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CHALLENGES AND POLICY IMPLICATIONS OF A LOW CARBON PATHWAY FOR ODISHA

AN INTEGRATED ASSESSMENT MODELLING APPROACH

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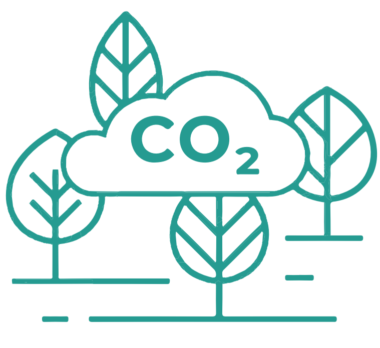

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Foreward

In recent years, considerable efforts have been made to identify pathways for achieving net zero emissions in India by the 2070s. However, most of this work focuses on the overall Indian perspective, not taking into account inter-State differences. It is a known fact that the States differ from each other in terms of the availability of primary resources such as land, minerals, capital, and labour, as well as the production processes, outputs, and socio-economic profiles of their respective populations. Thus, it may not be feasible to implement policy choices drawn from a national model at the State-level due to the economic or resource constraints mentioned above. Although most States have now drafted their individual climate action plans and a few have also identified their respective energy requirements, these plans are subjective and focus on the individual aspirations of the concerned States without factoring in their feasibility. The State-level energy calculations provide alternative energy pathways based on exogenous growth plans for each State and do not consider the price impacts or the socio-economic implications of low-carbon pathways.

This study by the National Council of Applied Economic Research (NCAER) is an attempt to fill the above gap by assessing feasible policy choices and the financial implications faced by a mineral-rich state like Odisha in transitioning towards a low-carbon pathway. It differs from similar studies undertaken in the past by examining the price factor, which plays a crucial role in determining choices for potential technologies to be deployed in consonance with the prevailing supply/demand situation. Only a comprehensive understanding of behavioural realities, markets and prices, and technological innovation and infrastructure taken together can ensure a coherent plan for building transition pathways for energy systems. Further, being a small State, the economy of Odisha is significantly impacted by external events in the rest of India and the world, which is why it is imperative for the economic framework of the State to take these into account as well.

The study uses an Integrated Assessment Modelling (IAM) tool linking a macro model with a bottom-up energy model to help endogenously determine the sectoral outputs and prices within the system. Most developed countries adopt this type of modelling tool to analyse energy transition issues. The model used in the study facilitates technology-based decisions in each of the sectors through cutting down of emissions and ensuring cost-effectiveness of implementing the pathways in a stipulated period. The integrated model is a recursively dynamic model with multiple periods to simulate changes based on short-, medium-, and long-term policy targets for low-carbon pathways.

We are grateful to our research collaborators, Dr Anindya Bhattacharya, Mr Mohit Kumar, and Ms Malavika Thampi of The Celestial Earth, and Dr Amarendra Das of the National Institute of Science Education and Research for their immense help in conducting this study.

Last but not the least, I would also like to thank members of the NCAER study team, including Professor Sanjib Pohit, Team Leader; Mr Devender Pratap, Senior Fellow; Dr Chetana Chaudhuri, Fellow; Ms Somya Mathur, Associate Fellow; and Ms Srijata Dutta, Research Associate, who worked tirelessly to complete this study within a stringent timeline.

I hope the findings of the report will be of immense value to the policymakers in achieving the best possible pathways for achieving net zero emissions at both the State and national levels by the targeted decade of the 2070s.

January 2024

POONAM GUPTA
Director General
National Council of Applied Economic Research


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Executive Summary

Odisha is situated in the eastern part of India, with a geographical area of 1,55,707 square km, and population of 4.2 crore. Per capita net state domestic product (at constant prices with 2011-12 base) in Odisha is Rs 79,607 in 2021-22, which is lower than the national average (Rs 91,481).

Though Odisha has the share of 3.47 per cent population in India, net GHG emission from Odisha was 9.3 per cent of the country in 2018. In per capita terms, net emission from Odisha (6.15 tCO_2e per capita) is higher than that of the national average (2.24 tCO_2e per capita). The GHG Platform India 2022 report for Odisha suggests that overall emission in Odisha increased at a compound annual growth rate (CAGR) of 7.85 per cent, from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e in 2018. Clearly, lowering carbon footprint is essential for Odisha's development strategy.

Understanding feasible policy choices and their financial implications are a must for adopting the correct policy interventions for the transition towards a low carbon pathway. This study is a small endeavour in this direction. It differs from similar studies by incorporating price in energy modelling framework. We believe that price plays a crucial role in determining choices of the feasible technologies depending on the supply/demand situation. Only by understanding the combined forces of behavioural realities, markets and prices, and technological innovation and infrastructure together, coherent responses can be built to facilitate transition of energy systems. Further, as Odisha is a small state, its economy is impacted by macro-economic environment of the rest of India and the world. So, policies need to be developed by considering the economic framework that take these factors into account.

In this context, we have used in our analysis an integrated assessment modelling (IAM) framework that links a macro model with a bottom-up energy model. Sectoral outputs and prices are endogenously determined within the system in this model unlike usual bottom–up energy models. Many developed countries had adopted modelling tools of this kind to analyse energy transition issues. However, in India, this tool, to the best of our knowledge, has not been adopted, and that too, at a subnational level. It is also important to note that while analysing Odisha's policy dilemmas, we have the assumption that the rest of the Indian states are also moving towards energy transition, because studying Odisha's economy in isolation would not be sufficient to derive the macro-economic consequences of a policy intervention.

The integrated modelling approach involves soft linking of the macroeconomic top-down CGE model and bottom-up (MESSAGEix) energy model. The top-down macroeconomic CGE model used for integration is a multi-sectoral, multi-regional (Odisha, Rest of India and Rest of World) variant of the GTAP power model with a disaggregated power sector.

The CGE model produces forecasts of sectoral output and prices for the business-as-usual and two policy scenarios. These CGE results, further, are used as an input as exogenous input demand projection into the MESSAGEix model, which is an energy optimisation model. The projected demands are derived such a way so that those are met by supplies subjected to least cost optimisations along with environmental, resource, and capacity constraints along with other policy constraints. The model provides technology-based decisions in each of its sectors in terms of cutting down of emissions and the cost of implementing those pathways in a given period. The integrated model is a recursively dynamic model with multiple periods to simulate changes as per policy targets for the short, medium and long term for the low carbon pathway of the Government of India.

Our business-as-usual (BAU) scenario assumes that Odisha's economy will hover around 6 per cent per annum growth over the model run period, namely, 2022–2050. Per capita emissions will rise from 6.69 tons CO_2e in 2030 to 31.41 tons CO_2e in 2050. According to our estimates, US$ 467 billion investment will be required in the base run in the energy sector during the period 2025-2050. This amounts to 7.3 per cent of cumulative SDP for the period 2025-50.

The key message that is brought out by our simulation is that energy transition towards renewable energy will not take place without complementary support polices towards this sector. The government needs to play a key role in effecting the change. A market-based approach with taxes/subsidies performs better in facilitating the growth of renewable electricity in Odisha. It is also pragmatic to augment the capacity of renewable capacity as far as possible. Since Odisha has high coal deposits and the presence of other minerals, the dependence on fossil fuel, despite projected reduction to a certain extent during the study period, will continue to be high in the energy/ fuel mix. The role of carbon capture and storage is a technology that Odisha needs to invest in. The investment in green hydrogen can also be explored since the State is endowed with large number of mines geographically located within the State facilitating the growth energy-intensive industries in the State.

Our observation is that increased energy efficiency along with productivity growth is essential for energy transition, since higher energy efficiency leads to energy saving and lower emission. An energy efficiency to the tune of 1.5 per cent concomitant with productivity growth of 1 per cent per annum leads to positive growth in majority of the sectors in the State. This also leads to a lower increase in per capita emissions. With these policy interventions, the per capita emission will rise to only 11.81 ton CO_2e in 2050 versus 31.41 ton CO_2e in 2050 in the base run. With increased energy efficiency, the need for funds for investment for energy transition also falls by nearly 1 per cent of cumulative SDP for the period 2025-50.

Our results show that direct employment from operation and maintenance of power plants would be affected by the shift towards green energy in 2050, since the coal mining and coal electricity sectors are still major providers of employment in the State. A major part of output from these sectors is also exported. With green transition, direct employment in these sectors would reduce, and employment in the renewable energy sector would increase, but as a result, the net effect on direct employment generated from operation and maintenance of power plants would still be less in the policy scenario 2 vis-à-vis base run in 2050, amounting to a 83,000 less direct employment in the energy sector by the year 2050. However, this would not have that negative effect on total employment. Through the interlinkage of renewable energy with other sectors of the economy, the economy as a whole is not facing employment shrinkage as a result of the transition to green energy. Total employment from operation and maintenance of power plants, which captures the direct, indirect and induced employment generated from all sectors including the energy sector, is expected to provide 8.6 million more employment under Policy scenario 2 in 2050 compared to the baseline scenario. Manufacturing and installation of new renewable power plants would also generate some more employment.

Abbreviations and Acronyms

2W (E20)	Two-wheelers with 20% blended ethanol fuel
2W (Elec)	Two-wheelers (electric)
3W (E20)	Three-wheelers with 20% blended ethanol fuel
3W (Gas)	Three-wheelers running on gas
AFOLU	Agriculture, forestry and other land use
Air (F, Oil)	Freight travel by air, mode aviation fuel
Air (P, Oil)	Passenger travel by air, mode aviation fuel
BAU	Business as usual
BEE	Bureau of Energy Efficiency
Biomass PP	Biomass for power plant
Bus (B20)	Bus running on 20% blended biofuel
Bus (Fcv)	Bus with fuel cell technology
Car (CBG)	Car with compressed biogas
Car (E20)	Car with 20% blended ethanol fuel
Car (Elec)	Car running on electric
Car (Gas)	Car running on CNG
CCUS	Carbon Capture, Utilisation and Storage
CDM	Clean Development Mechanism
CDP	City Development Plan
CEA	Central Electricity Authority
CGE	Computable General Equilibrium
CO_2e	Carbon dioxide equivalent
CoE	Centres of Excellence
CPP	Captive Power Plant
CZMP	Coastal Zone Management Plans
Diesel_LargeP_ferry	Diesel-based passenger ferry
DGCIS	Directorate General of Commercial Intelligence
DPR	Detailed Project Report
ECBC	Energy Conservation Building Code
EMC	Energy Management Centre
EV	Electric vehicle
FEWS	Flood Early Warning System
GDP	Gross Domestic Product

GRIDCO	Grid Corporation of Odisha
GW	Gigawatt
HP	Horsepower
IPR	Intellectual Property Right
IPPU	Industrial processes and product use
LFPR	Labour Force Participation rate
MRTS	Mass Rapid Transport System
MSME	Micro, Small and Medium Enterprises
MNRE	Ministry of New and Renewable Energy
MTOE	Million tonnes of oil equivalent
MW	Megawatt
OPWD	Odisha Public Work Department
OSDMA	Odisha State Disaster Management Authority
PAT	Perform, achieve and trade
PLFS	Periodic Labour Force Survey
PP	Power Plant
PAS	Principal activity status
PV	Photovoltaic
Rail (F, Elec)	Freight movement by rail, fuel mix: electric
Rail (F, Oil)	Freight movement by rail, fuel mix: oil
Rail (P, Elec)	Rail passenger travel by electric
RD	Recursively Dynamic
Road HDV(CBG)	Freight movement by heavy duty vehicle, fuel mix: compressed biogas
Road HDV(Gas)	Freight movement by heavy duty vehicle, gas
Road HDV(Oil)	Freight movement by heavy duty vehicle, oil based
Road LDV(Elec)	Freight movement by light duty vehicle, fuel mix: electric
Road LDV(Oil)	Freight movement by light duty vehicle, oil based
RPO	Renewable Purchase Obligation
R&M	Renovation and Modernisation
SAPCC	State action plan on climate change
SDP	State Domestic Product
Ship (F, Oil)	Freight movement by waterways, fuel mix: oil
SEAS	Subsidiary economic activity status
Taxi (E20)	Taxi with 20% blended ethanol fuel
Taxi (Elec)	Taxi electric
tCO_2e	Tons of carbon dioxide equivalent
TFP	Total Factor Productivity
ULB	Urban Local Bodies

Contents

Study Team ***II***

Foreward ***III***

Executive Summary ***V***

Abbreviations and Acronyms ***VII***

1. Introduction **1**

1.2 Policy Dilemma 2

1.3 Desired Methodology 3

1.4 Plan of the Report 4

2. Approach and Methodology of the Integrated Model **5**

2.1 Framework of Integrated Model (NCAER CGE Model – MESSAGEix) 6

2.2 Key Features of the Top-down CGE Model 7

2.3 Key Features of the Bottom-up Energy Model 9

3. Key Features of the Odisha Economy **11**

3.1 Generation of Electricity 13

3.2 Energy and Emissions Accounting 13

3.3 The Database 14

3.4 Policy Analysis with a Dynamic Model 15

4. Baseline Simulation **17**

4.1 Macroeconomic Results 17

4.2 Results from the Bottom-up Energy Model 20

4.2.1 Electricity capacity and generation mix 21

4.2.2 Industry: energy/fuel choices 22

4.2.3 Energy/fuel choices for broad sectors 23

4.2.4 Transport sector: energy/fuel choices 23

4.2.5 Energy/fuel choices for building, agriculture sector and cooking 24

4.2.6 Investments 25

4.2.7 Emissions 26

5. Policy Scenarios **27**

5.1 Results and Discussion, Policy Scenario 1 28

5.1.1 Sectoral results 29

5.1.2 Summing up 29

5.2 Results and Discussion, Policy Scenario 2 30

5.2.1 Macroeconomic results 31

5.2.2 Results from bottom-up energy model 33

5.3 Adoption of New Technologies 39

6. Employment Implications of Adopting a Low Carbon Pathway 41

6.1 Employment Effects 41

7. Concluding Remarks 45

Annex A1. Review of Odisha Climate and Energy Policies 47

A1. Introduction 47

A2. State of the Economy 47

A3. Emission Profile and Energy Mix for Odisha 49

A3.1 Trend of Supply and Demand Scenario of Power Sector 50

A3.2 Odisha's Energy Mix 51

A4. Odisha's Plan for Energy Transition 52
A4.1 Solar (Rooftop and Land-based) 52
A4.2 Rooftop Solar Programme 53
A4.3 Off-grid Solar Rooftop Power Plant 53
A4.4 Land-based Solar Parks 53
A4.5 Land-based Non-park Solar Projects (>1 MW) 53
A4.6 Floating Solar 53
A4.7 Solar Pump Drinking Water 53
A4.8 Solar Pump for Irrigation 54
A4.9 Solar Lanterns 54
A4.10 Solar Street Lighting System 54
A4.11 Solar Water Heater 54
A4.12 Other Policy Measures 54

A5. Climate Policies in Odisha 55
A5.1 Agriculture 55
A5.2 Fisheries and Animal Resources 57
A5.3 Forest Management 58
A5.4 Biodiversity Management 59
A5.5 Wildlife Conservation and Protection 60
A5.6 Water Conservation, Air and Water Pollution, and Health Management 60
A5.7 Mining 61
A5.8 Industry 63
A5.9 Energy 65
A5.10 Transport 67
A5.11 Urban Planning 68
A5.12 Coast and Disaster Management 68
A5.13 Water Resources 70

A6. Concluding Remarks 70

Annex A2. Top-down CGE Model 73

Annex A3. Bottom-up Energy (MESSAGEix) Model 77

A3.1 Introduction 77
A3.2 Energy Demand Projection Using the IM Framework 79
A3.2.1 Agriculture energy demand 80
A3.2.2 Household/cooking energy demand 80
A3.2.3 Commercial sector energy demand 80
A3.2.4 Transport (freight & passenger) energy demand 80
A3.2.5 Industrial energy demand 80

References 81

List of Tables

Table 2.1-1 Concordance Map between NCAER CGE and MESSAGEix Sectors 6
Table 2.2-1 Sectors of Top-down Macro (CGE) Model 8
Table 3-1 SDP Components from the Expenditure and Income Side, 2021 (US$ million) 11
Table 3-2 Composition of Value Added for Major Sectors, 2021 12
Table 3.1-1 Electricity Generation by Fuel Type, Consumption and Exports of Electricity, 2021-22 13
Table 3.2-1 Emission Contribution of Consumption of Different Energy Products in Odisha (tons CO_2e), 2018 14
Table 4.1-1 Macroeconomic Results for 2022–2050 (per cent) 18
Table 4.1-2 Average Annual Growth Rates of Output for Major Sectors in the Baseline (%) 19
Table 4.1-3 Major Export and Import Sectors in Odisha 20
Table 4.2-1 Cumulative Investment (million US$) 26
Table 4.2-2 Stylised Facts 26
Table 5.1-1 Policy Scenario 1: Annual Average Growth Rate of Major Sectors in Odisha Percentage Deviation from Base Run 30
Table 5.2-1 Policy Scenario 2: Sectoral Growth of Output in Odisha 32
Table 5.2-2 Average Deviation in Sectoral Growth between Policy Scenario 2 and BAU (%) 33
Table 5.2-3 Per Capita Emission (tons CO_2e) 38
Table 5.2-4 Principal Sources of Emissions (million tons CO_2e) 38
Table 5.2-5 Cumulative Investment for Base Run and Policy Scenario 2 (US$ million) 38
Table A1-1 Growth Rate of Gross State Value Added by Economic Activity at Constant Prices and Sectoral Composition (2017-18 to 2022-23) 48

