growth rates of energy consumption by various users of energy etc. are the key information displayed in this section.

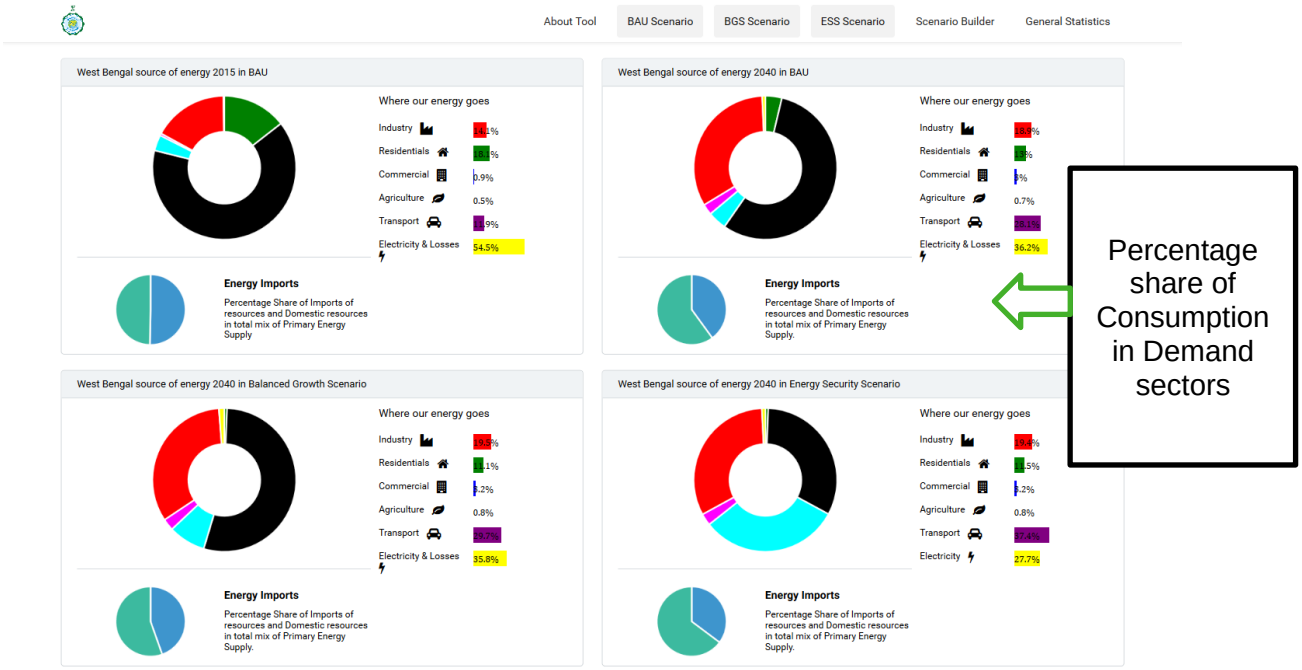


Figure 57: General Statistics

D. Purpose and benefits of the DST

The prime purpose this tool is to present comprehensive information, data and results in the simplest form. This can be easily understood and interpreted into guided decision making. It enables the policy makers to make more informed decisions at a quicker pace by giving necessary inputs.

Policies/schemes that are implemented without understanding the prospective benefits for a particular application will not achieve their full potential.

DST being a computerized decision support tool reduces decision cycle time substantially with more timely information in the form of results for decision making. The effectiveness in decision making is due to better analysis taking into account all the key indicators. This tool being model driven along with support calculation sheets, provides means for sharing facts and assumptions amongst decision/policy makers. This encourages fact based decision making.

A Appendix - Assumptions

A.1 Macro-economic Assumptions:

Parameters	Units	2015	2020	2025	2030	2035	2040
GSDP (BAU) Rate	%	12.2	14.0	15.0	15.5	16.0	16.5
Urbanization	%	30	33	36	39	42	45
Population	Million	9.6	10.3	10.9	11.7	12.5	13.3
Urban Households	Million	7	8	9	11	12	15
Rural Households	Million	14	15	16	17	17	18

A.2 Energy Supply Sector assumptions:

1. Subcritical Coal Thermal Power Plant PLF:
   i. For year 2015: 60%
   ii. For projections: 70%
2. Hydro Power Plant PLF: 40%
3. Solar Power Plant CUF for PV: 17.3%
4. The penetration of Supercritical Power Plant in the state is assumed to be after 2030

A.3 Agriculture Sector assumptions:

1. Pump rating assumptions

Type of Pumps	Rating in KW
Electricity	3.7
Diesel	3.7
Solar	2.2

(Source: Indian Energy Security Scenario 2047 Ver 2)

2. Tractor Energy Demand Assumptions

Parameters	Units	2015	2020	2025	2030	2035	2040
Percentage of tractors in use	%	60%	60%	60%	60%	60%	60%
Energy consumed per hour	*kWh*	43.8750	43.8750	42.2346	41.4375	41.4375	41.4375

Parameters	Units	2015	2020	2025	2030	2035	2040
Hours of operation per year	*hours*	500.0	500.0	500.0	500.0	500.0	500.0

(Source: Indian Energy Security Scenario 2047 Ver 2)

3. Assumptions for pumping Demand from Diesel Pump

Parameter	*Units*	2015	2020	2025	2030	2035	2040
Share of Diesel Pumps	*%*	*67%*	*56%*	*45%*	*34%*	*23%*	*12%*
Efficiency improvement in pumps	*%*	*0%*	*25%*	*28%*	*31%*	*33%*	*33%*

(Source: Indian Energy Security Scenario 2047 Ver 2)

4. Assumptions for pumping demand from electric pump

Parameters	Units	2015	2020	2025	2030	2035	2040
Share of Electricity Pumps	%	*33%*	*43%*	*54%*	*64%*	*74%*	*84%*
Efficiency improvement in pumps	%	0%	5%	10%	14%	18%	18%

(Source: Indian Energy Security Scenario 2047 Ver 2)

5. Assumptions for pumping demand from solar water pumps

Parameters	Units	2015	2020	2025	2030	2035	2040
Penetration of Solar Pumps	%	*0%*	*1%*	*1%*	*2%*	*3%*	*4%*

(Source: Indian Energy Security Scenario 2047 Ver 2)

A.4 Cooking Sector assumptions:

1. Household Annual Fuel Consumption

Assumption	Unit	Annual consumption Per hh	Life Cycle (Years)
LPG	TWh	1.41014E-06	15
Electricity	TWh	0.000001022	10
PNG	TWh	1.60272E-06	15
Improved Biomass	TWh	1.75067E-06	3
Coal	TWh	2.11524E-06	3

Kerosene	TWh	8.22445E-07	5
Biogas	TWh	1.24375E-06	15
Traditional Biomass	TWh	4.04156E-06	1

(Source: Indian Energy Security Scenario 2047 Ver 2)

2. Traditional cooking efficiency

Efficiency of a Traditional Biomass Chulha	13%

(Source: Indian Energy Security Scenario 2047 Ver 2)

A.5 Transport Sector Assumptions:

1. Average utilization for passenger vehicles

Assumptions for Vehicle Utilisation *(km/year)*								
Mode	**Sub-mode**	**Technology**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Road	BUS	DIESEL	*95,217*	*96,804*	*98,391*	*99,978*	*1,01,565*	*1,03,152*
		ELECTRIC	*95,217*	*96,804*	*98,391*	*99,978*	*1,01,565*	*1,03,152*
	ONMI-BUS	DIESEL	*36,659*	*37,452*	*38,246*	*39,039*	*39,833*	*40,626*
	CAR	PETROL	*12,216*	*12,216*	*12,216*	*12,216*	*12,216*	*12,216*
		DIESEL	*12,216*	*12,216*	*12,216*	*12,216*	*12,216*	*12,216*
		ELECTRIC	*12,216*	*12,216*	*12,216*	*12,216*	*12,216*	*12,216*
	2W	PETROL	*7,221*	*6,824*	*6,427*	*6,030*	*5,634*	*5,237*
		ELECTRIC	*1,865*	*2,063*	*2,261*	*2,460*	*2,658*	*2,857*
	3W	PETROL	*35,405*	*35,405*	*35,405*	*35,405*	*35,405*	*35,405*
		DIESEL	*35,405*	*35,405*	*35,405*	*35,405*	*35,405*	*35,405*
		ELECTRIC	*35,405*	*35,405*	*35,405*	*35,405*	*35,405*	*35,405*
	TAXI	DIESEL	*36,579*	*36,976*	*37,373*	*37,770*	*38,166*	*38,563*
		ELECTRIC	*36,579*	*36,976*	*37,373*	*37,770*	*38,166*	*38,563*
Rail		DIESEL	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*

	ELECTRIC	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*	*1,89,22,738*
Air	AIR	*16,64,33,803*	*16,64,33,803*	*16,64,33,803*	*16,64,33,803*	*16,64,33,803*	*16,64,33,803*

2. Average Passenger occupancy per vehicle

Mode	Sub-mode	Fuel Type	Occupancy
Transport	Buses	Diesel	45
		Electric	45
	IWT	Diesel	80
	Taxi	Diesel	3
		Electric	3
	Light Motor Vehicles(Passengers)	Petrol	3
		Electric	3
Non-Transport	Two-Wheeler	Petrol	2
		Electric	2
	Cars	Diesel	4
		Petrol	4
		Electric	4

(Source: Indian Energy Security Scenario 2047 Ver 2)

3. Fuel efficiency for passenger vehicles

Mode	Sub-mode	Technology	Efficiency *(litres of fuel/vehicle-passenger km)*					
			2015	2020	2025	2030	2035	2040
ROAD	BUS	DIESEL	0.004	0.004	0.004	0.004	0.004	0.004
		ELECTRIC	0.003	0.003	0.003	0.003	0.003	0.003
	ONMI-BUS	DIESEL	0.014	0.014	0.014	0.014	0.014	0.014
	CAR	PETROL	0.023	0.022	0.021	0.020	0.019	0.018
		DIESEL	0.028	0.027	0.025	0.024	0.023	0.022
		ELECTRIC	0.003	0.003	0.003	0.003	0.003	0.003
	2W	PETROL	0.012	0.012	0.012	0.012	0.012	0.012

		ELECTRIC	0.001	0.001	0.001	0.001	0.001	0.001
	3W	PETROL	0.016	0.016	0.016	0.016	0.016	0.016
		DIESEL	0.020	0.020	0.020	0.020	0.020	0.020
		ELECTRIC	0.002	0.002	0.002	0.002	0.002	0.002
	TAXI	DIESEL	0.038	0.038	0.038	0.038	0.038	0.037
		ELECTRIC	0.003	0.003	0.003	0.003	0.003	0.003
RAIL		DIESEL	0.003	0.002	0.002	0.001	0.001	0.001
		ELECTRIC	0.015	0.014	0.012	0.011	0.011	0.010
AIR		AIR	0.035	0.035	0.034	0.034	0.033	0.033

(Source: Indian Energy Security Scenario 2047 Ver 2)

4. Average utilization for freight transport

Average Annual Utilisation *(km/vehicle)*								
Mode	**Sub-mode**	**Technology**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
ROAD	HCV	DIESEL	1,61,442	1,77,835	1,87,428	1,94,190	2,01,248	2,07,116
	LCV	DIESEL	56,090	60,440	65,127	70,177	75,619	81,484
RAIL	Passenger	DIESEL	27,89,588	27,89,588	27,89,588	27,89,588	27,89,588	27,89,588
	Passenger	ELECTRIC	27,89,588	27,89,588	27,89,588	27,89,588	27,89,588	27,89,588
AIR	Passenger	AIR	1,53,77,465	1,53,77,465	1,53,77,465	1,53,77,465	1,53,77,465	1,53,77,465

(Source: Indian Energy Security Scenario 2047 Ver 2)

5. Average carrying capacity of freight transport

Average tonnage capacity *(tonnage/vehicle)*								
Mode	**Sub-mode**	**Technology**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
ROAD	HCV	DIESEL	6.1	6.1	6.1	6.1	6.1	6.1
	LCV	DIESEL	1.7	1.7	1.7	1.7	1.7	1.7
	Freight Other	DIESEL	3.02	3.02	3.02	3.02	3.02	3.02
RAIL	Freight	DIESEL	2830	2830	2830	2830	2830	2830
	Freight	ELECTRIC	2830	2830	2830	2830	2830	2830
AIR	Freight	AIR	17.34	17.34	17.34	17.34	17.34	17.34

(Source: Indian Energy Security Scenario 2047 Ver 2)

6. Energy requirement for freight transport

Energy (TWh)/vehicle-ton-km									
Mode	**Type**	**Technology**	**Annual improvement %**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
ROAD	HCV	DIESEL	-0.01412	3.3E-10	3.1E-10	2.9E-10	2.7E-10	2.5E-10	2.3E-10
	LCV	DIESEL	-0.01089	4.8E-10	4.6E-10	4.4E-10	4.1E-10	3.9E-10	3.7E-10
	Average			4.1E-10	3.9E-10	3.6E-10	3.4E-10	3.2E-10	3.0E-10
RAIL		DIESEL	-0.00403	5.2E-11	5.1E-11	4.9E-11	4.9E-11	4.8E-11	4.7E-11
		ELECTRIC	-0.01124	1.4E-11	1.4E-11	1.3E-11	1.2E-11	1.1E-11	1.1E-11
AIR		AIR	-0.0025	2.5E-09	2.4E-09	2.41E-09	2.4E-09	2.3E-09	2.3E-09

(Source: Indian Energy Security Scenario 2047 Ver 2)

A.6 Industry Sector Assumptions:

1. Energy mix for different type of industries

Energy Mix for different industry type (in %)					
Industry type	**Electricity**	**Coal (Solid Hydrocarbons)**	**Petroleum (Liquid hydrocarbons)**	**Others (Gaseous+Gaseous Biomass)**	**Total**
Cement	3	92	5	-	100

Energy Mix for different industry type (in %)					
Industry type	**Electricity**	**Coal (Solid Hydrocarbons)**	**Petroleum (Liquid hydrocarbons)**	**Others (Gaseous+Gaseous Biomass)**	**Total**
Fertilizers	18	42	40	-	100
Aluminium	1	94	5	-	100
Iron & steel	6	82	6	6	100
Pulp & Paper	3	92	4	1	100
Textile	23	54	19	4	100
Chlor Alkali	57	28	4	11	100
Others	27	20	39	14	100

(Source: Indian Energy Security Scenario 2047 Ver 2)

2. SEC reduction of industry sub-categories

Industry category	Unit	2015	2020	2025	2030	2035	2040
Iron and Steel	Twh/MT	6.97	6.63	6.50	6.32	6.23	6.11
Pulp and Paper	Twh/MT	7.36	7.08	7.08	7.08	7.08	7.08
Textile	Twh/MT	4.05	3.95	3.94	3.93	3.92	3.92
Others	Twh/INR Trillion	103164.72	81487.69	65234.87	53147.01	42243.78	33125.96

(Source: Indian Energy Security Scenario 2047 Ver 2)

3. Other assumptions for industrial sector
   a. Quantity of coal consumed, electricity purchased taken from Annual Survey of Industries for major industries group i.e. NIC 2-digit industry categories from 2005-06 to 2015-16. (Source: *Subscription based database of Indiastat*)

A.7 Buildings Sector Assumptions:

1. Energy consumption for each type of technologies in commercial buildings:

Energy consumption for each type of Technologies (in W)			
Type	**Lighting**	**HVAC**	**Others**
High Efficiency	6	1400	80