List of Figures

Figure 2-1 Structure of the Integrated Model....5
Figure 3.4-1 Policy Analysis with a Dynamic Model....15
Figure 4.2-1 Final Energy Demand....21
Figure 4.2-2 Final Energy Mix....21
Figure 4.2-3 Electricity Capacity Mix....22
Figure 4.2-4 Electricity Generation....22
Figure 4.2-5 Energy Demand in Industry....22
Figure 4.2-6 Composition of Fuel in Industry....22
Figure 4.2-7 Energy Demand in Various Sectors....23
Figure 4.2-8 Energy Demand in Transport Sector....23
Figure 4.2-9 Fuel Split: Private Transport....24
Figure 4.2-10 Fuel Split: Public....24
Figure 4.2-11 Fuel Split: Freight Transport....24
Figure 4.2-12 Energy Split: Building....24
Figure 4.2-13 Energy Split: Agriculture....25
Figure 4.2-14 Energy Split: Cooking (Rural)....25
Figure 4.2-15 Energy Split: Cooking (Urban)....25
Figure 4.2-16 Sector-wise Emissions....26
Figure 5.1-1 Policy Scenario 1: Share of Renewable and Fossil in Total Electricity in Odisha (%)....28
Figure 5.1-2 Policy Scenario 2: Share of Exports of Fossil Electricity and Domestic Production of Renewable in Odisha (%)....28
Figure 5.1-3 Policy Scenario 1: Average Year-wise Growth of Real SDP and Real Returns to Factors....29
Figure 5.2-1 Policy Scenario 2: Macroeconomic Results for Odisha....31
Figure 5.2-2 Policy Scenario 2: Real Returns to Factors of Production in Odisha....31
Figure 5.2-3 Final Energy Demand in Baseline and Policy Scenario 2....33
Figure 5.2-4 Fuel Mix in Baseline and Policy Scenario 2....34
Figure 5.2-5 Share of Electricity Capacity Mix in % (Policy Scenario 2)....34
Figure 5.2-6 Share of Electricity Generation Mix in % (Policy Scenario 2)....35
Figure 5.2-7 Energy/ Fuel Choices for Private Transport in Baseline and Policy Scenario 2....35
Figure 5.2-8 Energy/ Fuel Choices for Public Transport in the Baseline and Policy Scenario 2....36
Figure 5.2-9 Energy/ Fuel Choices for Freight Transport in the Baseline and Policy Scenario 2....36
Figure 5.2-10 Energy/ Fuel Choices for Industries in the Baseline and Policy Scenario 2....36
Figure 5.2-11 Energy/ Fuel Choices for Buildings in the Baseline and Policy Scenario 2....37

Figure 5.2-12 Energy/ Fuel Choices for Cooking in Rural Areas in the Baseline and Policy Scenario 2 37
Figure 5.2-13 Energy/ Fuel Choices for Cooking in Urban Areas in the Baseline and Policy Scenario 2 37
Figure 6.1-1 Direct Employment in Energy Sector from Operation and Maintenance 42
Figure 6.1-2 Total (Direct, Indirect and Induced Together) Employment in Energy Sector from Operation and Maintenance 42
Figure 6.1-3 Employment in Manufacturing and Installation of New Renewable Power Plants 43
Figure A1-1 Sector-wise Contribution (Mt CO_2e) in Emission and Percentage Share (%) in Overall GHG Emissions (excluding AFOLU Sector) in Odisha in 2005 and 2018 49
Figure A1-2 Power Generation from different Sources in Odisha in 2021-22 (MU) 51
Figure A1-3 Power Sales Across Sectors in Odisha in 2021-22 (MU) 51
Figure A2-1 Accounting Structure of the GTAP Model 74
Figure A2-2 Electric Power Substitution in GTAP E-Power Model 75
Figure A3-1 Representation of an Energy System Model in MESSAGEix 78
Figure A3-2 Structure of MESSAGEix Model 79

1. Introduction

Odisha is situated in the eastern part of India, with an area of 1,55,707 square km and a population of 4.2 crore, which is 3.47 per cent of India (Census 2011). On several population and economic parameters, Odisha ranks lower than the national average. Its population density was 270 per square km (Census 2011), which is lower than the national average (382); the decadal growth rate in 2001-2011 was 14.05 per cent versus 17.17 per cent for India; the urbanisation rate is 16.7 per cent versus the national average of 31.16 per cent in 2011; on the Multi-dimensional Poverty Index 2023, Odisha had a poverty rating of 15.68 per cent against the national average of 14.96 per cent in 2019-21; and the per capita Net State Domestic product at constant prices with 2011-12 base was Rs 79,607 in 2021-22, which is lower than the national average of Rs 91,481.

Although Odisha makes up only 3.47 per cent of the population in India, its net GHG emissions are relatively high, contributing to 9.3 per cent of the country's GHG emissions (GHG Platform India 2022). In 2018, net GHG emission from Odisha was 274.54 Mt CO_2e. In per capita terms, net emission from Odisha (6.15 tCO_2e per capita) is higher than the national average (2.24 tCO_2e per capita). A report by GHG Platform India 2022 found that overall emission in Odisha has increased at a compound annual growth rate (CAGR) of 7.85 per cent, from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e in 2018; this was based on emissions from the energy sector (fuel combustion from public electricity generation, transport, captive power plants, industries, agriculture, commercial, and residential categories and fugitive emissions from fuel production), the Agriculture, Forestry and Other Land Use (AFOLU) sector; Industrial Processes and Product Use (IPPU) and Waste sectors. Moreover, Odisha has a significant presence in energy-intensive industries like iron and steel, aluminium that contribute to large emissions from the industry sector.

As of December 2022 (CEA), Odisha had an installed capacity of 12,322 MW of which 9,540 MW is for coal-based power plants. So, emission in Odisha is largely driven by high dependence on coal (90 per cent) as a source of power generation in the State (in 2021-22). Other sources of power generation are hydro (8 per cent), small hydro (1 per cent), and solar (1 per cent).

Odisha is one of the few Indian states that is surplus in electricity production: only 33 per cent of the produced electricity is consumed within the State and the rest is exported to other states. Clearly, selling electricity is a source of revenue for the State; revenue received from taxes and duties on electricity in Odisha was Rs 393,846.21 lakh in 2020-21.

At the same time, Odisha is vulnerable to the effects of climate change. In recent years, Odisha has experienced a high number of natural disasters, such as cyclones, drought, flash floods, and coastal flooding that affect the livelihood of the coastal population of the State, who depend on agriculture, forestry, fishery etc. The economic impact of climate change on agriculture in the coastal zone of the State is significant (Mishra & Sahu 2014; Mishra et al. 2016; Paltasingh & Goyari 2015). The effect of climate change on public health in terms of severity, frequency and spread of vector-borne diseases also cannot be ignored (Karmakar & Pradhan 2020). The incidence of high poverty and the significant presence of indigenous communities who are primarily dependent on natural resources make the State extremely vulnerable to climate change. Studies suggest that the factors like annual income, access to irrigation, access to credit facility and landholding size of farming households play a crucial role in the household's capability to adapt (Sahu & Mishra 2013). In cyclone-prone areas, factors like demographic characteristics, distance of cyclone shelter, unemployment, adequate toilet facilities, frequency and impact of flood and cyclone, and lack of logistics support during cyclone determine the vulnerability of the population in the region and the development of an adequate coping mechanism is essential to reduce vulnerability (Yadav & Barve 2017).

Hence, environmental concerns are recognised as a serious issue by the government of Odisha and has been an agenda for development planning in the State for quite a few years. To keep up the pace of growth and development for the State and to meet the aspirations of the people, the State needs to continue generating electricity. It would not be prudent to import electricity from other states to reduce emissions within the state boundary. As all states moves towards the goal of achieving net zero, most states would face the same dilemma: how to produce electricity in a sustainable way.

Mitigation measures in terms of a transition to renewable energy are emphasised in policy design in Odisha. In 2021-22, contracted capacity of renewable power by GRIDCO from various sources was 1460.7 MW, i.e., 109.2 MW from eight small hydro-electric projects, 1,010 MW from solar PV projects including 25 MW from rooftop solar, 20 MW from one biomass power project and 321.5 MW from wind sources. The Odisha Renewable Energy Development Agency (OREDA) undertook initiatives in solar energy such as Konark Solarisation that aims to turn the temple town of Konark into a solar town as well as a net-zero town through solar street lighting, solar-powered drinking water kiosks, roof- top solar power plants, solarised night-time illumination of the Sun Temple, establishment of solar charging stations, introduction of electric vehicles, etc. Other initiatives are rooftop solar power plants in residential, commercial and government buildings and solarisation of agricultural pump sets under PM-KUSUM and Soura Jalanidhi (a state scheme).

The State Government of Odisha is also targeting the potential of renewable energy as reflected in the Renewable Energy Policy of Odisha, 2022 that offers exemptions on duty and surcharges along with other benefits. The policy target is to increase renewable capacity to 10 GW by 2030. Apart from traditional sources of non-fossil-fuel like hydro, solar and wind energy, the policy document also considered non-traditional sources such as green hydrogen, green ammonia, floating solar, biomass, and waste-to-energy.

1.2 Policy Dilemma

Given that the Government of India has declared India will be a net-zero emitter by 2070, all states are now gearing towards achieving that goal by adopting a low carbon pathway for their economic growth. Odisha is no exception to this trend. In this endeavour, Odisha, like any other state, faces several challenges and policy dilemma.

The major energy and climate policies in Odisha for energy transition and making the economy resilient to climate shock can be classified into two categories: (a) mitigation strategies, and (b) adaptation strategies. To achieve the goals outlined in the policy, the Odisha government has also laid out sector-specific policies such as industrial policy, renewable policy, and electricity vehicle policy. Annex A1 discusses these policies in detail. Our present exercise focuses on mitigation strategies for Odisha.

Mitigation strategies involve energy sectors that contribute more than 92 per cent of the emissions in the State.

- Power. More than 90 per cent of power in Odisha comes from coal, which is a major contributor to emission in the State. Of late, the focus has been on augmenting capacity in renewable energy-based power. Some steps in this direction include addition of floating solar power in reservoirs and artificial lakes, solar rooftop and land-based, off-grid solar rooftop power plant, and promoting the distribution of solar generation in remote areas with in-built incentives. Incentives are also being given to develop large and small hydropower plants, waste to energy, wind, biomass-based power, energy storage, etc.
- Transport. The emphasis is on adoption of battery-operated vehicles in the transport sector. Also, the plan is to promote solar-based electric vehicle (EV) charging stations. The policy also encourages increased use of public transport and electric mobility along with the development of water ways to reduce the carbon footprint.
- Industry. Being a mining-rich state, many energy-intensive industries are located in Odisha. As a result, emissions from industry need to be controlled for an energy transition. Odisha has already come out with policies to develop green hydrogen/green ammonia projects. The Industrial Policy Resolution 2022 for Odisha also emphasises increasing efficiency in the industrial sector along with support for the development of sustainable industrial infrastructure.
- Buildings. Urbanisation is an essential part of economic growth and Odisha is no exception. Green buildings are a priority area with the goals of developing guidelines to measure the energy efficiency of buildings.
- Agriculture. Policies are targeted at improving energy efficiency through the use of energy-efficient pumps, solarisation of off-grid and grid-connected agricultural pumps, agriculture feeder separation, and awareness campaigns.

Implementation of these policies have short-term and long-term costs and benefits. Understandably, the implementation of the changes has a large financial burden. So, sequencing the changes is a must considering the costs and benefits of alternative pathways. This is the principle objective of this study: to quantify the gains and losses of low carbon transition and their financial implications.

1.3 Desired Methodology

The transition to a low carbon pathway requires a methodology to provide an economy-wide assessment of alternative policy choices towards sustainable and inclusive economic development. Only by understanding the combined forces of behavioural realities, markets and prices, and technological innovation and infrastructure together can coherent responses be built to transition energy systems (Grubb, Hourcade & Neuhoff 2015).

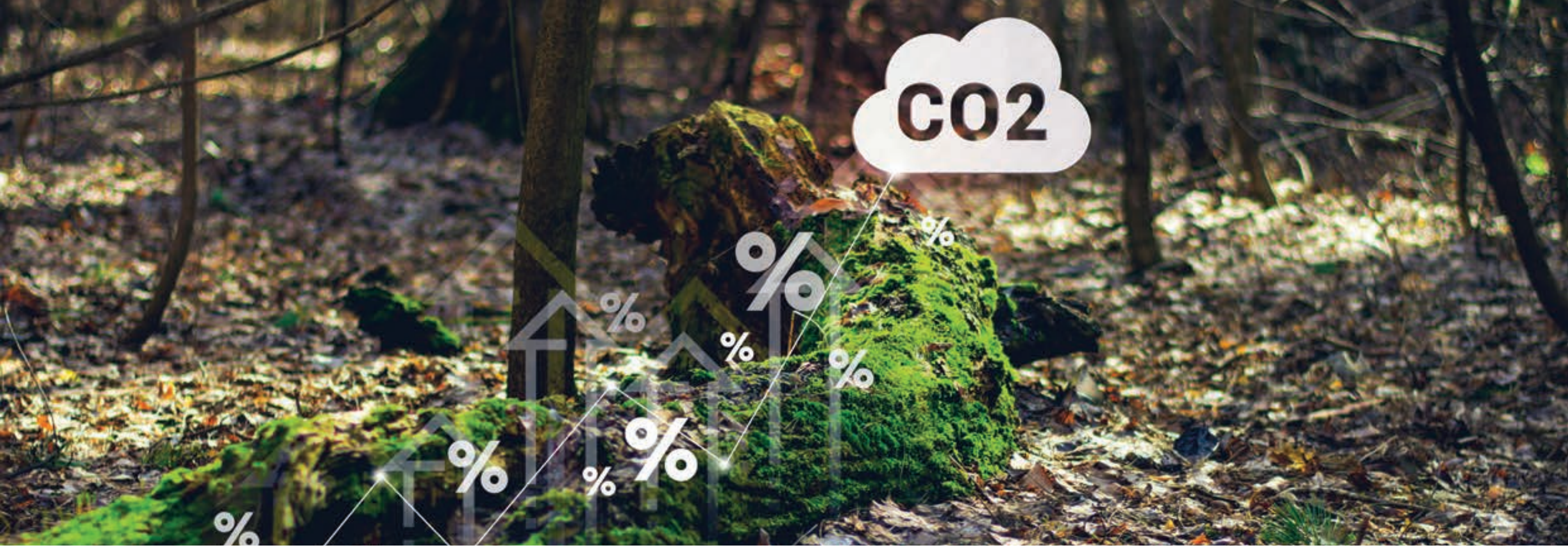
It is important to analyse the issues in a framework that determines prices in the system along with the interplay between energy and economic systems. This is possible only if price is endogenously determined in the model through sectoral demand/supply equation. In that case, economic equilibrium (where demand

and supply in the economy meet) would result in determination of price and output in the economy. In an economic model, demand and supply equations for all sectors of the economy, including the energy sector, are explicitly built in and, hence, price and output are endogenously determined. Typically, the supply function depends on labour, capital, other intermediate inputs and their prices. On the other hand, the demand function is derived from preferences of agents, income, and prices.

Since Odisha is an underdeveloped, mining-rich state, its economy is impacted by happenings in the rest of India and the world. So, the economic framework needs to take this into account by employing a multi-region modelling tool.

1.4 Plan of the Report

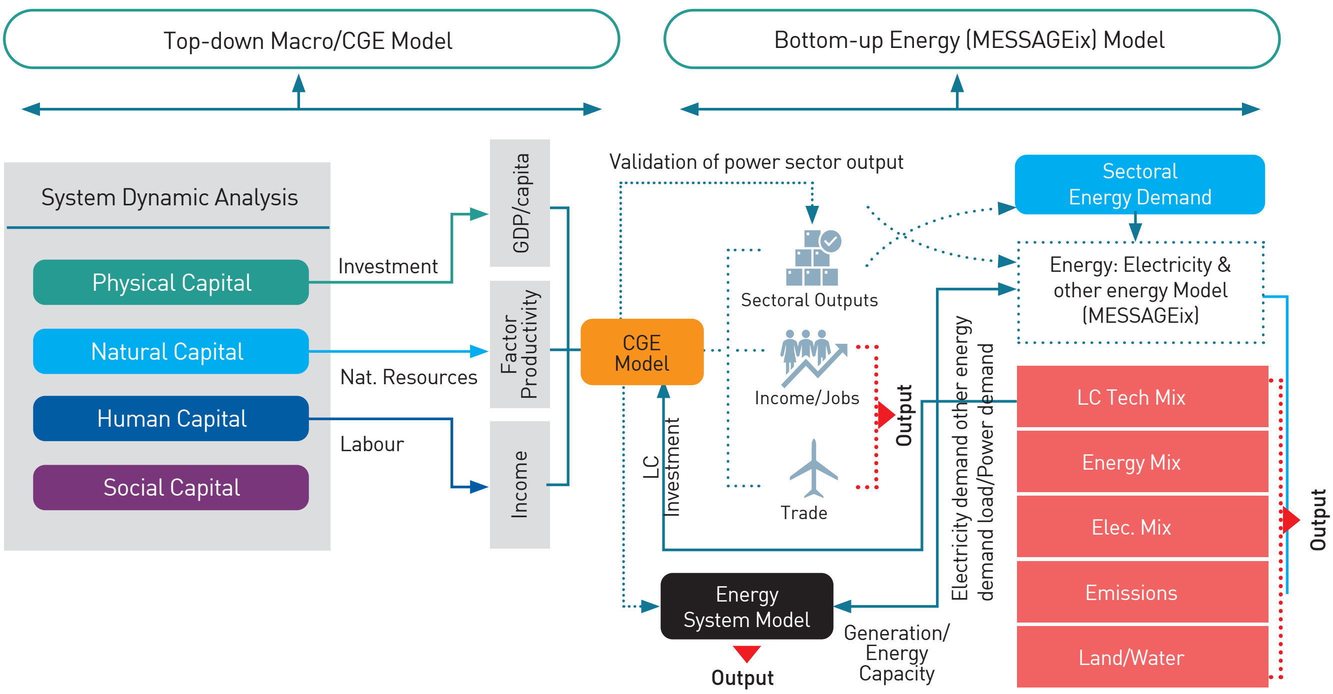
The rest of the report is organised as follows. Section 2 discusses the economic modelling tools used for this exercise. Section 3 provides an overview of Odisha's economy with the key structure for the base year of our model, namely, 2021. Section 4 describes the mechanism for policy analysis with the model. This section also describes the long-term baseline (business as usual scenario) of our model against with policy runs are analysed. Section 5 articulates the policy scenarios that we have undertaken in this study along with our results for the various policy simulations. Section 6 focuses on the employment implications of adopting a low carbon pathway. Finally, Section 7 provides concluding remarks.



2. Approach and Methodology of the Integrated Model

Figure 2-1 represents our integrated modelling structure. The modelling structure incorporates two models—a top-down computable general equilibrium (CGE) macro model and a bottom-up energy (MESSAGEix) model. The top-down CGE model provides a baseline/ policy forecast of overall gross domestic product (GDP), sectoral price and sectoral output. The results are then fed into the bottom-up energy (MESSAGEix) model that provides the best technology options among all the possible available technology bundles, given that the available resources are used in a least cost way. The bottom-up energy model also provides us with the investment numbers necessary to achieve these technology choices. These numbers are then fed back into the top-down CGE model to validate whether or not the growth path diverges. This process of two-way feedback continues until the differences in GDP numbers between the successive rounds converge.

Figure 2-1 Structure of the Integrated Model



2.1 Framework of Integrated Model (NCAER CGE Model – MESSAGEix)

Two separate soft-linked models are used to derive the results. For this, the models have to be constructed by aligning the sectoral classification of the two models (Table 2.1-1).

The top-down CGE model divides an economy into multiple sectors and defines the economic relationship between these sectors with the help of demand and supply equations. Based on these relationships, the model generates long-term projections for an economy considering the equilibrium state of the economy. In an equilibrium model, the growth or decline of the state of economy is reflected in the growth and decline of other sectors linked to the economy. Several outputs can be brought up from a CGE model, but the study focuses on one major outcome: the growth rates of the sector. The growth rates determine the value addition in a sector, which, with the help of an energy multiplier, can help determine the growth of energy demand in an individual sector.

Using the concordance map in Table 2.1-1, we obtained the outputs of the sectors that we aggregated/ disaggregated based on our requirement. The sectoral outputs are obtained in the form of quantity change in intermediate demand, sectoral aggregate demand and household demand, so as to be prioritised based on our requirements. The obtained results are aligned to the required disaggregated sectors.

Table 2.1-1 Concordance Map between NCAER CGE and MESSAGEix Sectors

S. No.	Sectors (NCAER)	MESSAGEix	S. No.	Sectors (NCAER)	MESSAGEix
1	Paddy	Agri pumping/ Agri transport	16	Land Transport	p_transport_road_ OMNIBUS
2	Wheat				f_transport_road
3	Other cereals				p_transport_road_BUS
4	Fruits & vegetables				p_transport_road_TAXI
5	Oil seeds				p_transport_road_CAR
6	Other crops				p_transport_road_2W
7	Oil	Power energy supply			p_transport_road_3W
8	Nuclear electricity	Nuclear electricity			f_transport_rail
9	Coal electricity	Coal electricity			p_transport_rail
10	Gas electricity	Gas electricity	17	Water Transport	f_transport_IWT
11	Wind electricity	Wind electricity (on-shore/ off-shore)			p_transport_ferry
12	Hydro electricity	Hydro electricity	18	Air Transport	f_transport_air
13	Oil power	Oil power			p_transport_air
14	Solar electricity	Solar electricity (all forms)	19	Livestock	Not applicable
15	Other renewable	Other renewable	20	Forestry	Not applicable

S. No.	Sectors (NCAER)	MESSAGEix	S. No.	Sectors (NCAER)	MESSAGEix
21	Fishing	Not applicable	36	Batteries, electrical & electronics equipment	
22	Coal	Power energy supply	37	Machinery	
23	Gas	Power energy supply	38	Vehicles	
24	Extraction	Not applicable	39	Transmission & distribution	
25	Food beverage & tobacco		40	Water distribution	
26	Textiles and garments		41	Construction	
27	Other manufacture		42	Trade	Commercial others
28	Wood, wood products & furniture		43	Hotels	
29	Paper & paper products, Printing & publishing		44	Storage & warehouses	
30	Petroleum products	Industry thermal	45	Communications	
31	Chemicals		46	Financial insurance services	
32	Pharmaceutical		47	Other services	
33	Non-metallic minerals		48	Public administration	
34	Ferrous metal		49	Dwelling	Residential others
35	Non-ferrous metal				

Source: Authors' estimates.
Note: p stands for passenger, f for freight, IWT for inland water transport, 2W for two-wheelers, 3W for three-wheelers.

2.2 Key Features of the Top-down CGE Model

The top-down CGE model recognises 49 industries producing 49 goods and services. Of the 49 industries, three produce primary fuels (coal, oil, and gas), one produces refined oil (petroleum products), and nine generate electricity (Table 2.2-1). The petroleum products industry produces refined oil products including gasoline. The eight generation industries are defined according to their primary source of fuel: electricity-nuclear includes nuclear-operated power plants using turbines that generate electricity; electricity-gas includes all plants using turbines, cogeneration, and combined cycle technologies driven by burning gas; electricity-hydro covers hydro generation; electricity-solar covers generation from photovoltaic systems; electricity-wind covers renewable wind generation; electricity-coal produces electricity by burning coal; electricity-oil produces electricity from oil sources; and other renewables produce small amounts of electricity from other renewables. Besides, there is one electricity distributor. In the model economy, there are 14 industries with all the major energy-intensive industries modelled separately.

Table 2.2-1 Sectors of Top-down Macro (CGE) Model

S. No.	Sectors (NCAER)	S. No.	Sectors (NCAER)
1	Paddy	26	Machinery
2	Wheat	27	Vehicles
3	Other cereals	28	Transmission & distribution
4	Fruits & vegetables	29	Nuclear electricity
5	Oil seeds	30	Coal electricity
6	Other crops	31	Gas electricity
7	Livestock	32	Wind electricity
8	Forestry	33	Hydro electricity
9	Fishing	34	Oil Power
10	Coal	35	Other renewable
11	Oil	36	Solar electricity
12	Gas	37	Water distribution
13	Extraction	38	Construction
14	Food, beverage & tobacco	39	Trade
15	Textiles and garments	40	Hotels
16	Other manufacture	41	Land transport
17	Wood, wood products & furniture	42	Water transport
18	Paper & paper products, printing & publishing	43	Air transport
19	Petroleum products	44	Storage & warehouses
20	Chemicals	45	Communications
21	Pharma	46	Financial insurance services
22	Non-metallic minerals	47	Other services
23	Ferrous metal	48	Public administration
24	Non-ferrous metal	49	Dwelling
25	Batteries, electrical & electronics equipment		

Note: Authors' estimates.

The model recognises three types of transport. Land transport moves goods or people by road/ rail using motor vehicles, rail and trucks; air transport moves passengers and freight via air; and water transport refers to moving people and goods by boat or ship over sea or river.

Our model is patterned after GTAP-power model (Corong et al 2020). It is a multi-region model with the regions being Odisha, rest of India and rest of the world. We assume that the regions trade among themselves in commodities/ services. However, we assume that electricity trade only takes place between Odisha and the rest of India. The detailed structure of the model is given in Annex A2.

2.3 Key Features of the Bottom-up Energy Model

The bottom-up model MESSAGEix requires the demand projections as an exogenous input to the model. Based on these projected demands, the supply side in the MESSAGEix model attempts to meet these demands in an optimal way. Optimisation in MESSAGEix is constrained to least cost optimisation which means that optimisation occurs for a least cost systems expansion plan to meet future demands in and around all the other policy constraints such as environmental constraints, resource constraints, and capacity constraints. Hence, the supply side of the information is relevant because it covers most of the policy aspects. To make it more robust in terms of linking the energy model to an economy based on economic performance, the energy demand that should be used in the MESSAGEix model as an input should be derived from a macro (CGE) model. The detailed structure of the model is given in Annex A3.

The model is multi-period in nature, where the unit of period is one year. It is a recursively dynamic (RD) model and is solved as a sequence of static, single-year CGE models, after updating sectoral capital stocks, available labour supply each year, and other plausible policy shocks over the year. The logic for using a recursive dynamic model is that the Indian government has set policy targets for short, medium and long term for low carbon pathways. To some extent, the RD version of the model can simulate these changes.

Sectoral capital stocks are exogenously given at the beginning of a particular period. Between two periods, there will be additions to capital stocks in each sector because of the investment undertaken in that sector in the previous period. More precisely, the sectoral capital stocks for any year t are arrived at by adding the investments by sectors of destination, net of depreciation in year t-1 to the sectoral capital stocks at the beginning of year t-1. By and large, we assume that the rate of investment is market determined and governed by the profitability of the investment.

Labour supply is updated each year by adding new entrants to the labour force, which is governed by population growth. Apart from the above variables, the dynamic version of the model needs assumptions about changes in foreign prices for future years, sectoral productivity growths of endowments, technology, and preferences (tastes). These may be shocked depending on the choices of policy interventions.

3. Key Features of the Odisha Economy

Table 3-1 reports the main components of State Domestic Product (SDP) from the income and expenditure side in Odisha for the base year of our model, namely 2021. On the income side, the share of labour is 47.45 per cent (skilled and unskilled), while the share of capital is 32.3 per cent. The combined share of natural resources (agricultural land and oil and gas reserves) is 1.6 per cent.

On the expenditure side of SDP, household consumption accounts for the largest share of 81 per cent. Investments attain 21.2 per cent of SDP, and government spending accounts for 9.6 per cent (Table 3-1). Both exports and imports as a share of SDP stood at 19.8 per cent and 31.4 per cent, respectively. This implies a large trade deficit of US$ 9.9 billion.

Table 3-1 **SDP Components from the Expenditure and Income Side, 2021 (US$ million)**

Expenditure Components	Value (US$)	Share (%)
Household consumption	69,226	80.8
Investment	18,135	21.2
Government consumption	8,246	9.6
Exports	17,009	19.8
Imports	-26,887	-31.4
SDP	85,729	**100**

Income Component	Value (US$)	Share (%)
Land	7364	8.6
Unskilled labour	22093	25.8
Skilled labour	18495	21.6
Capital	27701	32.3
Natural resources	1339	1.6
Indirect taxes	8737	10.2
SDP	**85,729**	**100**

Source: Authors' estimates.

Table 3-2 shows the valued added composition of sectors ranked by their share in aggregate value added in Odisha, indicating the relative size of each sector. Several heavy and energy-intensive industries are located in the State with shares in value added ranging from 0.5 per cent to 3 per cent.

Table 3-2	Composition of Value Added for Major Sectors, 2021

S. No.	Industry	Composition of value added (% share in total)						Value added by industry	
		Land	Unskilled Labour	Skilled labour	Capital	Natural Resources	Total	Share in value added	Rank
1	Agriculture and livestock	44.0	37.9	0.1	18.0	0.0	100.0	16.77	1
2	Forestry	0.0	49.1	0.2	41.5	9.2	100.0	3.05	11
3	Fishing	0.0	41.7	0.2	26.3	31.9	100.0	2.44	13
4	Extraction industries	0.0	25.0	2.3	56.7	16.0	100.0	2.05	17
5	Food, beverage & tobacco	0.0	47.2	8.2	44.6	0.0	100.0	3.27	10
6	Textiles & garments	0.0	47.4	8.2	44.3	0.0	100.0	3.50	8
7	Other manufacture	0.0	49.0	8.5	42.4	0.0	100.0	2.71	12
8	Wood, furniture, & products	0.0	58.8	10.2	31.0	0.0	100.0	1.00	23
9	Paper & paper products, printing & publishing	0.0	51.4	8.9	39.7	0.0	100.0	0.56	25
10	Petroleum products	0.0	8.5	1.5	90.0	0.0	100.0	2.41	14
11	Chemicals	0.0	25.3	4.4	70.3	0.0	100.0	2.11	16
12	Pharma	0.0	17.4	3.0	79.5	0.0	100.0	1.04	21
13	Non-metallic minerals	0.0	27.5	4.8	67.7	0.0	100.0	0.24	28
14	Ferrous metal	0.0	23.8	4.1	72.1	0.0	100.0	1.00	22
15	Non-ferrous metal	0.0	42.6	7.4	50.0	0.0	100.0	0.57	24
16	Batteries, electrical & electronics equipment	0.0	39.0	6.8	54.2	0.0	100.0	0.52	26
17	Machinery	0.0	43.4	7.5	49.1	0.0	100.0	1.20	20
18	Vehicles	0.0	47.4	8.3	44.3	0.0	100.0	2.04	18
19	Electricity	0.0	24.4	47.8	27.8	0.0	100.0	1.55	19
20	Water distribution	0.0	12.9	29.6	57.5	0.0	100.0	0.19	29
21	Construction	0.0	55.4	25.7	18.9	0.0	100.0	6.89	4
22	Trade	0.0	20.3	15.2	64.4	0.0	100.0	7.14	3
23	Hotels	0.0	26.8	20.0	53.2	0.0	100.0	0.49	27
24	Land transport	0.0	56.6	10.9	32.6	0.0	100.0	3.58	7
25	Water transport	0.0	52.0	10.0	37.9	0.0	100.0	0.01	32
26	Air transport	0.0	46.7	9.0	44.3	0.0	100.0	0.09	30
27	Storage & warehouses	0.0	40.1	7.7	52.2	0.0	100.0	0.06	31
28	Communications	0.0	45.2	8.7	46.1	0.0	100.0	2.40	15
29	Financial insurance services	0.0	6.0	24.2	69.8	0.0	100.0	3.29	9
30	Other services	0.0	10.6	64.1	25.3	0.0	100.0	7.76	2
31	Public Administration	0.0	11.5	62.2	26.3	0.0	100.0	4.75	6
32	Dwelling	0.0	2.1	11.3	86.6	0.0	100.0	5.74	5

Source: Authors' estimates.

Table 3-2 further suggests that factor (i.e. labour, capital) intensities are important constituents in understanding changes in industry activities, given the changes in the macro economy as well as on the global front. For example, unskilled labour is high in sectors like wood, wood products & furniture; land transport; water transport, construction; water transport; paper & paper products, printing & publishing. Odisha seems to have a presence in capital-intensive manufacturing sectors like iron and steel, non-metallic minerals, etc (Table 3-2).

3.1 Generation of Electricity

Table 3.1-1 shows the contribution of Odisha's energy mix in total electricity supply in terms its own use and exports to the rest of India in 2021. As one of the largest coal-producing state of the country, 90 per cent of its electricity is coal-based. Hydel, solar and others constitutes 7.87 per cent, 0.9 per cent and 0.72 per cent, respectively. It is worth noting that 82.4 per cent of its electricity is consumed within the State, and only 17.6 per cent is net export to other states.

Table 3.1-1 **Electricity Generation by Fuel Type, Consumption and Exports of Electricity, 2021-22**

	Per cent Share in Total Generation			
Total Generation (GWh)	**Coal**	**Hydro**	**Solar**	**Other**
66473	90.50	7.84	0.91	0.72
	State's Own Consumption		Exports	
	82.4 %		17.6 %	

Source: CEA and model database.

3.2 Energy and Emissions Accounting

Table 3.2-1 shows the contribution of emissions by four major constituents in 2018. The GHG emission level of Odisha is estimated to have grown at an annual growth rate of 7.85 per cent, from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e in 2018. The significant rise in emission levels is attributed to higher emissions from the energy sector in 2018, which rose by 7.85 per cent, from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e in 2018. The share of emissions from this sector rose 8 percentage points during 2005-2018 from 85 per cent in 2005 to 93 per cent in 2018. The main source of emissions in 2018 is fuel combustion based on coal (92 per cent). In contrast, the share of the Agriculture, Forestry and Other Land Use sector (AFOLU) in total emissions moderated from 10 per cent in 2005 to 2 per cent in 2018.