Energy consumption for each type of Technologies (in W)			
Type	**Lighting**	**HVAC**	**Others**
Medium Efficiency	11	1570	109
Low Efficiency	15	1870	139

(Source: Indian Energy Security Scenario 2047 Ver 2)

2. Penetration of efficient technology for commercial buildings

Type of efficient technology	2015	2020	2025	2030	2035	2040
High	6%	12%	16%	21%	28%	37%
Medium	50%	50%	50%	50%	50%	50%
Low	44%	39%	37%	35%	33%	31%

(Source: Indian Energy Security Scenario 2047 Ver 2)

3. Share of electricity consumption for various appliances used in households

Appliance	Electricity Consumption share (in %)
Lighting	28%
Ceiling Fans	34%
TV	4%
Refrigerators	13%
ACs	7%
Other Appliances	14%

(Source: Planning Commission Study on Energy Consumption in Residential Sector (2011))

4. Average consumption of lighting appliances in residential buildings

Lighting category	Power consumption (W)
Bulb	60
Tubelight	28
CFL	15
LED	8

(Source: Indian Energy Security Scenario 2047 Ver 2)

5. Penetration of appliance in residential buildings

Appliance	Region	2015	2020	2025	2030	2035	2040
Lighting	Urban	38%	37%	37%	35%	35%	34%
	Rural	38%	41%	41%	38%	36%	35%
Ceiling Fans	Urban	44%	43%	43%	42%	42%	41%
	Rural	47%	44%	42%	43%	43%	43%
Televisions	Urban	4%	4%	4%	4%	4%	4%
	Rural	3%	3%	3%	4%	4%	4%
Refrigerators	Urban	9%	9%	10%	11%	11%	12%
	Rural	4%	6%	7%	9%	10%	10%
Room Air Conditioners	Urban	1%	2%	2%	3%	4%	4%
	Rural	1%	2%	2%	2%	3%	3%
Others	Urban	4%	4%	4%	4%	4%	5%
	Rural	6%	5%	5%	5%	4%	5%

Source: Indian Energy Security Scenario 2047 Ver 2)

6. Other assumptions for residential buildings
   a. Share of rural consumption of power for WBSEDCL in 2015 is 38% and 2019 will be 44% *(Source: West Bengal Power for All document, 2016)*
   b. Power consumption of residential consumer segment in DISCOMS (other than WBSEDCL) are considered under urban. Except for WBSEDCL, CESC operates in completely urban area and consumption of residential customers for IPCL, DPSC etc. negligible. *(Source: West Bengal Statistical Handbook 2015)*
   c. ECBC compliant buildings are 20% efficient than conventional building and ECBC+ and Super ECBC buildings are 30-35% and 40-45% efficient than conventional buildings. *(Source: Implementation of ECBC (AEEE Website))*

A.8 Investment Costs for Different Technology:

Technology	Units	2015	2020	2025	2030	2035	2040
Biomass Power Plant	Million USD/GW	949.16	949.16	949.16	949.16	949.16	949.16
Coal Supercritical Power Plant	Million USD/GW	1,107.36	1,159.00	1,213.05	1,269.62	1,328.83	1,390.80

Technology	Units	2015	2020	2025	2030	2035	2040
Coal Subcritical Power Plant	Million USD/GW	1,001.90	1,048.62	1,048.62	1,048.62	1,048.62	1,048.62
Coal Ultra Supercritical Power Plant	Million USD/GW			1,452.32	1,539.12	1,625.96	1,712.71
Electric Grid	Million USD/GW	35.16	34.71	34.27	33.82	33.38	32.93
Gas Combined Cycle Power Plant (Peak Load)	Million USD/GW	756.49	797.10	837.72	878.34	918.96	959.58
Gas Combined Cycle Power Plant	Million USD/GW			837.72	878.34	918.96	959.58
Gas Import Terminal	Million USD/GW	26.95	26.95	26.95	26.95	26.95	26.95
Nuclear Power Plant	Million USD/GW	2,467.83	2,421.56	2,375.29	2,329.02	2,282.75	2,236.47
Oil Import Terminal	Million USD/GW	3.03	3.03	3.03	3.03	3.03	3.03
Solar PV Grid Integrated	Million USD/GW	1,490.12	1,043.08	894.07	1,819.57	782.31	745.06
Solar PV Off-grid	Million USD/GW	2,109.26	1,898.33	1,797.09	1,745.12	1,710.59	1,684.35
Solar Thermal Technology	Million USD/GW	2,867.86	2,867.86	2,867.86	2,867.86	2,867.86	2,867.86
Wind Farm Off-Shore	Million USD/GW			3,111.16	3,281.25	3,072.92	2,947.92
Wind Farm On-Shore	Million USD/GW	1,117.59	1,141.88	1,130.79	1,123.33	1,104.77	1,086.22

Source: Indian Energy Security Scenario 2047 Ver 2

B Bibliography

1. ACEEEE. (2014). *Induction Cooking Technology Design and Assessment*. Retrieved from https://aceee.org/files/proceedings/2014/data/papers/9-702.pdf
2. ASHRAE India. (2018). *Energy savings in cold storage installation*. Retrieved from http://www.ashraeindia.org/pdf/Energy_Savings.pdf
3. BEE. (2018, July 30). *State Energy Efficiency Index - West Bengal*. Retrieved from http://www.aeee.in/state-ee-index/wp-content/uploads/2018/07/West-bengal.pdf
4. BEE-GEF-World Bank. (2015). *Best Practices - Energy Effciency Initiatives in Forging Industry*. Retrieved from http://www.indiasavesenergy.in/Uploads/Documents/635955349367237369.pdf
5. Bijli Bachao. (2015). *Solar Panel Cost Price in India*. Retrieved from https://www.bijlibachao.com/solar/solar-panel-cell-cost-price-list-in-india.html
6. Bijli Bachao. (2016). *Primer on Solar Water Heaters*. Retrieved from https://www.bijlibachao.com/solar/solar-water-heater-system-how-can-it-save-energy-and-its-prices-in-india.html
7. Bloombergquint Report. (2018, June). *India Veers Towards European Electric Vehicle Charging Standard*. Retrieved from https://www.bloombergquint.com/technology/india-veers-towards-european-electric-vehicle-charging-standard#gs.f0nO1Tgz
8. Bureau of Energy Efficiency (BEE). (2018). *PAT Cycle documents*. Retrieved from https://beeindia.gov.in/sites/default/files/3%20S.O.%20687%20dated%2030.%20Mar%202012-%20Targtes%20under%20PAT%20-%20I.pdf
9. Bureau of Energy Efficiency. (2016). *Snapshot of performance of PAT I.* Retrieved from https://beeindia.gov.in/sites/default/files/Final%20Booklet%2029-9-2017.pdf
10. Bureau of Energy Efficiency. (n.d.). *Chapter on Cogeneration*. Retrieved from https://beeindia.gov.in/sites/default/files/2Ch7.pdf
11. Business Standard. (2018). *Report*. Retrieved from https://www.business-standard.com/article/news-ians/japan-to-lend-rs-1-817-cr-for-hydel-power-project-in-bengal-118110201563_1.html
12. *Business Standard*. (2019, January 9). Retrieved from https://www.business-standard.com/article/companies/h-energy-plans-rs-3-700-cr-investment-for-regasification-project-in-bengal-119010900841_1.html
13. CARET AMU Aligarh. (2018, May). *Business of Charging Infrastructure for Electric Vehicles*. Retrieved from http://www.iitk.ac.in/ime/anoops/IEX%20Training-2018/presentation/CARET_IITK_IEX.pdf
14. CBIRC Ministry of Finance GOI. (2019). Retrieved from https://cbec-gst.gov.in/gst-goods-services-rates.html
15. CEEW. (2015, February). *Clean, affordable and sustainable cooking energy in India*. Retrieved from https://www.ceew.in/sites/default/files/CEEW-Clean-affordable-and-sustainable-cooking-energy-in-India-Feb2015.pdf
16. Central Electrical Authority. (2018, March). *Monthly Archives - Renewable Power Supply.* Retrieved from http://www.cea.nic.in/reports/monthly/renewable/2018/renewable-03.pdf
17. Central Electricity Authority. (2018, March). *Monthly Archives - Power Supply Position.* Retrieved from http://www.cea.nic.in/reports/monthly/powersupply/2018/psp_energy-03.pdf
18. Central Electricity Authority. (2018, March). *Monthly Reports - Generation Report.* Retrieved from http://www.cea.nic.in/reports/monthly/generation/2018/March/actual/opm_16.pdf
19. Centre for Budget and Governance Accountability, India. (2018, February 1). *West Bengal Budget Analysis 2018-19.* Retrieved from http://www.prsindia.org/uploads/media/State%20Budget%202018-19/West%20Bengal%20Budget%20Analysis%202018-19.pdf
20. CESC Limited. (2018, March). *Investor Presentation*. Retrieved from https://www.cesc.co.in/wp-content/uploads/invpresent/CESC%20Investor%20Presentation-March%202018.pdf