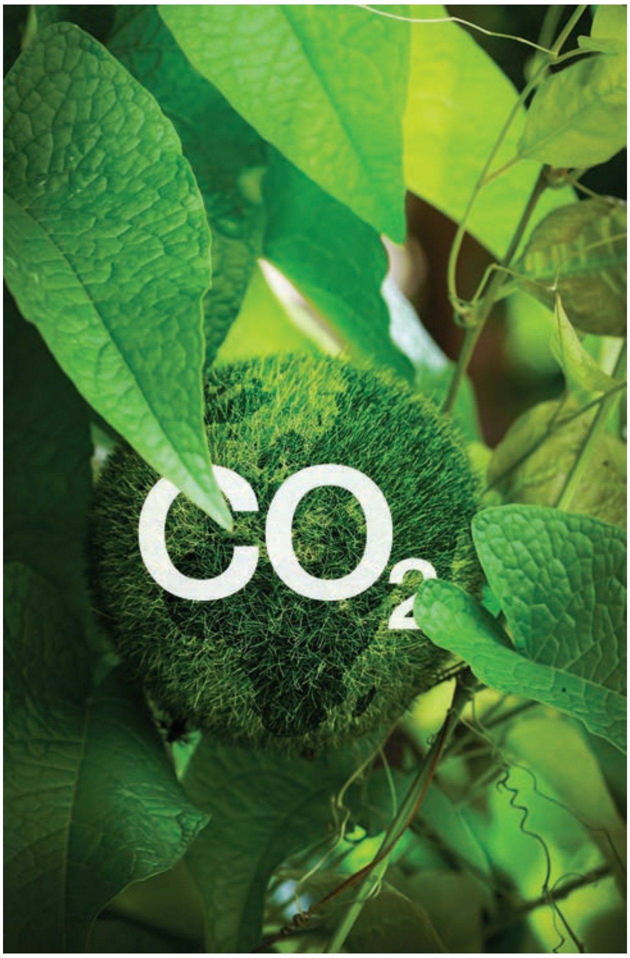


Table 3.2-1	Emission Contribution of Consumption of Different Energy Products in Odisha (tons CO_2e), 2018

S. No.	Broad Category	Category	Emission in 2018	Share in Emission excluding AFOLU
1	Agriculture, Forestry and Other Land Use (AFOLU)	Aggregate Sources and Non-CO_2 Emissions Sources on Land	25111049	-
		Land	-2957785	
		Livestock	20910143	-
		Total	**43063406**	**-**
2	Energy	Fuel Combustion Emissions	965858425	92.0
		Fugitive Emissions	8373668	0.8
		Total	**974232093**	**92.8**
3	Industrial Processes and Product Use	Chemical Industry	0	0.0
		Metal Industry	43548296	4.1
		Mineral Industry	22886873	2.2
		Non-Energy Products from Fuels and Solvent Use	26054	0.0
		Total	**66461223**	**6.3**
4	Waste	Domestic Wastewater	5898467	0.6
		Industrial Wastewater	3182964	0.3
		Solid Waste Disposal	569602	0.1
		Total	**9651032**	**0.9**
Grand Total (excluding AFOLU)			**1206289**	**100.0**

Source: GHG Platform India.

3.3 The Database

Our CGE model has been calibrated to the the Odisha economy for the year 2021. The principal source of our data is an Odisha input-output table that we prepared for this study following the methodology outlined in Pal, Pohit and Roy (2014). The model also requires other parameters and elasticities that are drawn from literature surveys with a focus on India.[1]

Most of the parameters and elasticities are drawn from Ojha, Pohit and Pal (2009). The sectoral productivity numbers are collated from various Indian studies and the India KLEMS[2] database. The time series data on population for India and Odisha is available from Census of India. To estimate the labour supply for India, we used data from the Labour Force Participation Rate (LFPR) of India/Odisha.

Finally, using a time series of the exogenous variables of the model, we generate a sequence of equilibria for the period 2021 to 2051. From the sequence of equilibria, the growth paths of selected (macro) variables of the economy are outlined to describe the baseline scenario, spanning the 30-year time interval from 2021 to 2050.[3]

[1]See Ojha, Pohit and Pal (2009), Pal, Pohit and Rajeev (2022).

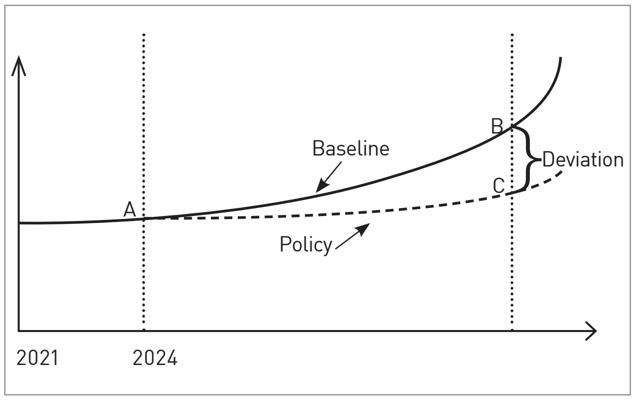
[2]India KLEMS database compiled by the Reserve Bank of India for measuring productivity at industry level.

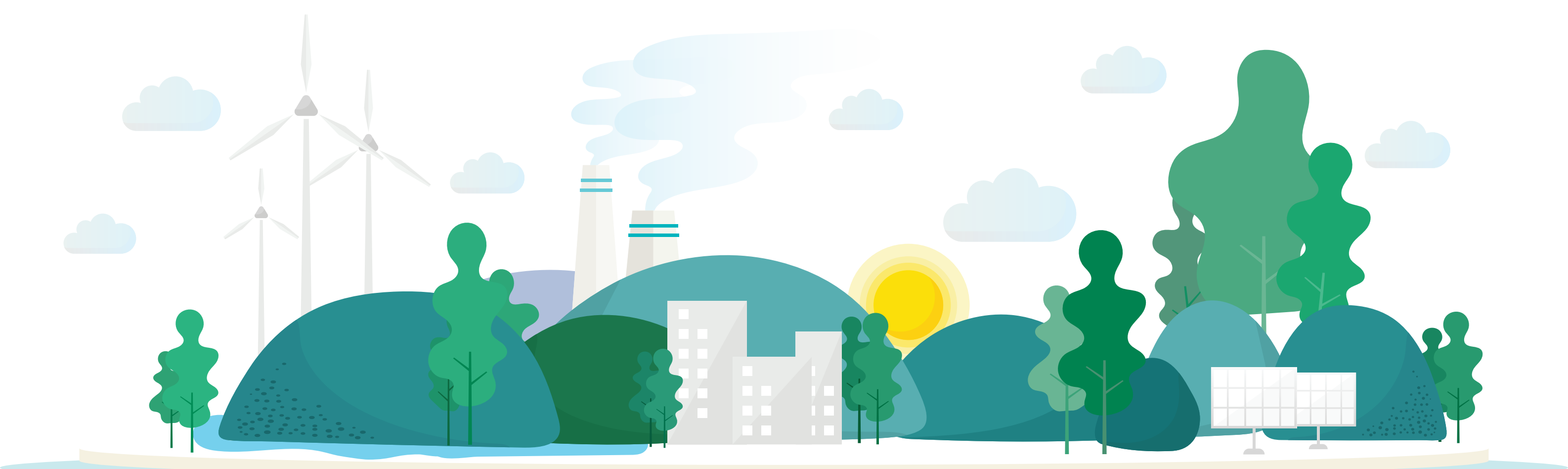
[3]The time series data on population for All India and states for the time period 2011 to 2036 is available from Census of India (July 2020). We used UN Population projection, 2022 thereafter from 2037 to 2050 for All India. To estimate the labour supply for India we used data from Labour Force Participation Rate (LFPR) of India. The extrapolation for CENSUS and LFPR 2021 were done for projecting the figures for future years.

3.4 Policy Analysis with a Dynamic Model

The model is a versatile and flexible comprehensive analytical framework that explicitly traces each variable through time at annual intervals. As illustrated in Figure 3.4-1, policy analysis with a *dynamic* CGE model requires two simulations.[4] The first simulation is the *baseline* forecast or business-as-usual simulation (see Sections 4). This simulation models the growth of the economy over time in the absence of the policy change under consideration. The second simulation is the policy simulation. In this, a second forecast is generated that incorporates all the exogenous features of the baseline forecast plus policy-related shocks reflecting the details of the policy under consideration. The impacts of a policy are typically reported through percentage deviations away from the baseline forecast.

Figure 3.4-1 **Policy Analysis with a Dynamic Model**





[4] For a more complete discussion, see Dixon and Rimmer (2002).

4. Baseline Simulation

The baseline simulation is the control projection against which policy scenarios are compared (Figure 3.4-1).

To accommodate the extraneous information supplied to the model, numerous naturally endogenous variables in the model are made exogenous.[5] To allow the naturally endogenous variables to be exogenously determined, an equal number of naturally exogenous variables are made endogenous. For example, real SDP is a naturally endogenous variable in the model, whereas the economy-wide technology variable is naturally exogenous. To accommodate the exogenous settings of real SDP, the economy-wide technology variable is set endogenously and allowed to adjust so as to accommodate change in real SDP.

4.1 Macroeconomic Results

Table 4.1-1 shows baseline projections for key macroeconomic variables. We report results for both income and expenditure-side components of SDP, and for other variables such as SDP deflator and consumer price index. The first five columns of Table 4.1-1 show annual average growth rates over six periods from 2024 to 2050. The last column reports annual average growth rates over the entire forecast period. The first four columns imply rapid growth in the Indian economy with a subdued growth at the end of the simulation period (2046-2050). The results show that tentatively 6.0 per cent annual growth in real SDP is likely to be sustained for 29 years. This means that the Odisha economy in 2050 will be approximately a little over six times bigger than in 2021.

[5]We use the term exogenous to mean user-determined. The term 'endogenous' means model-determined. In each simulation, every variable is classified as either exogenous or endogenous, with the number of endogenous variables equal to the number of equations in the model. A feature of the Indian model and all other models solved using the GEMPACK software is that users are allowed to choose which variables are exogenous and which are endogenous, provided that the choice is economically sensible.

Table 4.1-1	Macroeconomic Results for 2022–2050 (per cent)

	Selected Variables	2022–2030	2031–2035	2036–2040	2041–2045	2046–2050	2022–2050
A.	**Income components of SDP (growth rate)**						
1	Real SDP	6.2	6.0	6.3	6.0	5.3	6.0
2	Demand for capital	5.3	6.2	6.4	6.6	1.9	6.1
3	Demand for skilled labour	0.5	0.1	0.1	0.1	0.1	0.2
4	Demand for unskilled labour	0.5	0.1	0.1	0.1	0.1	0.2
5	Multi-factor productivity	0.9	0.9	1.0	0.9	0.7	0.9
6	Real wage for unskilled labour	4.3	4.5	4.7	4.3	3.7	4.3
7	Real wage for skilled labour	5.0	5.3	5.7	5.2	4.3	5.1
B.	**Expenditure components of SDP (growth rate)**						
8	Real private consumption	6.1	5.9	6.2	5.8	5.1	5.8
9	Real government consumption	5.7	5.5	5.9	5.7	5.3	5.6
10	Real investment	7.6	6.8	7.0	6.8	6.2	7.0
C.	**Other macro indicators (growth rate)**						
11	SDP deflator	5.3	5.2	5.5	5.7	5.8	5.5
12	Population	0.23	0.04	0.01	0.01	0.01	0.08
13	Consumer price index (CPI)	5.5	5.4	5.8	6.0	6.1	5.7
D.	**Other variables (growth rate)**						
14	CO_2 emissions	2.2	2.1	2.6	3.2	3.4	2.6
E.	**Other Variables at the end of the year**	2030		2040		2050	
15	Emission per person (ton CO_2e)	6.69		13.73		31.41	
16	Elec. Consumption per person (KWh)	1586		3261		7020	

Source: Authors' estimates.

The forecast data imposed on SDP suggests that the average annual growth in real SDP over the period 2022–2050 is 6.0 per cent per annum (Table 4.1-1, Row 1). The demand for unskilled labour/ skilled labour is expected to grow at an average annual growth rate of 0.2 per cent. The growth in capital is tied down by the high growth in investment. The demand for capital (Table 4.1-1, Row 2) is set to grow at 6.1 per cent per annum on average during 2022-2050. An important point is that while real SDP grew during all first four periods and dipped thereafter, the visible growth in the last period was followed by slower investment growth as well (Row 10). With SDP, labour and capital determined, multi-factor productivity (Table 4.1-1, Row 5) is projected to increase approximately 0.9 percentage points per annum.

Average growth in the real wage rate for skilled labour (Table 4.1-1, Row 7) is estimated to be 5.1 per cent per year across the entire period, while the same for unskilled labour (Row 6) is estimated to be 4.3 per cent. This could be attributed to the higher share of wage payment for both skilled and unskilled labour (52.8 per cent) compared to capital payment (47.2 per cent). Of course, the major share of labour in Odisha is unskilled ones.

Table 4.1-2 shows projected growth rates in the production of major sectors that are selected on the basis of their contribution in the gross value added of the State. Together, these sectors contribute 82 per cent of the value added of Odisha.

Table 4.1-2	Average Annual Growth Rates of Output for Major Sectors in the Baseline (%)

S. No.	Sectors	2022–2025	2026–2030	2031–2035	2036–2040	2041–2045	2046–2050	2022–2050
1	Other services	4.4	4.9	5.1	5.5	5.5	5.1	5.1
2	Trade	6.0	6.4	6.5	7.0	7.1	6.7	6.6
3	Construction	2.4	2.4	2.4	2.5	2.5	2.3	2.4
4	Fruits & vegetables	6.3	5.3	4.4	4.5	4.4	4.2	4.8
5	Dwelling	5.7	5.7	5.4	5.6	5.5	5.0	5.5
6	Public administration	2.3	2.2	2.1	2.2	2.1	1.8	2.1
7	Coal	5.4	6.0	6.3	6.6	6.8	6.5	6.3
8	Land transport	5.9	6.0	6.0	6.3	6.1	5.5	5.9
9	Textiles and garments	3.2	3.2	3.2	3.4	3.2	2.7	3.1
10	Other crops	8.0	8.2	8.0	8.3	8.0	7.3	7.9
11	Livestock	5.2	5.3	5.1	5.4	5.3	4.9	5.2
12	Financial insurance services	4.2	4.2	4.2	4.2	4.2	4.0	4.2
13	Food, beverage & tobacco	2.4	2.3	2.5	2.6	2.5	2.4	2.5
14	Forestry	3.8	3.6	3.3	3.2	3.0	2.5	3.2
15	Oil	3.5	3.2	2.8	2.7	2.5	2.0	2.7
16	Other manufacture	8.0	8.0	7.7	7.9	7.6	6.8	7.7
17	Fishing	4.2	4.2	4.1	4.0	3.7	3.2	3.9
18	Petroleum products	3.3	3.1	3.2	3.2	3.0	2.5	3.0
19	Communications	2.1	2.0	2.1	2.2	2.2	1.9	2.1
20	Chemicals	6.3	6.1	5.8	5.3	4.5	3.4	5.2
21	Extraction	2.0	1.9	2.0	2.1	2.1	1.9	2.0
22	Vehicles	5.8	6.4	6.9	7.5	7.1	5.3	6.5
23	Paddy	6.2	5.8	5.6	5.6	5.4	5.1	5.6
24	Machinery	4.6	4.0	3.6	3.4	3.1	2.7	3.5
25	Coal electricity	6.6	6.5	6.5	6.1	5.8	5.9	6.2
26	Pharma	4.9	5.5	5.5	5.5	5.2	4.6	5.2
27	Ferrous metal	5.5	4.8	4.8	4.2	3.5	4.6	4.5
28	Wood, wood products & furniture	4.4	4.1	3.8	4.0	4.0	3.8	4.0

Source: Authors' Simulations.

Note: *Sectors having share in total value-added of more than 1 per cent are considered here.

Almost all the major sectors have positive growth during the study period. The baseline projection showed higher average growth for manufacturing sectors compared to services. Manufacturing sectors like vehicles, other manufactures, chemicals, and pharma show higher average annual growth for the period 2022–50. The services sector, which plays a crucial role in Odisha's development, also shows a higher growth rate, particularly in trade, dwelling, financial insurance, land transport, and hotels.

Table 4.1-3 shows the major export and import sectors between Odisha and the rest of India based on our estimated model and their respective shares in the economy. As expected, coal electricity, with positive growth during the period 2021-2050, continues to remain an important exporting sector to the rest of India. Given the aggregative nature of the model, we find that the some of the commodities/ services items are both exported/ imported between Odisha and the rest of India.

Table 4.1-3 Major Export and Import Sectors in Odisha

Major export sectors of Odisha (to other states of India) in 2021			Major import sectors (from other states of India to Odisha) in 2021		
S. No.	Export Sector	Average annual growth between 2022-2050	S. No.	Import Sector	Average annual growth between 2022-2050
1	Coal electricity	6.92	1	Construction	7.7
2	Construction	0.77	2	Other manufacture	8.2
3	Coal	9.17	3	Trade	7.7
4	Other manufacture	5.97	4	Other crops	7.4
5	Hotels	7.27	5	Communications	5.7
6	Communications	3.12	6	Oil seeds	2.4
7	Chemicals	14.17	7	Financial insurance services	6.7
8	Hydro electricity	7.65	8	Cereals	4.9
9	Financial insurance services	7.56	9	Other cereals	4.9
10	Ferrous metal	4.40	10	Chemicals	14.5

Source: Authors' estimates.

4.2 Results from the Bottom-up Energy Model

Our macro model is run in conjunction with a bottom-up energy model. The results of the bottom-up model provide us with the decomposition of the energy mix/emissions at a more granular level which we report here.