21. Clean Future. (2018, September 15). *NKDA Sets Up EV Charging Docks In Kolkata*. Retrieved from http://www.cleanfuture.co.in/2018/09/15/nkda-sets-up-ev-charging-docks-in-kolkata/
22. Climate Investment Fund. (2017). *Note on preliminary financial and economic analysis of energy storage and floating solar photovoltaic system*. Retrieved from https://www.climateinvestmentfunds.org/sites/cif_enc/files/meeting-documents/note_on_financial_and_economic_analysis_for_storage_and_floating_solar_applications_07202017.pdf
23. CloudFront. (2018). *Report*. Retrieved from https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2018/06/Lilita-Pacudan-Floating-Solar-PV-Global-Developent-Through-2017.pdf
24. Coalspot. (2012). Retrieved from http://www.coalspot.com/news/1888/capital-costs-of-indian-coal-mining-project/1
25. Cochin Shipyard. (2018, August). *Investor Presentation*. Retrieved from https://cochinshipyard.com/links/Investor%20Presentation%20Aug%2018.pdf
26. CRI Pumps. (2017). Retrieved from https://www.business-standard.com/article/press-releases/bee-s-energy-saving-pilot-project-awarded-to-c-r-i-pumps-110082300089_1.html
27. DeepResource. (2012). Retrieved from https://deepresource.wordpress.com/2012/04/23/energy-related-conversion-factors/
28. Department of Fisheries, Govt. of West Bengal. (2019). *Harvesting the treasures of our water.* Kolkata.
29. Department of Information & Cultural Affairs, GoWB. (2018). *Chronicles of Bengal's Progress - 7 years.* Retrieved from http://www.wbpublibnet.gov.in/node/3302
30. Department of MSME & Textiles, GoWB. (2018, April). *MSME Sector in West Bengal - Backbone of the State's Economy.* Retrieved from https://myenterprisewb.in/home/download/cmJHSU84N3Q0TGlQdllSRWVBUVhpNWNhaXJad0RSdndLTlM1aHFFb3MvN0owTWlBZHFYamRVU3BVbndZRDFPbmV2TzkxeW5GZ1J3RWF2Rk1JNG5pUEt6TERFWmhqNU94Z2tCYWkvbmpJc1I3eWRvRjZ2azRYT2tyelFqM3hPY3M=
31. Department of MSME and Textiles, GoWB. (2013). *MSME Policy 2013-18.* Retrieved from http://bharatchamber.com/MSME-policy-2013-18.pdf
32. Department of Planning & Statistics, Govt. of West Bengal. (n.d.). *Statistical Abstract (2009-10 to 2014-15).*
33. Department of Planning and Statistics. (2017). *West Bengal Economic Review 2016-17*. Retrieved from https://www.wbpspm.gov.in/SiteFiles/Publications/1_22072017161809.pdf
34. Department of Power & NES, Government of West Bengal. (n.d.). Information gathered from the Department officials.
35. Department of Power & NES, Govt. of West Bengal. (2012, June). *Policy on Co-generation and Generation of Electricity from Renewable Sources of Energy.* Retrieved from https://mnre.gov.in/file-manager/UserFiles/Grid-Connected-Solar-Rooftop-policy/West_Bengal_Solar_Policy_2012.pdf
36. Department of Power & NES, Govt. of West Bengal. (2016, March 22). *West Bengal Energy Conservation Building Code, 2016.* Retrieved from http://www.aeee.in/wp-content/uploads/2017/05/West-Bengal_ECBC-notification_2016.pdf
37. Department of Power. (2012). *Renewable Energy Policy*. Retrieved from http://www.wbgedcl.in/wp-content/themes/wbgedcl/images/pdf/policy-renewable-wb.pdf
38. Dept. of Agriculture, Govt. of West Bengal. (2019). *Investment opportunities in Agri and Allied business sector in West Bengal.* Kolkata.
39. Dept. of Fisheries, Govt. of West Bengal. (2015). *Fisheries Statistical Handbook 2015-16*. Retrieved from https://www.wbfisheries.in/files/Statistical%20handbook15-16.pdf
40. Dept. of Fisheries, Govt. of West Bengal. (2015, June 4). *West Bengal Fisheries investment policy 2015.* Retrieved from https://bengalglobalsummit.com/pdf/policies/West-Bengal-Fisheries-Investment-Policy-2015.pdf

41. Dept. of Municipal Affairs, Govt. Of West Bengal. (2009, September 9). *The Kolkata Municipal Corporation Building Rules.* Retrieved from https://www.kmcgov.in/KMCPortal/downloads/Building_%20Rules2009.pdf
42. Down to Earth. (2015). *Power Hat trick*. Retrieved from https://www.downtoearth.org.in/coverage/power-hat-trick-40331
43. Down to Earth. (2015, July). *Solid biomass as cooking fuel is a killer*. Retrieved from https://www.downtoearth.org.in/news/solid-biomass-as-cooking-fuel-is-a-killer-8001
44. DowntoEarth Report. (2015, June). *What's cooking in India's largest biogas plant*. Retrieved from https://www.downtoearth.org.in/coverage/whats-cooking-in-indias-largest-biogas-plant-12615
45. Economic Times. (2018, August 18). *West Bengal to add over 2,000 Mw power capacity over five years*. Retrieved from https://energy.economictimes.indiatimes.com/news/power/west-bengal-to-add-over-2000-mw-power-capacity-over-five-years/65447425
46. Economic Times Report. (2016, September). Retrieved from https://economictimes.indiatimes.com/tech/internet/vodafone-rolls-4g-service-in-bengal-circle/articleshow/54294578.cms
47. Economic Times report. (2018, August 28). *West Bengal to meet fish production target: Chandra Nath Sinha, Minister for fisheries*. Retrieved from https://economictimes.indiatimes.com/news/economy/agriculture/west-bengal-to-meet-fish-production-target-chandra-nath-sinha-minister-for-fisheries/articleshow/65580797.cms
48. EESL. (2018, January 10). *National Ujala Dashboard - West Bengal*. Retrieved January 10, 2018, from http://ujala.gov.in/state-dashboard/west-bengal
49. Electrek. (2018, February). *All-electric ferry cuts emission by 95% and costs by 80%, brings in 53 additional orders*. Retrieved from https://electrek.co/2018/02/03/all-electric-ferry-cuts-emission-cost/
50. EnergyMatters. (2016, July). *Better Renewable Energy Forecasting In Germany*. Retrieved from https://www.energymatters.com.au/renewable-news/germany-renewables-forecasting-em5511/
51. Financial Express. (2017, May). *Government starts multiple waterways transportation*. Retrieved from https://www.financialexpress.com/india-news/government-starts-multiple-waterways-transportation/657156/
52. Financial Express. (2018, November 30). *Report - West Bengal's cement capacity may touch 30million tonne in 3 years, say officials*. Retrieved from https://www.financialexpress.com/industry/west-bengals-cement-capacity-may-touch-30million-tonne-in-3-years-say-officials/1399697/
53. Financial Express Report. (2017, January 10). *Blue revolution: West Bengal eyes fishery as sunrise sector*. Retrieved from https://www.financialexpress.com/market/blue-revolution-west-bengal-eyes-fishery-as-sunrise-sector/502774/
54. Fisheries Department, Govt of West Bengal. (2016, September). *Handbook of Fisheries Statisics 2015-16.* Retrieved from https://www.wbfisheries.in/files/Statistical%20handbook15-16.pdf
55. Fisheries Department, Govt. of West Bengal. (1993, June 14). *The West Bengal Marine Fishing Regulation Act, 1993.* Retrieved from https://www.wbfisheries.in/files/WB%20Marine%20Fishing%20Act.pdf
56. Fisheries Dept, Govt. of West Bengal. (1984, September 4). *West Bengal Inland Fisheries Act, 1984.* Retrieved from https://wbxpress.com/wp-content/uploads/2011/06/WB-Inland-Fisheries-Act-1984.pdf
57. Fisheries Dept, Govt. of West Bengal. (1995, April 22). *West Bengal Marine Fishing Regulation Rules, 1995.* Retrieved from https://www.wbfisheries.in/files/WB%20Marine%20Fishery%20Rules.pdf
58. Fisheries Dept, Govt. of West Bengal. (2019). *Investment opportunities in Agri & Allied Business sector in West Bengal.*