Final energy demand is dominated by industry in Odisha, with other important sectors in terms of final energy demand being transport (passenger and freight) and building. As seen in Figure 4.2-1, the share of energy demand in industry decreases from 67 per cent to 60 per cent from 2030 to 2050. Energy demand in transport (passenger) will fall from 13 per cent in 2030 to 12 per cent in 2050. There is almost no change in the share of freight transport over the years. Building, one of the major energy-intensive sectors, marked an increase in the sector's share in final energy from 9 per cent in 2030 to 19 per cent in 2050.

With regard to energy mix, coal (hydrocarbon) is expected to emerge as the major sector hovering around 85 per cent in 2050 (Figure 4.2-2). The share of electricity seems to increases significantly, from 25 per cent in 2030 to 50 per cent in 2050 in the base run. We find that the share of biofuel will decrease from 15 per cent to 11 per cent from 2030 to 2050. The share of oil seems to remain unchanged over the years. The model has also explored the presence of biogas, off-grid solar and wind electricity, solar thermal electricity, and green hydrogen in Odisha. But in our base run, these technologies do not emerge as major ones.

Figure 4.2-1 Final Energy Demand

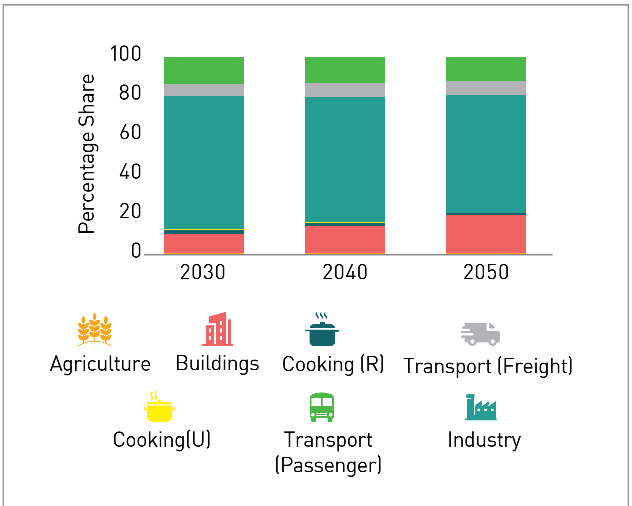
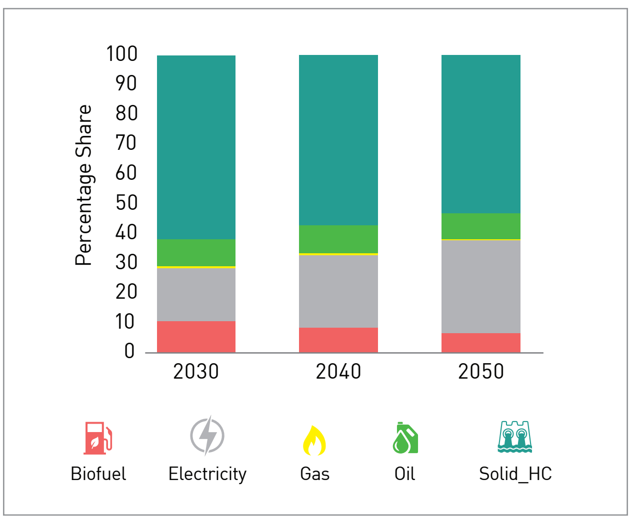


Figure 4.2-2 Final Energy Mix



4.2.1 Electricity capacity and generation mix

In the baseline scenario, capacity is expected to rise in three components; solid hydrocarbon capacity is expected to rise from 19 GW in 2025 to 148.9 GW in 2050, hydropower capacity from 2.44 GW in 2030 to 9.15 GW in 2050, and onshore wind capacity from 0.5 GW to 2.2 GW from 2030 to 2050. On other components, the increase between 2030 and 2050 is very marginal: small hydro capacity rises from 0.11 GW to 0.23 GW, biomass-based power (biomass PP) increases marginally from 0.03 GW to 0.12 GW; and solar photovoltaic (PV) grows marginally from 0.4 GW to 1 GW. As Figure 4.2-3 shows, the share of solid hydrocarbon capacity increases from 85 per cent in 2030 to 92 per cent in 2050. Our model also explores the emergence of technologies like gas, nuclear, offshore-wind, oil, solar CSP, and solar PV storage-based electricity capacity, but these do not play any significant role in the business-as-usual scenario.

In terms of generation, solid hydrocarbon is the major source of electricity generation in Odisha and it is expected to rise from 139.2 TWh in 2030 to 936.3 TWh in 2050 in the baseline scenario. Hydropower, the second most important source of electricity generation, is expected to grow from 11.4 TWh in 2030 to 48.1 TWh in 2050. Small hydropower generation rises marginally from 0.6 TWh in 2030 to 1.6 TWh in 2050.

Renewable energy sources are also expected to grow in the baseline scenario, though their share in generation remains almost stagnant: onshore wind (from 1.3 TWh in 2030 to 6.0 TWh in 2050), solar PV (from 0.7 TWh in 2030 to 1.9 TWh in 2050), biomass power (PP) (from 0.1 TWh in 2030 to 0.48 TWh in 2050). As Figure 4.2-4 indicates, the generation share of solid hydrocarbon also turned higher from 91 per cent in 2030 to 94 per cent in 2050. The share of other electricity types remains unchanged.

Figure 4.2-3 Electricity Capacity Mix

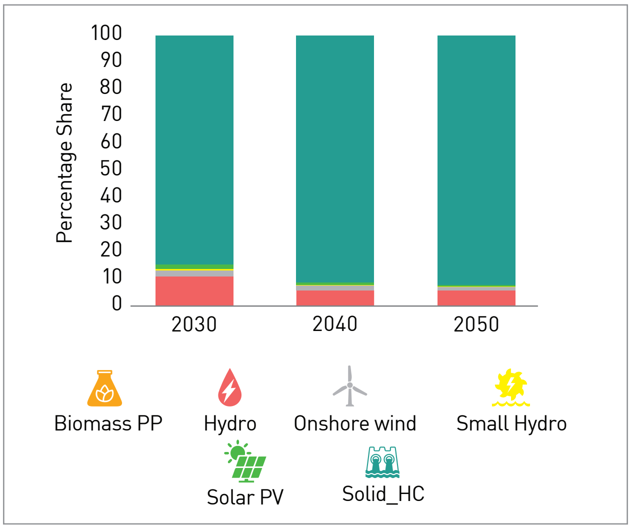
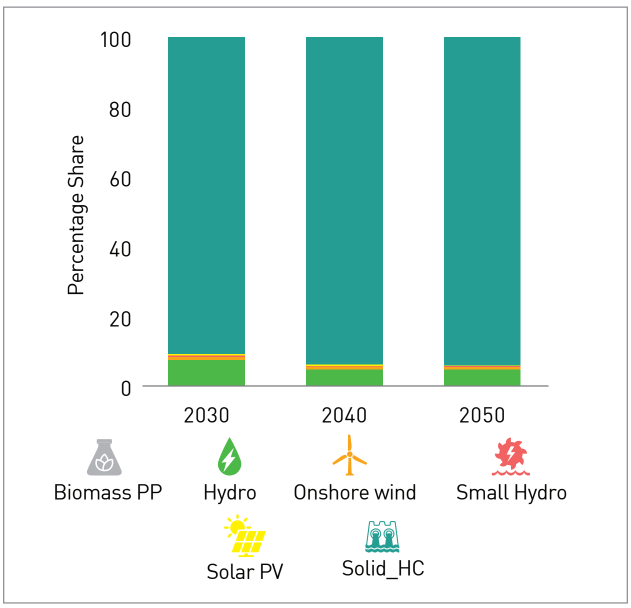


Figure 4.2-4 Electricity Generation



4.2.2 Industry: energy/fuel choices

There seems to have significantly higher energy demand originating from industry. While the share of final energy demand by the industry sector is around 84 per cent in 2030 it consumes around 25 MTOE of energy comprises of electricity, coal and industrial oil (FO, HSD etc). By 2050, it is projected that the share of industrial energy consumption will be around 74 per cent of total energy consumption of the State amounting to 56 MTOE of energy consumption. Under the baseline condition, coal will remain as the major source of energy for industrial activities in the State with slight decline in share during the later part of 2040s. Odish being the industry driven economy with the home of several large industries will face challenge to deal with the coal abatement issue in the overall context of net zero or deep decarbonization of the State. The growth of different types of fuel used in industry is shown in Figure 4.2-5.

Figure 4.2-5 Energy Demand in Industry

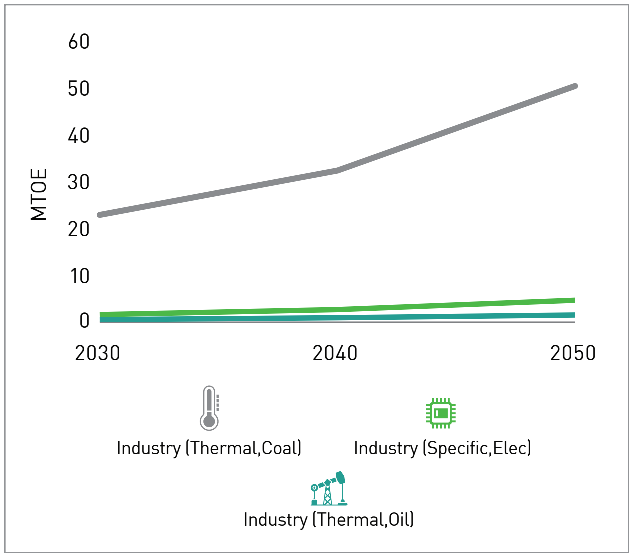


Figure 4.2-6 Composition of Fuel in Industry

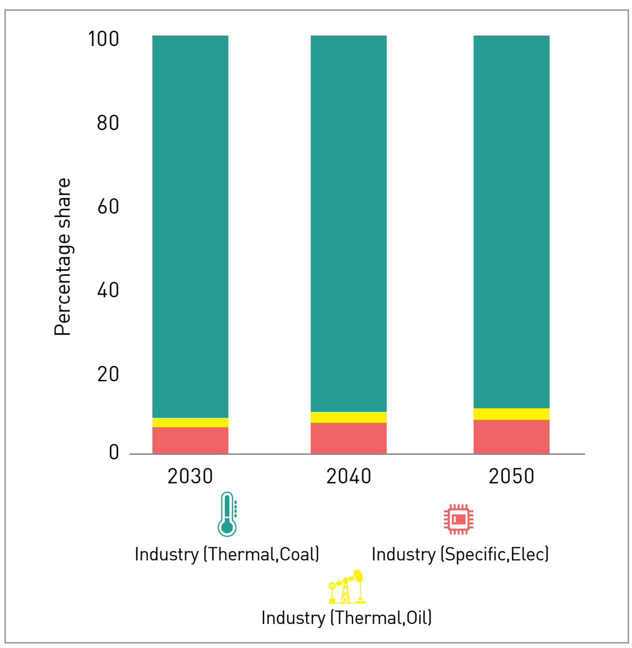
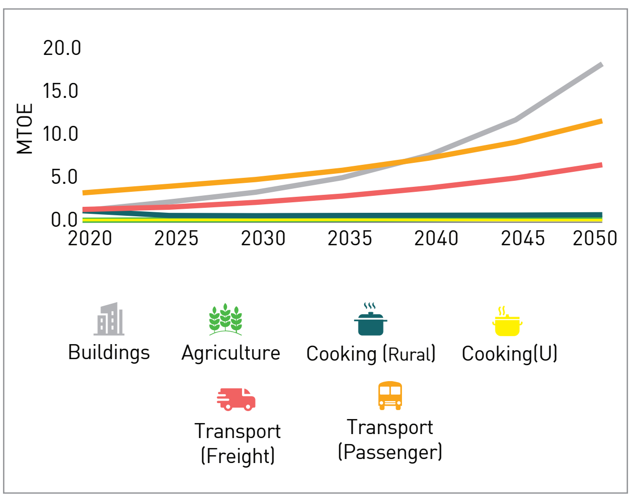


Figure 4.2.6 shows that the principal source of demand is coal-based thermal energy (91.4 per cent), followed by electric (6.4 per cent), and oil-based energy (2.2 per cent) in 2030 in industry. The respective share levels were unchanged over our model run period. The model also explored the options of new technologies like thermal biomass, compressed biogas, electric, gas, and green hydrogen. However, in our business-as-usual scenario, these do not seem to emerge as a notable choice for industry.

4.2.3 Energy/fuel choices for broad sectors

Figure 4.2-7 indicates energy demand in sectors other than industry. These sectors comprise transport (freight), transport (passenger), building, agriculture, cooking (rural), and cooking (urban). Buildings and transport (passenger) are sectors that register higher energy use in the baseline. Agriculture has the lowest energy demand among all sectors in the baseline. This group together accounts for 12.1 MTOE energy in 2030, which could go up to 38.5 MTOE in 2050.

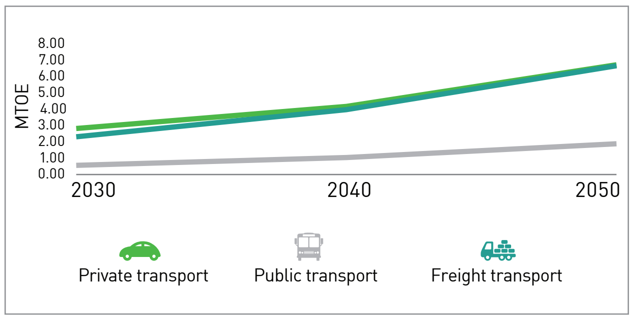
Figure 4.2-7 **Energy Demand in Various Sectors**



4.2.4 Transport sector: energy/fuel choices

Energy demand in the transport sector will rise from 5.7 MTOE in 2030 to 15.3 MTOE in 2050 (Figure 4.2-7). In Figure 4.2-8, we decompose passenger (transport) into public and private components. As this figure shows, the energy demand for freight transport exceeds but is almost close to that of private transport. The value of the energy demand for freight transport is expected to increase from 2.32 MTOE in 2030 to 6.68 MTOE in 2050. The demand for public transport remains very low in terms of energy demand.

Figure 4.2-8 **Energy Demand in Transport Sector**



Figures 4.2-9 to 4.2-11 report the break-up by vehicle type under different technologies for these three modes namely, private transport, public transport and freight transport. Cars with 20 per cent ethanol blended in private transport mode, aviation fuel oil in air passenger in public transport mode, and oil-based road heavy duty vehicles have the highest shares in private, public and freight transport modes. respectively. In all three types of transport, electric vehicle technology was considered but it has not occupy an important share in private, public and freight transport.

Even though our model explored the emergence of various other technologies in the transport sector, like electric heavy-duty road vehicles and fuel cells in cars, they do not seem to be cost effective till 2050 in Odisha.

Figure 4.2-9 Fuel Split: Private Transport

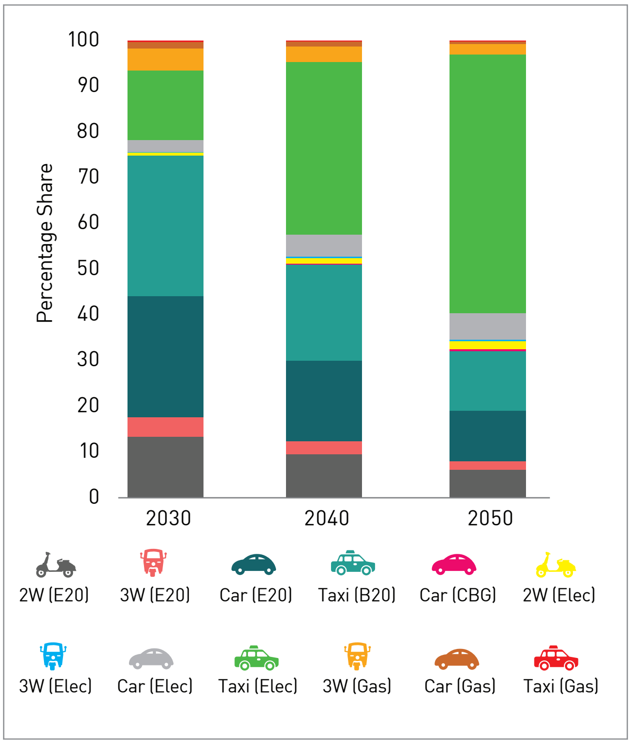


Figure 4.2-10 Fuel Split: Public

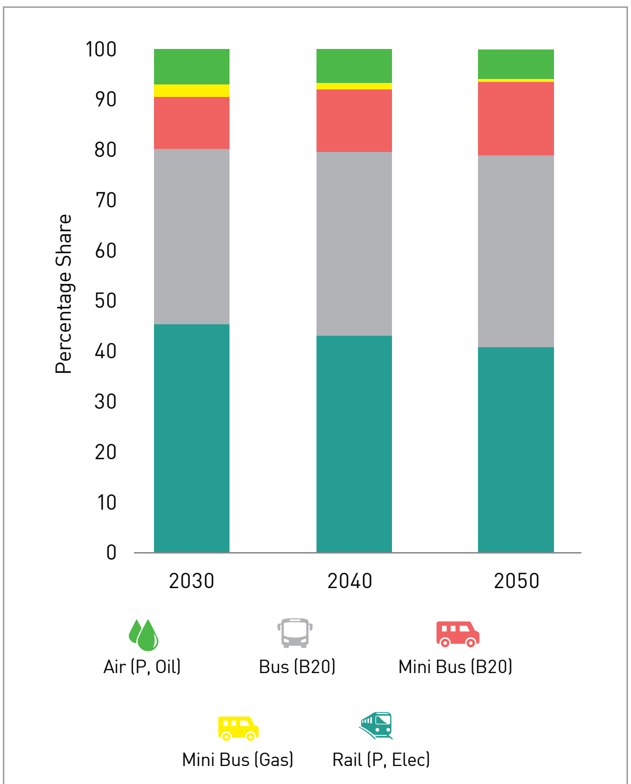
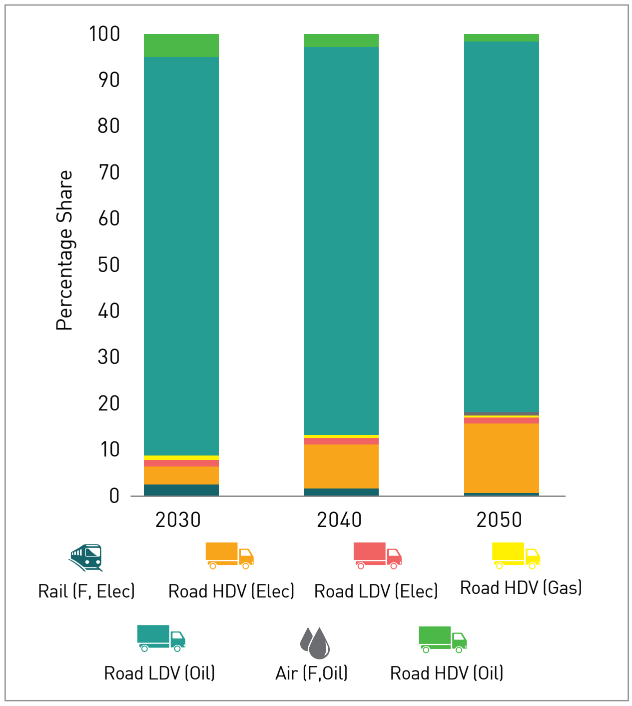


Figure 4.2-11 Fuel Split: Freight Transport



4.2.5 Energy/fuel choices for building, agriculture sector and cooking

In the building sector, residential (other electricity) predominates, whereas commercial (other electricity) has a marginal presence (Figure 4.2-12). In agriculture, the electric pump occupies the highest demand share, which is expected to rise from 2030 to 2050 (Figure 4.12-13).