59. Fisheries Dept., Govt. of West Bengal. (1985, May 6). *West Bengal Inland Fisheries Rules, 1985.* Retrieved from https://www.wbfisheries.in/files/Inland%20Fisheries%20Act.pdf
60. GHMC. (2017, April).
61. GIZ-IGEN. (2015). *Report on Forecasting, Concept of Renewable Energy Management Centres and Grid Balancing*. Retrieved from https://mnre.gov.in/sites/default/files/uploads/draft-report-fscb-remcs.pdf
62. Global Energia. (2013). Retrieved from http://indianpowersector.com/wp-content/uploads/2013/04/Smart-Grid.pdf
63. HeatCalc. (n.d.). *Article on Iron & Steel*. Retrieved from http://heatcalc.com/steel/
64. Hindu Business Line. (2018). Retrieved from https://www.thehindubusinessline.com/news/national/set-up-integrated-cement-plants-in-bengal-minister/article25636688.ece
65. IBEF. (2018, May). *Industrial Development & Economic Growth in West Bengal.* Retrieved from https://www.ibef.org/archives/state/west-bengal-reports/industrial-dev-economic-growth-may-2018
66. IBEF. (2018, December). *Industrial Development & Economic Growth In West Bengal.* Retrieved from https://www.ibef.org/states/west-bengal-presentation
67. ICAR. (2015). *CIFT Develops a Solar Powered Boat*. Retrieved from https://icar.org.in/node/5787
68. IEEE. (2013). *On-board solar power for small-scale distant-water fishing vessels*. Retrieved from https://ieeexplore.ieee.org/document/6713644
69. IEEE. (2013). *On-board solar power for small-scale distant-water fishing vessels*. Retrieved from https://ieeexplore.ieee.org/document/6713644
70. IEEE report. (2013). *On-board solar power for small-scale distant-water fishing vessels*. Retrieved from https://ieeexplore.ieee.org/document/6713644
71. IIASA. (n.d.). *Internation Institute for Applied Systems Analysis*. Retrieved from https://messageix.iiasa.ac.at/
72. IIASA. (n.d.). *Internationa Institute for Applied Systems Analysis*. Retrieved from http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/MESSAGE.en.html
73. IISC. (2015). *Calorific value of different fuels*. Retrieved from http://www.ces.iisc.ernet.in/energy/paper/alternative/calorific.html
74. India Fillings. (2015). *Gatidhara Scheme*. Retrieved from https://www.indiafilings.com/learn/gatidhara-scheme/
75. India Smart Grid Forum. (2013). *Smart Grid Vision and Roadmap for India*. Retrieved from http://www.indiasmartgrid.org/reports/Smart%20Grid%20Vision%20and%20Roadmap%20for%20India.pdf
76. India Smart Grid Forum. (2018, September). *EV charging station business models for India*. Retrieved from http://www.indiasmartgrid.org/reports/ISGF%20White%20Paper%20-%20EVSE%20Business%20Models%20for%20India.pdf
77. Indian Bureau of Mines. (2018, March). *Indian Minerals Yearbook 2017: Coal & Lignite.* Retrieved from http://ibm.nic.in/writereaddata/files/03202018145834Coal%20and%20Lig_AR_2017.pdf
78. Indian Council of Agricultural Research. (n.d.). *CIFT Develops a Solar Powered Boat*. Retrieved from https://icar.org.in/node/5787
79. Indian Railways. (2018). *Vibrant Railways - Strengthening Bengal.* Retrieved from http://www.indianrailways.gov.in/railwayboard/uploads/directorate/secretary_branches/Inititives_Statewise_Achievements/4_Years_Achievement_Booklet_West_Bengal_English.pdf
80. IndianWeb2. (2016, April). Retrieved from https://www.indianweb2.com/2016/04/13/7-promising-cleantech-startups-india-right-now/
81. Indiastat. (2016).
82. Indraprastha Gas Limited. (2019, April 4). *Current CNG/PNG prices*. Retrieved from https://www.iglonline.net/english/Default.aspx?option=article&type=single&id=40&mnuid=103&prvtyp=site

83. Innovation Seeds. (2012). *ECO-POINT INCENTIVE PROGRAM IN JAPAN*. Retrieved from http://www.innovationseeds.eu/policy-library/core-articles/eco-point-incentive-program-in-japan.kl
84. International Energy Agency. (2008). *Energy Improvement and Extension Act 2008 - Tax Incentives*. Retrieved from https://www.iea.org/policiesandmeasures/pams/unitedstates/name-24422-en.php?s=dHlwZT1lZSZzdGF0dXM9T2s,&return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEgaHJlZj0iLyI-SG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlczwvYT4gJ
85. Intersolar Systems. (2017). *Cost Of Solar Water Heaters In India*. Retrieved from https://www.intersolarsystems.com/cost-of-solar-water-heaters-in-india
86. ISGF. (2015). *Demand Response - Primer*. Retrieved from http://www.indiasmartgrid.org/Demand-Response.php
87. Jakson. (2018, August 18). *Floating Solar Power Plants – A promising technology that needs time to evolve*. Retrieved from https://www.jakson.com/blog/floating-solar-power-plants-a-promising-technology-that-requires-time-to-evolve/
88. Kelltontech. (2018, July 29). *THE IMPACT OF IOT ON THE ENERGY SECTOR*. Retrieved from https://www.kelltontech.com/kellton-tech-blog/impact-iot-energy-sector
89. Livemint Article. (2018, July 6). *Article - Bengal govt won't chase the centre's 2022 target on solar power generation*. Retrieved from https://www.livemint.com/Politics/zYW7HJWCnC4UHN8NajGUON/Bengal-govt-wont-chase-the-centres-2022-target-on-solar-po.html
90. Lloyd. (2018). *AC Energy savings*. Retrieved from https://www.amazon.in/dp/B073ZTMN3N/ref=pd_lpo_sbs_dp_ss_2?pf_rd_p=cd818f9c-142a-4b42-ad2c-f0421857aaf5&pf_rd_s=lpo-top-stripe&pf_rd_t=201&pf_rd_i=B016OB0RW4&pf_rd_m=A1VBAL9TL5WCBF&pf_rd_r=NNG1DNTP5YXW8V9RMJR1&pf_rd_r=NNG1DNTP5YXW8V9RMJR1&pf_rd_p=cd818f9c
91. M.R.Boopendranath. (n.d.). *Energy Optimization in Fishing.* Retrieved from http://drs.cift.res.in/bitstream/handle/123456789/883/energy%20optimization%20in%20fishing.pdf?sequence=1
92. McKinsey report. (2019, March). *How residential energy storage could help support the power grid*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/Electric%20Power%20and%20Natural%20Gas/Our%20Insights/How%20residential%20energy%20storage%20could%20help%20support%20the%20power%20grid/How-residential-energy-storage-could-help-support-the-power-grid.
93. MERCOM. (2018). Retrieved from https://mercomindia.com/mnre-benchmark-cost-off-grid-distributed-solar/
94. Mercom India. (2018, August 30). *Telangana First State to Comply with Energy Conservation and Building Code Guidelines*. Retrieved from https://mercomindia.com/telangana-first-state-ecbc-compliant/
95. METI Government of Japan. (2014, April). *Fourth Strategic Energy Plan*. Retrieved from http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf#search='Strategic+Energy+Plan+of+Japan%2C+March+2014'
96. Millenium Post. (2018, June 13). *Kolkata turns new leaf as it becomes third city in India to get e-car rental facility*. Retrieved January 10, 2018, from http://www.millenniumpost.in/kolkata/kolkata-turns-new-leaf-as-it-becomes-third-city-in-india-to-get-e-car-rental-facility-304393
97. *Millenium Post*. (2019, January 9). Retrieved from http://www.millenniumpost.in/kolkata/gail-to-make-rs-5000-cr-investment-forconstruction-of-natural-gas-cng-pipelines-335649
98. Milleniumpost report. (2018, August 12). *Popularity of electric buses on the rise in New Town*. Retrieved from http://www.millenniumpost.in/kolkata/popularity-of-electric-buses-on-the-rise-in-new-town-314017

99. Ministry of Coal, Govt. of India (2016-17). (2018, June). *Coal Statistics 2016-17.* Retrieved from http://www.coalcontroller.gov.in/writereaddata/files/download/coaldirectory/CoalDirectory2016-17.pdf
100. Ministry of Coal, Govt. of India (2017-18). (2018, December). *Provisional Coal Statistics 2017-18.* Retrieved from http://www.coalcontroller.gov.in/writereaddata/files/download/provisionalcoalstat/ProvisionalCoalStat2017-18.pdf
101. Ministry of Drinking Water and Sanitation. (2018, April). *Gobar Dhan Policy Brief - Swachh Bharat Mission*. Retrieved from https://swachhbharatmission.gov.in/SLRM/Download.aspx?FileName=GOBAR%20DHAN%20Policy%20Brief.pdf
102. Ministry of Law and Justice GOI. (2016). *The National Waterways Act, 2016*. Retrieved from http://egazette.nic.in/WriteReadData/2016/168716.pdf
103. Ministry of Petroleum & Natural Gas, Economic & Statistics Division. (2018). *Indian Petroleum & Natural Gas Statistics 2017-18.* Retrieved from http://petroleum.nic.in/sites/default/files/ipngstat_0.pdf
104. Ministry of Power. (2018, November 29). *8 states achieve 100% household electrification under Saubhagya*. Retrieved from http://pib.nic.in/PressReleaseIframePage.aspx?PRID=1554205
105. Ministry of Power GoI. (2016). *Lok Sabha Qestion*. Retrieved from http://www.indiaenvironmentportal.org.in/files/file/Demand%20and%20Supply%20of%20Power.pdf
106. Ministry of Power GoI. (2017). *Revised AT&C Loss Trajectory*. Retrieved from http://www.ipds.gov.in/Whats_New_Files/ATandC_loss_Trajectory_13Apr17.pdf
107. Ministry of Power GoI. (2018, December). *Charging Infrastructure for EVs - Guidelines and Standards*. Retrieved from https://powermin.nic.in/sites/default/files/webform/notices/scan0016%20%281%29.pdf
108. Ministry of Power, Government of India. (2017, September 17). *AT&C Loss trajectory.* Retrieved from http://www.ipds.gov.in/Whats_New_Files/ATC_Loss_Trajectory_letter_11Sep2017.pdf
109. MNRE. (n.d.). *Probable question on Biogas programme*. Retrieved from https://mnre.gov.in/file-manager/UserFiles/faq_biogas.htm
110. MNRE, Govt. of India. (2005). *Biomass resource potential in West Bengal.* Retrieved from https://biomasspower.gov.in/west-bengal.php
111. MNRE, Govt. of India. (2011). *Biomass & Co-Generation.* Retrieved from https://mnre.gov.in/biomass-powercogen
112. MNRE, Govt. of India. (2019, February 13). *Physical Progress (Achievements).* Retrieved from https://mnre.gov.in/sites/default/files/uploads/State.xlsx
113. MOSPI. (2017). *Statistical Yearbook*. Retrieved from http://www.mospi.gov.in/statistical-year-book-india/2017/190
114. MOSPI, Govt. of India. (2016). *Annual Survey of Industries 2015-16.* Retrieved from http://microdata.gov.in/nada43/index.php/catalog/143
115. MSME - Development Institute. (2018, August 23). *SAMEEKSHA Platform - Presentation*. Retrieved from http://sameeeksha.org/pdf/presentation/EET_Presentation_MSME-DI_Kolkata.pdf
116. MyClimate Projects. (2019). *Biogas Plants for 9,000 Families*. Retrieved from https://www.myclimate.org/information/climate-protection-projects/detail-climate-protection-projects/india-biogas-7149/
117. Mydigitalfc. (2017, January). *Interview with MD & CEO of NavAlt*. Retrieved from http://www.mydigitalfc.com/my-world/navalt%E2%80%99s-solar-and-electrical-boats-would-change-water-transport-system-country
118. MyGov.in. (2017). *CSIR-CIMFR Installs and Commissions first-of-its-kind Coal to Liquid (CTL) Pilot Plant for Producing Diesel and Gasoline from Coal*. Retrieved from