Figure 4.2-12 Energy Split: Building

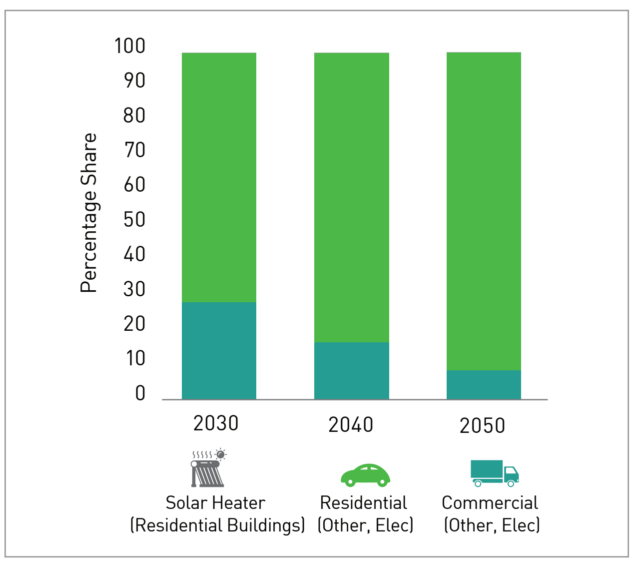
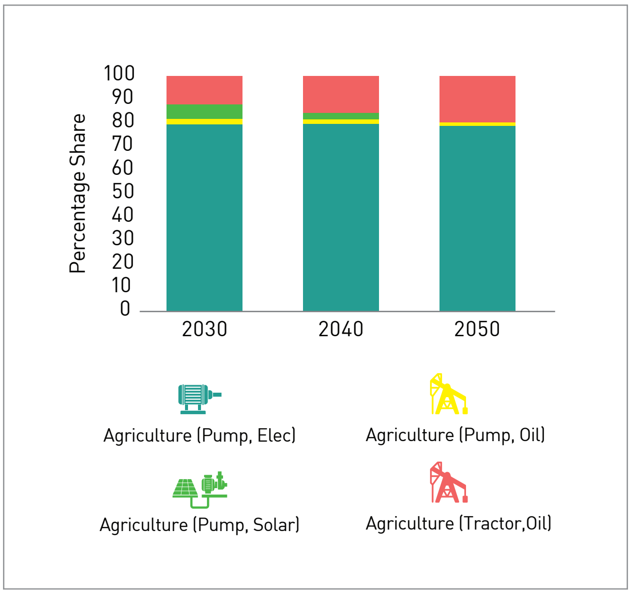


Figure 4.2-13	Energy Split: Agriculture



Figures 4.2-14 and 4.2-15 report the types of fuel uses for both rural and urban areas. In an urban setting, the presence of cooking (LPG) and cooking (PNG) was reported at a lower scale compared to energy use in other sectors.

Figure 4.2-14	Energy Split: Cooking (Rural)

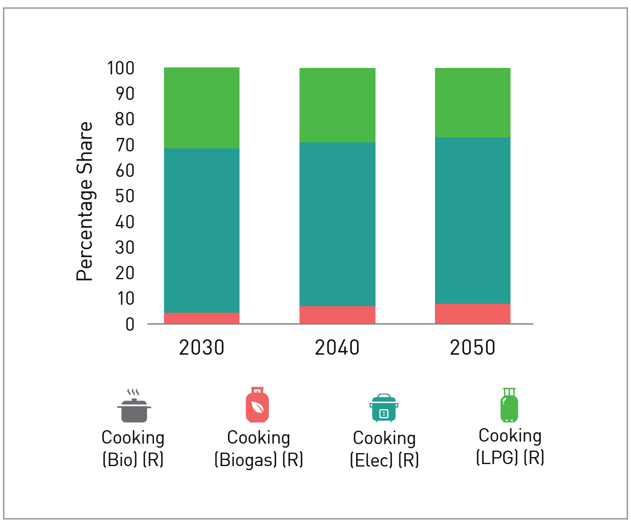
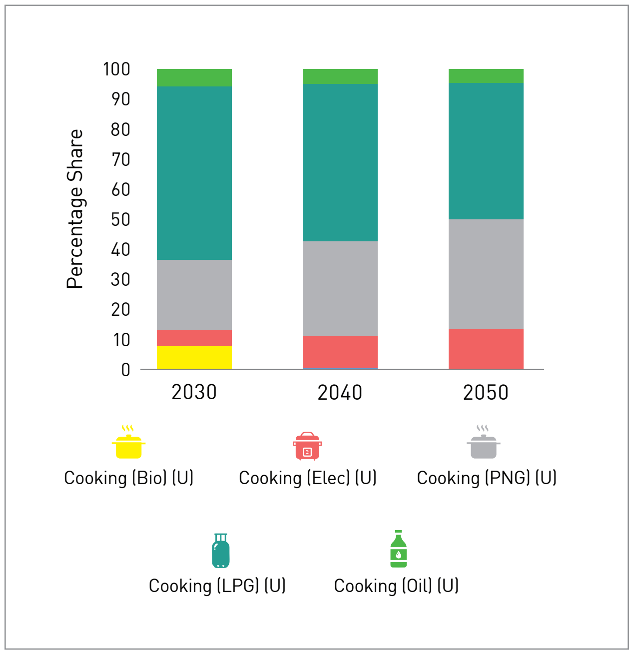


Figure 4.2-15	Energy Split: Cooking (Urban)



In summing up, our bottom-up energy model has explored the presence of the following technologies but could not find their emergence till 2050 in the business-as-usual scenario:

- Industries: thermal biomass, compressed biogas, electric, gas, and hydrogen.
- Buildings: solar in residential buildings, solar heater in commercial buildings, and diesel generator sets in residential buildings.
- Rural cooking: traditional chullah, LPG, oil, PNG-based cooking in rural areas.
- Urban cooking: bio and biogas-based cooking in urban areas, oil-based cooking, traditional chullah, and coal fuel-based urban cooking.

4.2.6 Investments

Below, we provide the additional investments required to achieve energy transition following the business-as-usual scenario. As Table 4.2-1 indicates, the highest investment is required in the transport sector, followed by the building sector.

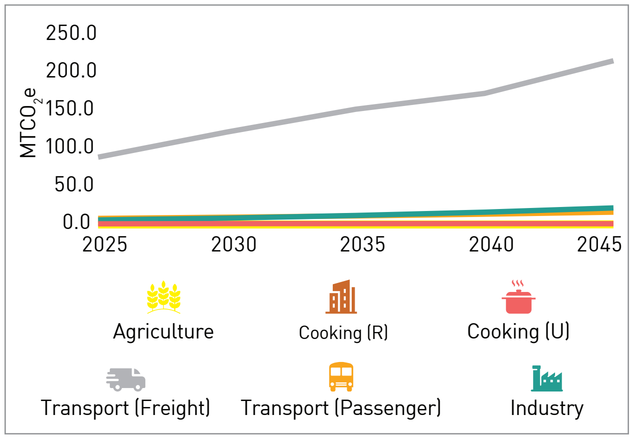
Table 4.2-1	Cumulative Investment (million US$)	
Sector	**Base Run**	
	2025-30	**2025-50**
Agriculture	616	2527
Biofuel	84	135
Buildings	1725	14337
Cooking (rural)	488	1696
Cooking (urban)	98	350
Domestic (resource)	137	406
Electricity	11189	156143
Gas	2	11
Industry	8	39
Transport (freight)	67	16999
Transport (passenger)	9	223
Biogas	16079	83111
Green hydrogen	28930	191819
Total	**59432 (7.3 per cent of cumulative SDP)**	**467796 (3.3 per cent of cumulative SDP)**

Source: Authors' estimates.

4.2.7 Emissions

Figure 4.2-16 provides emissions over the baseline period. As this figure indicates, industry is the main source of emission in the baseline.

Figure 4.2-16 Sector-wise Emissions



Of course, emission of other gases like CH_4, etc. also takes place which are not accounted above. Table 4.2-2 provides our estimates of total emissions in Odisha by 2050 and on a per capita basis. Total emission on a per capita basis is expected to rise from 4.60 million tons CO_2e per person in 2025 to 31.41 million tons CO_2e in 2050 according to our base run model results. As most of the electricity generation mix in Odisha is coal, emission levels in Odisha will be high unless the electricity mix is changed.

We also observe that per capita electricity consumption, with development, would rise 6.2 times by 2050.

Table 4.2-2 Stylised Facts

Indicator	2025	2030	2035	2040	2045	2050
Total emission (MTCO_2e)	205.0	300.6	430.5	618.3	929.4	1415.4
Per capita emission (MTCO_2e)	4.60	6.69	9.56	13.73	20.63	31.41
Per capita electricity consumption (KWH)	1116	1586	2248	3261	4753	7020

5. Policy Scenarios

The earlier section indicates that Odisha will be on a path of high emission in the business-as-usual scenario unless corrective policy interventions are undertaken. Due to heavy industries, mining activities and coal based power generating stations, the State is in hard to abate situation in terms of achieving low carbon pathway and net zero subsequently. It is important that the State formulates adequate and appropriate policies to strike balance between development, economic growth and emissions mitigation. Below, we have undertaken the following illustrative policy scenarios to understand whether these help Odisha move on a low carbon pathway along with their economic implications.

(a) Scenario 1: Capacity Augmentation of Renewable Electricity (Aug_R_Elec)

Currently, Odisha is a major exporter of fossil-based electricity to the rest of India. Our baseline suggests that this trend would continue till 2050. When all other states move towards renewable energy instead of cheaper fossil-based electricity to reduce their carbon footprint, it makes sense for Odisha to augment its renewable energy capacity. The targeted intervention to renewable electricity is based on the actual and potential installed capacity of solar, wind, small and large hydro, nuclear and bio- power in Odisha and the rest of India. We assume that 50 per cent of the existing potential of renewable electricity by various modes is achieved in Odisha and the rest of India by the terminal year of our model run (2050). To achieve this transition, we impose an endogenously determined indirect tax on fossil-based electricity to dampen its growth and the revenue so collected is distributed as counter-veiling subsidy on electricity generated from clean energy sources. Simultaneously, we impose a ban on import of fossil-based electricity from the rest of India, so that cheaper imported fossil-based electricity does not substitute for domestic fossil-based electricity.

(b) Scenario 2: Scenario 1 + Enhanced Energy Efficiency (Incr EE)

In this scenario, we consider increased energy efficiency to the tune of 1.5 per cent in Odisha and the rest of India concomitant with policy scenario 1. Further, we have assumed 1 per cent total productivity growth per year in all sectors. The range of total factor productivity (TFP) growth has been achieved in the past in India. Also, in our bottom-up energy model, we assume that sectoral intervention takes place in industry, building, transport, and agriculture so that low carbon technologies become more economically viable.

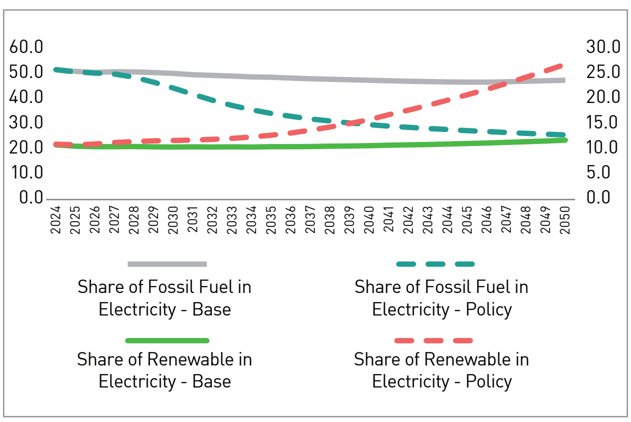
Energy efficiency has been the discussed widely in the policy document in Odisha.

Moreover studies in the Indian context suggest that these are low-hanging fruits and are very effective in reducing the carbon footprint.

5.1 Results and Discussion, Policy Scenario 1

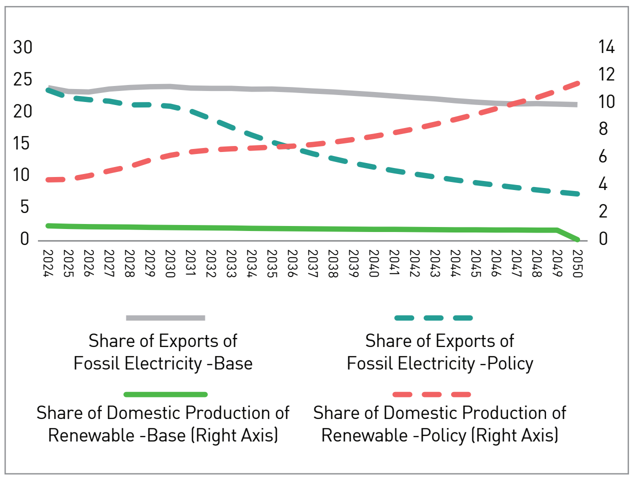
Figure 5.1-1 reports the share of fossil-based and renewable electricity in total electricity in the baseline and Policy Scenario 1. Being the second-largest coal-producing state in the country, Odisha has a high dependence on coal-based electricity generation. As this figure shows, without policy intervention in the form of tax/subsidy policy, Odisha will not be able to step up the growth of renewable electricity because coal-based electricity, ceteris paribus, remains cheaper. The share of fossil electricity, which was 52 per cent in 2024, turned lower to 25.8 per cent in the terminal year under this policy scenario, while the share of renewable, which was 11 per cent in 2024, increased to 27 per cent in 2050. With a larger share of 24 per cent in its total exports, Odisha is also an exporter of coal electricity to other states (Figure 5.1-1). However, the export of electricity to the rest of India will decline to some extent in this scenario. The share of fossil electricity exports in total exports of Odisha dipped to 15.1 in terminal year 2050 compared to 24 per cent in 2024.

Figure 5.1-1 **Policy Scenario 1: Share of Renewable and Fossil in Total Electricity in Odisha (%)**



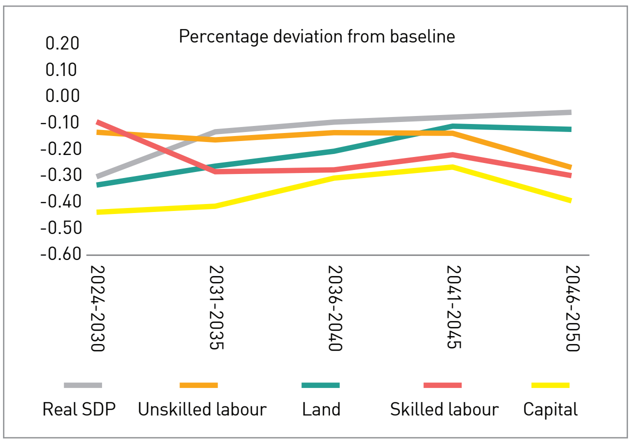
The shares of fossil and renewable electricity in total electricity, which were 52 per cent and 11 per cent, respectively in 2024 in the baseline run, turn to 26 per cent and 27 per cent, respectively, in the policy run in terminal year 2050 (Figure 5.1-1). We notice that policies to promote renewable energy such as Renewable Energy Policy (2022) help reducing the dependency on coal use for power generation through the natural process of price competitiveness in the market. The structural change in electricity generation has implications for both output and exports of fossil electricity. It is notable that the share of renewable in total output turned higher to 13.2 per cent in year 2050, compared to 1 per cent in base year 2024 (Fig 5.1-2).

Figure 5.1-2 **Policy Scenario 2: Share of Exports of Fossil Electricity and Domestic Production of Renewable in Odisha (per cent)**



The impact of change in the electricity mix with the policy implementation under Scenario 1 has implications in both economy-wide and sectoral terms (Figure 5.1-3). The percentage deviations vis-à-vis the base run projects real SDP to decline for all five periods. The relative decline in real SDP in Odisha is also attributed to negative deviations in real returns to both skilled and unskilled labour and capital. Expenditure-side GDP components, viz., real consumption-private, consumption-public and investment also turned negative. Since energy is an important input in all production activities, restrictions on the import of fossil fuel-based electricity would have an effect on all industries, leading to a reduction in the output of all industries. The negative deviation in return to unskilled labour are much pronounced compared to that of skilled labour. The output curtailing effect of fossil fuel and heavy dependence on both unskilled and skilled category of labour were impacted. Further, negative deviation for three factors, namely, capital and two labour types, contributed to the decline in SDP. The impact of restrictions on the import of fossil fuel might have affected industries that are unskilled labour-intensive compared to ones that use skilled labour.

Figure 5.1-3 **Policy Scenario 1: Average year-wise Growth of Real SDP and Real Returns to Factors**



Since energy is an integral part of the production process, restrictions on the import of coal-based electricity affects returns to capital as well. In the short-run, the imposition of restrictions has affected both labour and capital. In the long run, the economy may adjust to this gradual shift to renewable as the decline in real SDP growth is less severe particularly during in the last two periods. The returns to land also turned lower, but land is not a constraint in Odisha. With restrictions on the import of fossil fuel, the requirement for electricity generation from renewable energy could easily be met. However, the same has not happened in terms of returns to land in Odisha.

5.1.1 Sectoral results

The sectoral results in terms of percent deviations from the baseline show a mixed trend (Table 5.1-1). The sectoral results are shown as a deviation from the base run. This implies that some sectors exhibit small negative growths compared to the base run. However, it must be mentioned that all the sectors in our policy run exhibit positive growth even though the growth rate may be only half percent lower compared to business-as-usual. The services sectors, viz.,financial insurance services and communications, showed improvement in output during all five periods relative to the base run. Other major services sectors (other services, trade, construction, and dwelling etc.) registered lower output growth compared to the baseline. Public administration and land transport showed a mixed pattern of deviations during the study period with improvement in the last two periods over a lower growth during the first three time periods.

The manufacturing sector (textiles and garments, food beverage and tobacco, other manufactures, vehicles, machinery, pharmaceuticals, and wood and wood products) indicates improvement in output growth during all five periods. The relative growth in other manufactures turned in close to one per cent or higher during the second, third, and fourth time periods. The result indicates that while strict within state RE development policy is promoted (without much dependence on outside sources of RE power) which is otherwise providing much stronger energy security and price control, service sector of the State economy will be impacted. The main reason could be enhanced cost of power. Output of the service sectors are highly elastic to the cost of power and thus there is an expected decline (though very marginal) in outputs.

5.1.2 Summing up

Lower SDP growth in all five time periods was observed. The factor-side reallocations in terms of real returns to factors also turned lower.

Table 5.1-1	Policy Scenario 1: Annual Average Growth Rate of Major Sectors in Odisha Percentage Deviation from Base-run

S. No.	Sectors	2024-2030	2031-2035	2036-2040	2041-2045	2046-2050
1	Other services	-0.03	-0.11	-0.06	-0.01	0.06
2	Trade	-0.09	-0.07	-0.03	-0.02	-0.02
3	Construction	-0.19	-0.12	-0.05	-0.11	-0.27
4	Fruits & vegetables	-0.03	-0.06	-0.06	-0.05	-0.03
5	Dwelling	-0.31	-0.31	-0.17	-0.08	-0.02
6	Public administration	-0.15	-0.12	0.01	0.07	0.14
7	Land transport	-0.44	-0.24	-0.03	0.08	0.09
8	Textiles and garments	0.14	0.42	0.42	0.27	0.12
9	Other crops	0.06	0.11	0.13	0.15	0.11
10	Livestock	-0.05	-0.11	-0.09	-0.05	0.00
11	Financial insurance services	0.26	0.38	0.37	0.34	0.32
12	Food, beverage & tobacco	0.03	0.16	0.20	0.20	0.17
13	Forestry	0.07	0.08	0.06	0.04	0.03
14	Other manufacture	0.31	0.97	1.15	1.04	0.74
15	Fishing	-0.07	-0.04	-0.02	0.00	0.19
16	Communications	0.03	0.07	0.12	0.13	0.15
17	Chemicals	-0.75	0.04	0.66	1.04	1.04
18	Extraction	-0.07	0.15	0.11	0.00	-0.08
19	Vehicles	-0.14	0.12	0.22	0.16	0.05
20	Paddy	0.00	0.05	0.09	0.15	0.30
21	Machinery	0.23	0.81	0.89	0.71	0.43
22	Pharma	0.27	0.81	1.05	1.11	0.94
23	Ferrous metal	-0.10	0.42	0.43	0.18	-0.11
24	Wood, wood products & furniture	0.06	0.15	0.13	0.09	0.04

Source: Authors' simulation.

5.2 Results and Discussion, Policy Scenario 2

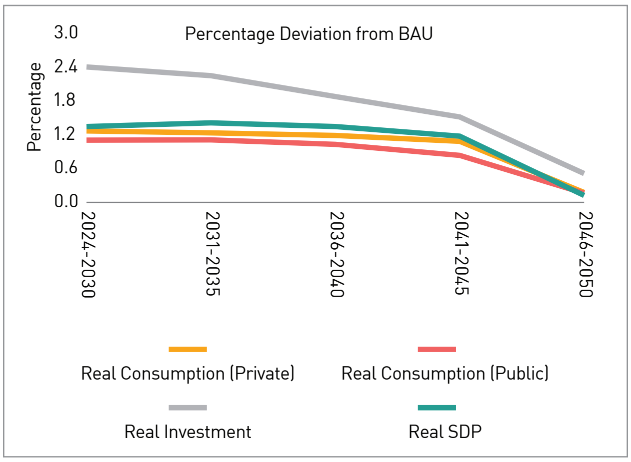
Energy efficiency is a must for adopting a low carbon pathway. India has made significant strides in terms of paving the way in this direction. In this scenario, we assume an increase in autonomous efficiency in all energy sectors by 1.5 per cent per annum in energy-consuming sectors; the calibration of this number from the literature is quite plausible. Additionally, we assume economy-wide productivity growth of 1 per cent per annum; in the past, India achieved more than 1 percent total productivity growth (TPF) per annum. These policy shocks are assumed for both Odisha and the rest of India. This scenario is run concomitant with Scenario 1.

It simulates the imposition of an import ban on fossil-based electricity in Odisha and the augmentation of renewable electricity in Odisha and the rest of India.

5.2.1 Macroeconomic results

Figure 5.2-1 shows higher SDP growth compared to the baseline. The growth turns out to be in the range of 1.4 to 1.2 per cent during the first four periods. The deviation in growth also turned higher for three major components of absorption, namely, real private and public consumption and real investment. Investment grew by a higher percentage point in all four periods and stayed put in the last period (2046-50). Both real private and public consumption showed lower growth.

Figure 5.2-1 **Policy Scenario 2: Macroeconomic Results for Odisha**



Expectedly, the enhancement in energy efficiency along with an economy-wise factor productivity shock leads to an improvement in real returns to unskilled and skilled labour and capital. After the initial years, the real returns to land also increases compared to the baseline. Among the two labour components, real returns to skilled labour turn higher.

Figure 5.2-2 **Policy Scenario 2: Real Returns to Factors of Production in Odisha**

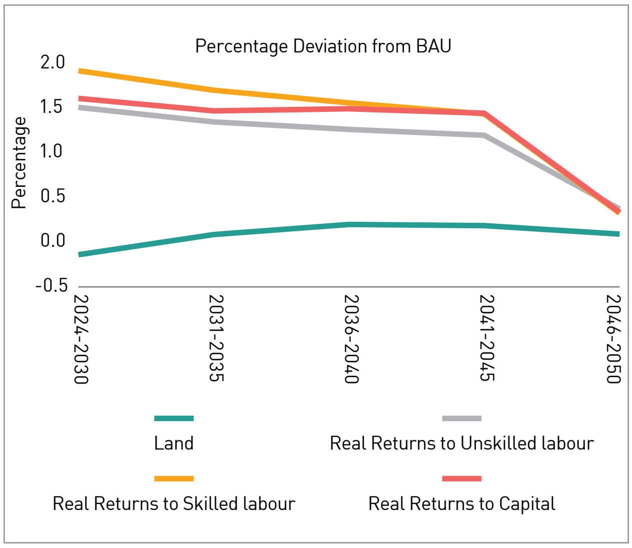


Table 5.2-2 shows that energy efficiency leads to higher growth in prominent sectors of Odisha such as dwellings, public administration, other services, trade, construction, and financial insurance services. The growth in chemicals, machinery, other manufactures and pharmaceuticals also turns out to be higher.

Table 5.2-1	Policy Scenario 2: Sectoral Growth of Output in Odisha

S. No.	Sectors	2024–2030	2031–2035	2036–2040	2041–2045	2046–2050
1	Other services	4.7	5.0	5.5	5.4	5.0
2	Trade	6.0	6.5	7.1	7.0	6.6
3	Construction	6.0	4.3	4.4	4.2	3.9
4	Fruits & vegetables	2.3	2.3	2.5	2.4	2.2
5	Dwelling	7.7	7.6	8.1	7.8	7.1
6	Public administration	5.6	5.3	5.7	5.5	5.1
7	Land transport	5.4	5.7	6.3	6.1	5.4
8	Textiles and garments	4.3	4.5	4.4	3.9	3.2
9	Other Crops	2.4	2.2	2.3	2.2	1.9
10	Livestock	3.1	3.1	3.3	3.1	2.6
11	Financial insurance services	5.9	6.7	7.1	7.1	6.8
12	Food, beverage & tobacco	3.3	3.3	3.4	3.1	2.6
13	Forestry	3.8	3.3	3.3	2.9	2.4
14	Other manufacture	6.7	6.6	6.4	5.4	3.9
15	Fishing	3.4	2.7	2.7	2.4	2.1
16	Communications	5.3	5.2	5.5	5.3	4.9
17	Chemicals	8.6	10.4	11.9	11.4	9.5
18	Extraction	4.5	3.7	3.5	3.1	2.5
19	Vehicles	6.0	5.7	5.8	5.5	5.1
20	Paddy	2.4	2.6	2.7	2.7	2.7
21	Machinery	6.9	7.2	7.0	6.5	6.3
22	Pharma	5.4	6.3	6.6	6.3	5.5
23	Ferrous metal	5.5	5.1	4.6	3.8	4.6
24	Wood, wood products & furniture	4.5	4.0	4.2	4.1	3.8

Source: Authors' estimates.

Table 5.2-2 shows the relative growth of sectors under Scenario 2 vis-à-vis the baseline. The manufacturing sector seems to be benefited in terms of registering higher growth under Scenario 2 compared to the BAU scenario. The selected sectors registering higher average growth are machinery (1.6 per cent), vehicles (1.4 per cent), other manufacturing (1.3 per cent), ferrous metal (1.3 per cent), and construction (1.2 per cent). Average output growth in 'other services' trade sectors are found to be 0.8 per cent and 0.9 per cent, respectively. Table 5.2-2 further shows that each sector experiences at least half a per cent rise in sectoral output.

Table 5.2-2	Average Deviation in Sectoral Growth between Policy Scenario 2 and BAU (%)

S. No.	Sectors	Per cent	S. No.	Sectors	Per cent
1	Other services	0.8	13	Forestry	0.5
2	Trade	0.9	14	Other manufacture	1.3
3	Construction	1.2	15	Fishing	0.7
4	Fruits & vegetables	0.6	16	Communications	0.8
5	Dwelling	1.2	17	Chemicals	0.5
6	Public administration	0.9	18	Extraction	0.5
7	Land transport	0.5	19	Vehicles	1.4
8	Textiles and garments	0.8	20	Paddy	0.4
9	Other crops	0.3	21	Machinery	1.6
10	Livestock	0.9	22	Pharma	0.5
11	Financial insurance services	0.4	23	Ferrous metal	1.3
12	Food, beverage & tobacco	1.2	24	Wood, wood products & furniture	0.5

Source: Authors' estimates.

5.2.2 Results from Bottom-up Energy Model

The results from the macro model are more aggregative in nature. Let us review the results from the linked energy model which shows the breakup of energy use at a more granular level.

Energy demand and fuel mix

Figure 5.2-3 shows the final energy demand in baseline and Policy scenario 2. It indicates that the industry sector is the major contributor of energy demand both in the base and policy scenario in Odisha. This is primarily due to the concentration of energy-intensive industries in Odisha, which we believe will still grow in the coming years. In Policy scenario 2, final energy requirement in buildings falls sharply, whereas in cooking it declines marginally in rural areas. We do not expect any major change in agriculture.

Figure 5.2-3 Final Energy Demand in Baseline and Policy Scenario 2

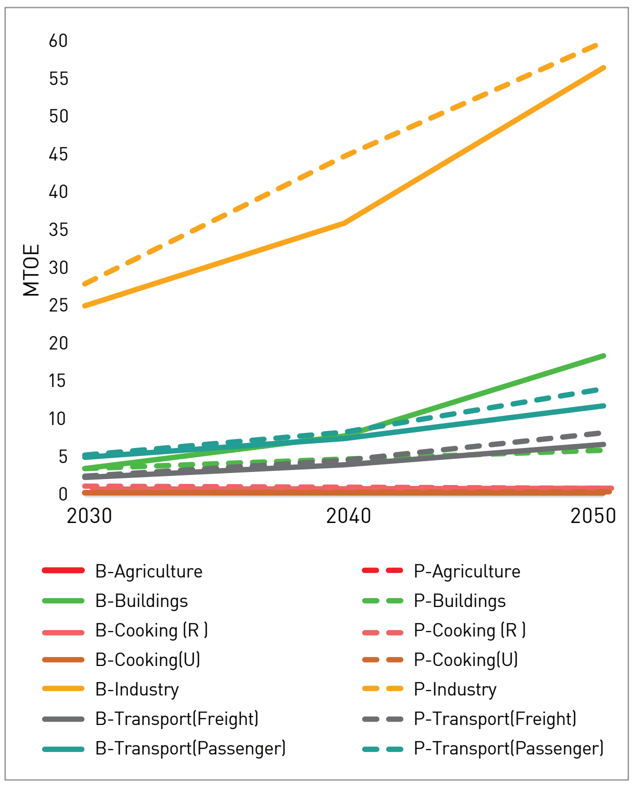


Figure 5.2-4 Fuel Mix in Baseline and Policy Scenario 2

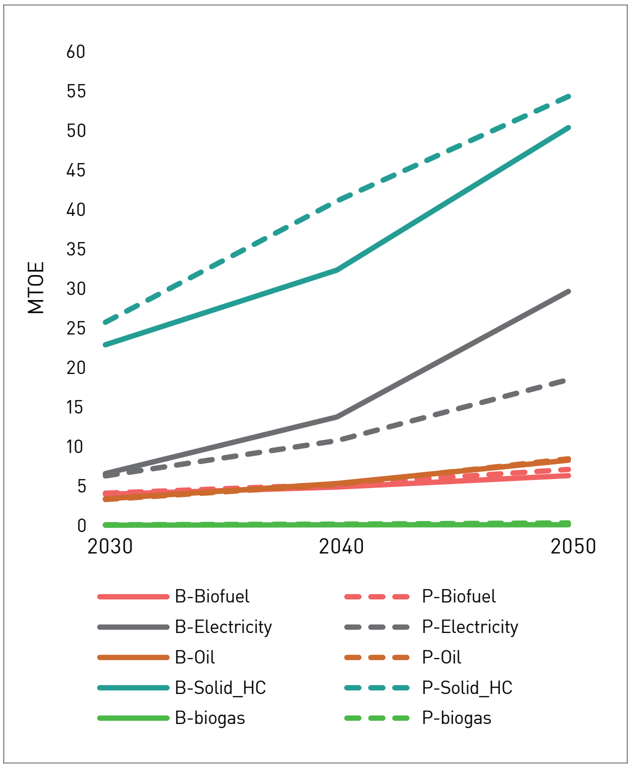


Figure 5.2-4 shows the fuel mix in the baseline and policy scenarios. There is a rise in solid hydrocarbons and electricity in the policy scenario. There is a marginal rise in oil, biofuel, and biogas fuel mix in Odisha. The model explored the presence of fuel mix technologies such as biogas, biomass, off-grid wind electricity, solar thermal, green hydrogen, and solar off-grid electricity in baseline and policy simulations. Except for biogas, biofuel, gas and solar off-grid electricity, which showed a marginal rise in the policy run, none of the other fuel mixes showed any presence in the baseline or this policy run.

Electricity capacity and generation mix

Electricity's share in final energy consumption in Odisha is expected to be 15 per cent in 2025. According to our model, it may hover around 17 per cent during the 2040s. per capita electricity consumption in Odisha will rise from 1,138 KWh in 2025 to 2,569 KWh in 2040 and further to 4,424 KWh by 2050.