https://blog.mygov.in/csir-cimfr-installs-and-commissions-first-of-its-kind-coal-to-liquid-ctl-pilot-plant-for-producing-diesel-and-gasoline-from-coal/
119. National Center for Sustainable Transportation. (2015, November). *Intelligent Transportation systems for Improving traffic energy efficiency* . Retrieved from https://ncst.ucdavis.edu/wp-content/uploads/2014/08/02-22-2016-NCST_WP_ITS_GHG-UCR-final3.pdf
120. National Institute Of Solar Energy (NISE). (2014, November). *State wise Estimated Solar Power Potential in the Country*. Retrieved from https://mnre.gov.in/file-manager/UserFiles/Statewise-Solar-Potential-NISE.pdf
121. National Ujala Dashboard, EESL. (2019, January 16). *State Dashboard - West Bengal*. Retrieved from http://ujala.gov.in/state-dashboard/west-bengal
122. Navgathi Marine. (2014). Retrieved from https://www.prlog.org/12287086-navgathi-marine-hands-over-indias-first-compact-solar-fishing-boat-sun-boat.html
123. NEDO. (2014, July). *Demonstration of a Waste Heat Recovery System.* Retrieved from https://www.nedo.go.jp/content/100567628.pdf
124. NEDO. (2014). *Demonstration of a Waste Heat Recovery System*. Retrieved from https://www.nedo.go.jp/content/100567628.pdf
125. New Indian Express Report. (2018, August 28). *Kerala government to prod fishing boats to tap solar energy*. Retrieved from http://www.newindianexpress.com/thesundaystandard/2018/aug/26/kerala-government-to-prod-fishing-boats-to-tap-solar-energy-1862778.html
126. New Indian Express report. (2019, February). Retrieved from http://www.newindianexpress.com/cities/kochi/2019/feb/07/second-solar-boat-to-be-launched-by-cift-soon-1935313.html
127. *News Article: Energy Efficiency Scheme Launched In West Bengal*. (2017, January 15). Retrieved from https://numerical.co.in/numerons/collection/5882fd7ee7ca631c20e6b535
128. News18 report. (2017, November 23). *Gujarat, West Bengal, UP, Rajasthan and Maharashtra - Top 5 States With Maximum Electric Vehicles*. Retrieved from https://www.news18.com/news/auto/gujarat-west-bengal-up-rajasthan-and-maharashtra-top-5-states-with-maximum-electric-vehicles-1585603.html
129. Next-Kraftwerke. (n.d.). *What are Dispatch and Redispatch?* Retrieved from https://www.next-kraftwerke.com/knowledge/dispatch
130. NITI Aayog. (2016). *IESS Ver 2.2*.
131. NKDA. (2018, May 3). *In a first, electric buses roll out in New Town*. Retrieved from https://timesofindia.indiatimes.com/city/kolkata/in-a-first-electric-buses-roll-out-in-new-town/articleshow/64011683.cms
132. NKDA. (2018, May 21). *Quiet and efficient, electric buses in New Town*. Retrieved from https://www.telegraphindia.com/states/west-bengal/quiet-and-efficient-electric-buses-in-new-town/cid/1417282
133. OCL Bengal Cement Works. (2017). Retrieved from http://greenbusinesscentre.com/energyaward2017presentations/Cement/17.%20OCL%20Bengal%20Cement%20works.pdf
134. OCL Bengal Cement Works. (2017, August). *Presentation - National Award for excellence in energy management*. Retrieved from http://greenbusinesscentre.com/energyaward2017presentations/Cement/17.%20OCL%20Bengal%20Cement%20works.pdf
135. OCL India Limited. (2017). Retrieved from http://greenbusinesscentre.com/energyaward2017presentations/Cement/17.%20OCL%20Bengal%20Cement%20works.pdf
136. Onlie Shopping Site [Amazon india]. (2019). *Tubelight price*. Retrieved from https://www.amazon.in/dp/B073ZTMN3N/ref=pd_lpo_sbs_dp_ss_2?pf_rd_p=cd818f9c-142a-4b42-ad2c-f0421857aaf5&pf_rd_s=lpo-top-stripe&pf_rd_t=201&pf_rd_i=B016OB0RW4&pf_rd_m=A1VBAL9TL5WCBF&pf_rd_r=NNG1DNTP5YXW8V9RMJR1&pf_rd_r=NNG1DNTP5YXW8V9RMJR1&pf_rd_p=cd818f9c

137. Online shopping site [Amazon India]. (2019). Retrieved from https://www.amazon.in/Gorilla-Energy-Saving-Ceiling-Control/dp/B071Y7K862/ref=sr_1_1_sspa?s=kitchen&ie=UTF8&qid=1550638514&sr=1-1-spons&keywords=gorilla+fan&psc=1
138. Online Shopping Site [Amazon India]. (2019). *5 star 1.5T AC*. Retrieved from https://www.amazon.in/Daikin-Inverter-Split-Copper-FTKF50TV/dp/B07HFK5FSD/ref=sr_1_1_sspa?s=kitchen&ie=UTF8&qid=1550640021&sr=1-1-spons&keywords=5+star+split+ac+1.5ton&psc=1%22
139. Online shopping site [Indiamart]. (2019). Retrieved from https://www.indiamart.com/proddetail/central-air-conditioner-4194677273.html
140. P&RD Department, Govt. of West Bengal. (n.d.). *Procedure for seeking permission for erection of new structure or building or to make any addition to existing structure of building in rural areas and grant of permission thereof.* Retrieved from http://wbprd.nic.in/writereaddata/EODB/SOP%20-I.pdf
141. Petroleum Planning and Analysis Cell. (2013). *All India Study on Sectoral Demand of Diesel & Petrol.* Retrieved from http://ppac.org.in/WriteReadData/Reports/201411110329450069740AllIndiaStudyonSectoralDemandofDiesel.pdf
142. Planning & Statistics Deparment, G. (n.d.). Power Sales data (1900 to 2015).
143. Planning & Statistics Dept, Govt. of West Bengal. (2015). *Statistical Handbook 2015.*
144. Plugin India. (2018). *Electric Vehicles in India*. Retrieved from http://www.pluginindia.com/vehicles.html
145. (2016). *Power for all - West Bengal.*
146. Power For All Document, G. o. (2016, August). *Power For All Document for West Bengal.* Retrieved from https://powermin.nic.in/sites/default/files/uploads/joint_initiative_of_govt_of_india_and_West_Bengol.pdf
147. Prayas. (2017, August). *Understanding the impacts of India's LED bulb programme, UJALA*. Retrieved from Shakti Foundation: http://shaktifoundation.in/wp-content/uploads/2017/10/UJALA_Low-res.pdf
148. Press Bureau of India. (2018, December). *ECO Niwas Samhita 2018 - an Energy Conservation Building Code for Residential Buildings launched*. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=186406
149. Press Information Bureau. (2017, March). *Inland Water Transport to Reduce Overall Logistics Cost*. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=159571
150. PRlog report. (2014). *Navgathi Marine hands over India's first compact solar fishing boat – Sun Boat*. Retrieved from https://www.prlog.org/12287086-navgathi-marine-hands-over-indias-first-compact-solar-fishing-boat-sun-boat.html
151. *Prod to plug power losses*. (2018, August 23). Retrieved from The Telegraph: https://www.telegraphindia.com/states/west-bengal/prod-to-plug-power-losses/cid/1531702
152. *Prod to plug power losses.* (2018, August 23). Retrieved from https://www.telegraphindia.com/states/west-bengal/prod-to-plug-power-losses/cid/1531702
153. REHVA. (2017, December). *India's First District Cooling System at GIFT City*. Retrieved from https://www.rehva.eu/publications-and-resources/rehva-journal/2018/012018/indias-first-district-cooling-system-at-gift-city.html
154. Representative of Transport Dept., G. o. (2019, January 9).
155. Reuters. (2018). *Report*. Retrieved from https://www.business-standard.com/article/news-ians/japan-to-lend-rs-1-817-cr-for-hydel-power-project-in-bengal-118110201563_1.html
156. RGPV. (2017). Retrieved from https://www.rgpv.ac.in/PDF/Adoption of Supercritical Technology.ppt
157. Schneider Electric. (2014). *The Benefits of Demand Response for Utilities*. Retrieved from https://www.energy-pool.eu/wp-content/uploads/2016/07/The-benefits-of-Demand-Response-for-Utilities.pdf

158. Sector Experts from GIZ . (2019). *Production of bricks through natural draft zigzag kilns.* Retrieved from http://www.ccacoalition.org/en/file/4225/download?token=8LNLY_YQ
159. Shakti Sustainable Energy Foundation. (2013). *Technology compendium on energy saving opportunities - Pulp & Paper*. Retrieved from http://www.indiaenvironmentportal.org.in/files/file/pulp_paper.pdf
160. Shakti Sustainable Energy Foundation. (2017, November 1). *Implementation Plan for Electrification of Public Transport in Kolkata.* Retrieved from http://www.indiasmartgrid.org/reports/Report_Implementation_Plan_for_Electrification_of_Public_Transport_in_Kolkata_1_November_2017.pdf
161. SIDBI. (2014). *Importance of IGDPR & possible EE projects in MSME* . Retrieved from http://www.indiasavesenergy.in/Uploads/Documents/635955333390157307.pdf
162. Smart Cities Council - India. (2017, November 16). *See how district cooling system will make Raiya the "coolest" smart city*. Retrieved from https://india.smartcitiescouncil.com/article/see-how-district-cooling-system-will-make-raiya-coolest-smart-city
163. Smart Energy International. (2018, April). *West Bengal gears up for smart meter pilot project*. Retrieved from https://www.smart-energy.com/industry-sectors/west-bengal-smart-meter-project/
164. Smriti Chand. (n.d.). *Paper Industry: Growth and Distribution of Paper Industry in India*. Retrieved from http://www.yourarticlelibrary.com/industries/paper-industry-growth-and-distribution-of-paper-industry-in-india/14193
165. Society of Manufacturers of Electric Vehicles (SMEV). (2018, May). *Going Electric*. Retrieved January 10, 2018, from https://mediaindia.eu/environment/going-electric/
166. State EE Preparedness Index dashboard. (2018, July). *State Energy Efficiency Preparedness Index - Transport*. Retrieved from http://www.aeee.in/state-ee-index/view/
167. TERI. (2015). *Green growth and clean coal technologies in India*. Retrieved from https://www.teriin.org/projects/green/pdf/India-CCT.pdf
168. TERI. (2016). *Cluster Profile - Howrah Foundry industries*. Retrieved from http://sameeeksha.org/pdf/clusterprofile/Howrah-Foundries-West-Bengal.pdf
169. The Better India. (2018, March 6). *Punjab Village Uses Cow Dung To Deliver Piped Biogas Straight to Kitchens*. Retrieved from https://www.thebetterindia.com/132988/lambra-punjab-village-biogas-plant-gobar-dhan/
170. The Hindu. (2018, December). *Japan's cold chain for Singur*. Retrieved from https://www.thehindu.com/news/national/other-states/japans-cold-chain-for-singur/article25735979.ece
171. The Hindu BusinessLine. (2014, October). *Bengal gets its first hybrid solar micro cold storage facility*. Retrieved from https://www.thehindubusinessline.com/news/national/bengal-gets-its-first-hybrid-solar-micro-cold-storage-facility/article23161118.ece
172. The Hindu BusinessLine. (2019, January). *H-Energy to kick-start LNG project in June*. Retrieved from https://www.thehindubusinessline.com/companies/h-energy-to-kick-start-lng-project-in-june/article25952606.ece
173. Times of India. (2018, February 28). *Kolkata, five districts to get green piped gas soon* . Retrieved from https://timesofindia.indiatimes.com/city/kolkata/kolkata-five-districts-to-get-green-piped-gas-soon/articleshow/63104232.cms
174. Times of India report. (2018, June). *Pollution Due To Burning Of Cow Dung & Wood As Fuel Killed 1.24 Lakh People In One Year*. Retrieved from https://www.indiatimes.com/news/india/pollution-due-to-burning-of-cow-dung-wood-as-fuel-killed-1-24-lakh-people-in-one-year-332719.html
175. Transport Department. (2018). *Vahan website*.
176. Transport Department. (2019, January 9).
177. Transport Dept GoWB 2018. (2018, December 15). *January debut for electric bus fleet in Calcutta*. Retrieved from https://www.telegraphindia.com/states/west-bengal/january-debut-for-electric-bus-fleet-in-calcutta/cid/1678901

178. Trolley Project EU. (2013). *Transport Mode Efficiency Analysis: Bus and Trolleybus system*. Retrieved from http://www.trolley-project.eu/fileadmin/user_upload/download/TROLLEY_WP4_Transport_Mode_Efficiency_Analysis_Bus_vs_Trolleybus.pdf
179. UD&MA Dept, Govt. of West Bengal. (2016, December 28). *Order on incremental fees/charges & guidelines for grant of additional FAR & green building certification.* Retrieved from https://www.wbdma.gov.in/PDF/567-ma_2016-2017.pdf
180. UD&MA Dept., Govt. of West Bengal. (2017, February 20). *Operational guidelines for Green City Mission*. Retrieved from https://wbxpress.com/operational-guidelines-green-city-mission/
181. UD&MA Dept., Govt. of West Bengal. (2019, January 17). *Green City Adminitrative Approval List (2016-17 to 2018-19)*. Retrieved from https://www.wburbandev.gov.in/Home/adm_appv_green_2016_17
182. UNESCAP. (2012). *Case Study: Low Carbon Green Growth Roadmap for Asia and the Pacific*. Retrieved from https://www.unescap.org/sites/default/files/28.%20CS-Japan-housing-eco-point-system.pdf
183. Uniindia report. (2018, February). *Bengal Govt to distribute e-rickshaws to unemployed rural youths*. Retrieved from http://www.uniindia.com/bengal-govt-to-distribute-e-rickshaws-to-unemployed-rural-youths/states/news/1152775.html
184. Uniindia Report. (2018, November 19). *Financial assistance to buy e-rickshaws, courtesy Bengal Govt.* Retrieved from http://www.uniindia.com/news/east/financial-assistance-to-buy-e-rickshaws-courtesy-bengal-govt/1409297.html
185. US Dept of Energy's PNNL. (2016, November). *Implementing the Energy Conservation Building Code: Toolkit for Smart Cities*. Retrieved from https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26000.pdf
186. US DOE. (2018). Retrieved from https://www.bijlibachao.com/appliances/cooktop-comparison-gas-electric-and-induction.html
187. V.K. Tewari, A. A. (2012, December 23). *Farm mechanization status of West Bengal in India.* Retrieved from http://basicresearchjournals.org/agric/pdf/Kumar%20et%20al.pdf
188. Vikaspedia. (2019). *Pradhan Mantri Krishi Sinchai Yojana*. Retrieved from http://vikaspedia.in/agriculture/policies-and-schemes/crops-related/pradhan-mantri-krishi-sinchai-yojana
189. Vikaspedia Article. (n.d.). *Fishing Boats in India*. Retrieved from http://vikaspedia.in/agriculture/fisheries/marine-fisheries/capture-fisheries/fishing-boats-in-india?content=normal#section-31
190. WBIDC. (2014). *The West Bengal State Support for Industries Scheme, 2013 (as*. Retrieved from http://www.wbidc.com/images/pdf/WBSSIS_Amended_full_book_12092014_Notified.pdf
191. WBIDC, Government of West Bengal. (2018). *Bengal Global Business Summit 2017-18.* Kolkata.
192. WBSEDCL. (2017). *Tariff Order 17-18*. Retrieved from https://www.wbsedcl.in/irj/go/km/docs/internet/new_website/pdf/Tariff_Volumn/Tariff_Order_1718.pdf
193. WBSEDCL. (2018, September). *Distribution Projects*. Retrieved from https://www.wbsedcl.in/irj/go/km/docs/internet/new_website/Distribution_Projects.html
194. WBSEDCL. (2019). *IT Infrastructure*. Retrieved from https://www.wbsedcl.in/irj/go/km/docs/internet/new_website/Information_Technology.html
195. West Bengal Energy Model Analysis (2019).
196. West Bengal Renewable Energy Development Agency. (2011). *RE Programme for Fishing Trawler in Deep Sea*. Retrieved from http://www.wbreda.org/re-programme-for-fishing-trawler-in-deep-sea/
197. World Bank. (2019). *About WBADMI*. Retrieved from http://www.wbadmip.org/uploads/about_us.pdf
198. World Bank. (2019). *WBADMI Website*. Retrieved from http://www.wbadmip.org/

199. WRIDD, GoWB. (2019). *Jal Dharo Jal Bharo*. Retrieved from http://www.wbwridd.gov.in/index.php/wridd/jal_dharo_jal_bharo
200. Y Dhayaneswaran, L. A. (2013, August 31). *A Study on Energy Conservation in Textile Industry*. Retrieved from https://link.springer.com/content/pdf/10.1007%2Fs40031-013-0040-5.pdf