The electricity capacity mix in Policy scenario 2 experiences a rise in percentage share of hydro and small hydro-electricity from baseline shares. Odisha being a sun-rich state has the potential for solar electricity to rise sharply in Policy scenario 2 with energy efficiency/augmentation of renewable energy capacity compared to the base run (Figure 5.2-5). Expectedly, the share of solid hydrocarbons experiences a sharp decline in the electricity capacity mix of Odisha over the years in our policy run. The same pattern is observed in the electricity generation mix. We observe that there will be a marginal rise in onshore wind and small hydro, while hydroelectricity will experience a sharp rise (Figure 5.2-6). Solid hydrocarbon also experiences a sharp decline in its share of the electricity generation mix.

Figure 5.2-5 Share of Electricity Capacity Mix in % (Policy Scenario 2)

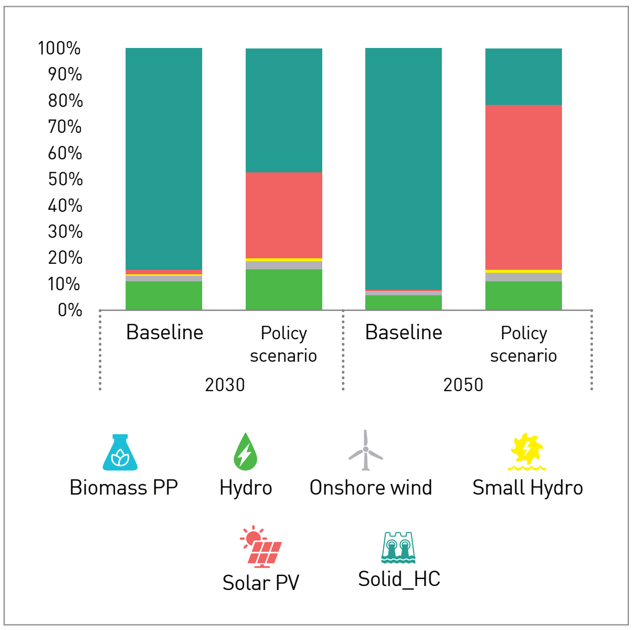
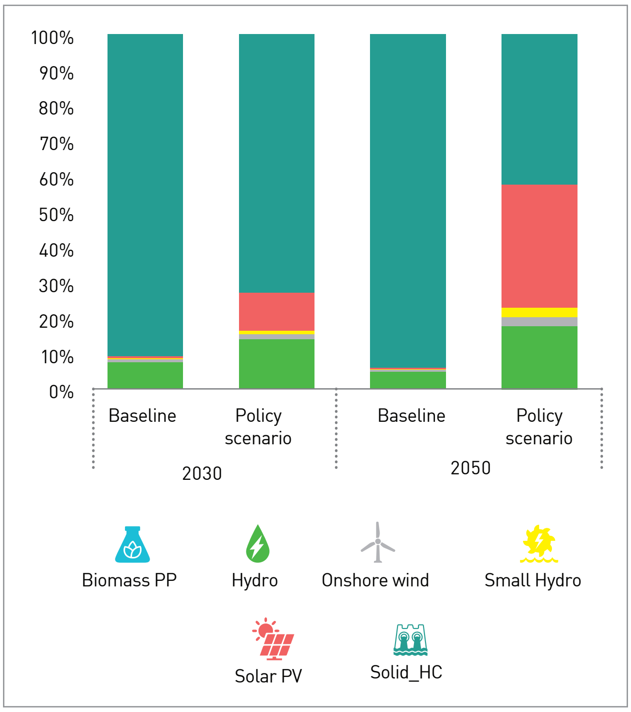


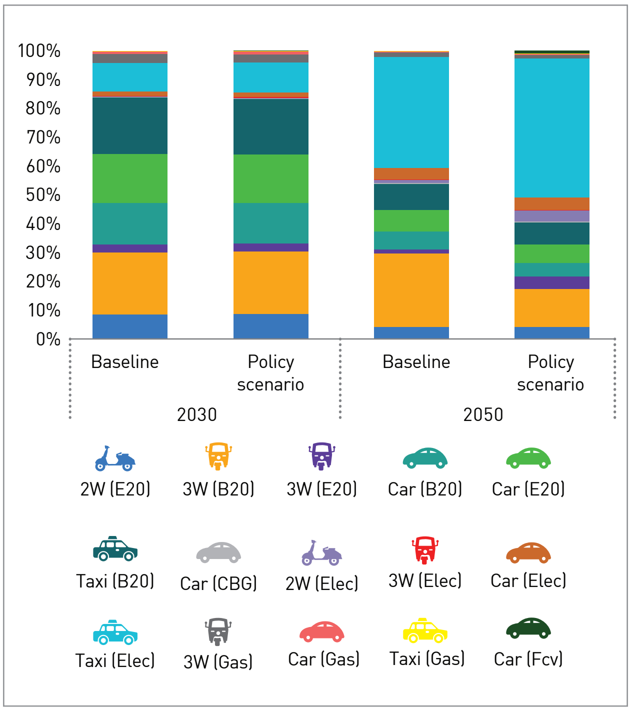
Figure 5.2-6 Share of Electricity Generation Mix in % (Policy Scenario 2)



Transport sector: energy/fuel choices

In the transport sector, it is observed that there are marginal decline in cars, two-wheelers running on 20 per cent blended biofuel and 20 per cent blended ethanol fuel, and taxis running on 20 per cent blended biofuel, and a marginal rise in electric taxis (Figure 5.2-7). Our model explored the emergence of the following vehicles and fuel types in Odisha: taxi based on compressed biogas, car running on fuel cell, oil-based two-wheelers, three-wheelers, cars, and taxis. We find that hydrogen based cars will play a minimal role in the private transportation sector until 2050.

Figure 5.2-7 Energy/ Fuel Choices for Private Transport in Baseline and Policy Scenario 2



Coming to the component of public transport, we find that fuel choice does change in the future (Figure 5.2-8). There will be a marginal rise in the share of buses running on fuel cell (H2) technologies in the coming years, which is nearly absent in our base run. The role of rail (electric) seems to play a larger role by 2050.

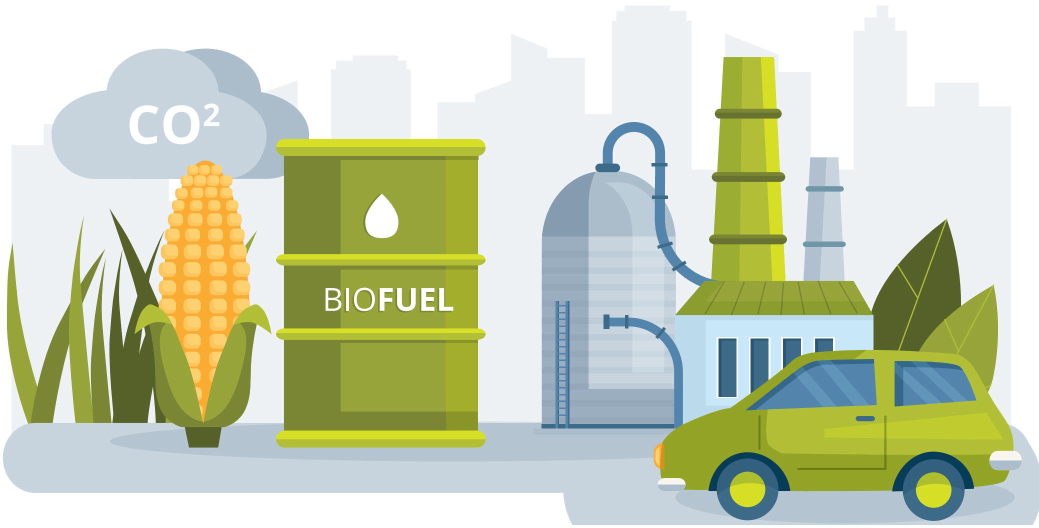
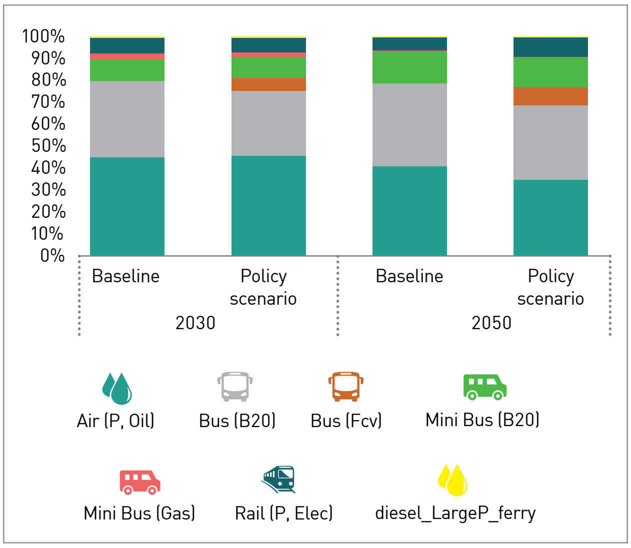
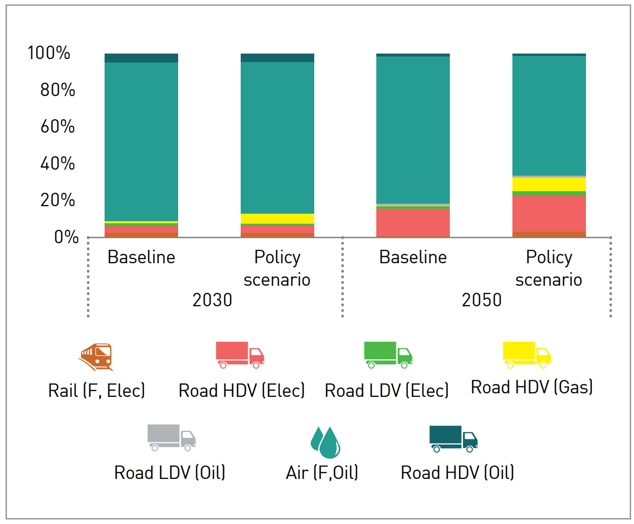


Figure 5.2-8	Energy/ Fuel Choices for Public Transport in the Baseline and Policy Scenario 2



In freight transport, the share of electric heavy-duty vehicles in road transport will rise in the policy scenario in 2030 and 2050 relative to the baseline (Figure 5.2-9). The share of gas-based, heavy duty vehicles in road transport exhibit a small rise in the policy scenario relative to the baseline. The share of oil-based, heavy duty vehicles also falls in the policy scenario relative to the baseline. Our model also explored the emergence of the following vehicles and fuel types in Odisha: compressed biogas in heavy and light duty road freight transport, gas-based light duty road freight transport, oil-based air and rail freight transport, and oil-based ship freight transport. However, they do not seem to play any role in this scenario until 2050.

Figure 5.2-9	Energy/ Fuel Choices for Freight Transport in the Baseline and Policy Scenario 2



Energy/fuel choices for other sectors

Figure 5.2-10 shows the trends in energy/fuel mix for the industry sectors for our base/policy run. As this figure shows, coal-based electricity will still play a dominant role in the industry sector. The rest of the energy/fuel choices in industries show a very marginal rise in the energy efficiency scenario compared to the baseline. The model also explores the emergence of the following energy/fuel choices in the industry sector in Odisha: biomass energy, compressed biogas energy, thermal electricity, solar off-grid electricity, and gas-based and hydrogen-based energy. Towards the end of our model run (2050), solar off-grid electricity and hydrogen-based energy exhibit some presence, albeit small.

Figure 5.2-10	Energy/ Fuel Choices for Industries in the Baseline and Policy Scenario 2

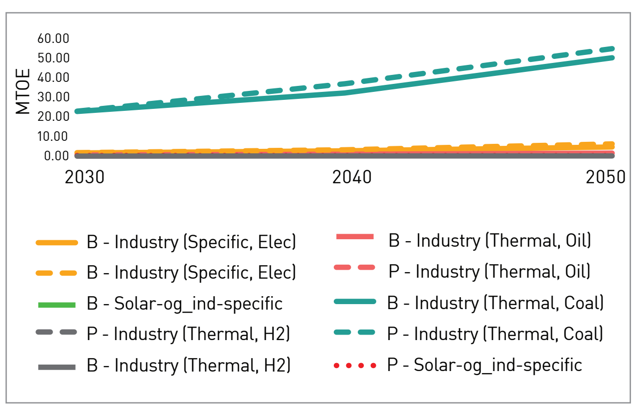
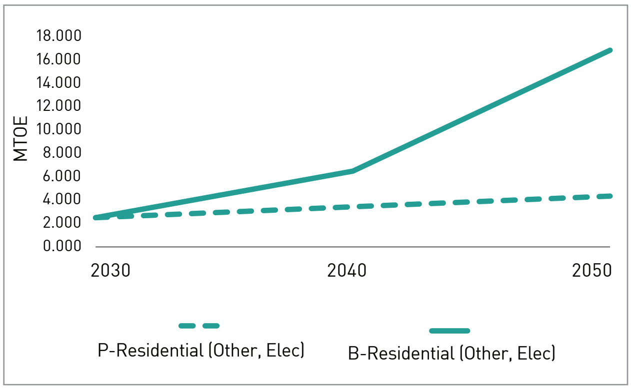


Figure 5.2-11 shows that there will be a significant decline in the demand for residential electricity in the building sector in our policy scenario relative to the baseline. The role of other choices such as diesel generator sets in commercial and residential buildings and solar heaters in commercial and residential buildings do not seem to emerge as a choice in our policy run.

Figure 5.2-11 Energy/ Fuel Choices for Buildings in the Baseline and Policy Scenario 2



We do not observe any major shifts in fuel choices in agriculture over the model period between Policy scenario 2 and the business-as-usual scenario.

Figures 5.2-12 and 5.2-13 shows the fuel choices for the cooking sector in rural/urban areas in our policy run vis-à-vis the base run. With energy efficiency, the demand of fuel for cooking reduces over time. This is true both in rural and urban area.

Figure 5.2-12 Energy/ Fuel Choices for Cooking in Rural Areas in the Baseline and Policy Scenario 2

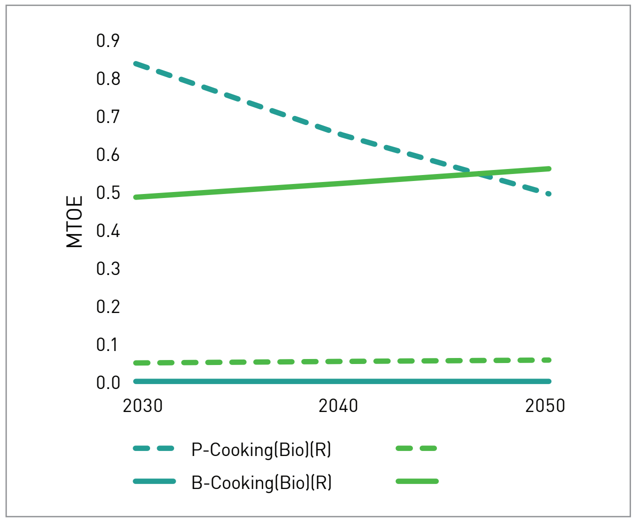
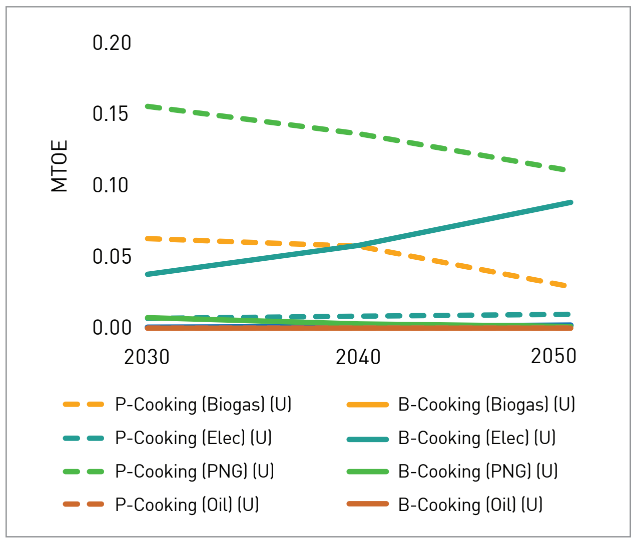


Figure 5.2-13 Energy/ Fuel Choices for Cooking in Urban Areas in the Baseline and Policy Scenario 2



Emissions

Table 5.2-3 shows overall emissions in Odisha for the base run and Policy scenario 2. It shows that per capita emission in this low carbon pathway declines from 31.41 tons CO_2e to 11.81 tons CO_2e.

Table 5.2-3	Per Capita Emission (tons CO_2e)		
Per Capita Emission	**2030**	**2040**	**2050**
Policy Scenario 2	5.03	7.29	11.81
Base Run	6.69	13.73	31.41

Source: Authors' estimates.

The principal sources of emissions are shown in Table 5.2-4 for the base run and this policy run. As this tables indicates, the reduction in emission from electricity is the major factor for the reduction in emissions.

Table 5.2-4 Principal Sources of Emissions (million tons CO_2e)

Policy Run	2030	2040	2050	Base Run	2030	2040	2050
Total Emissions	243	358	580	Total Emissions	323	674	1543
Emissions from demand side	157	251	436	Emissions from demand side	143	205	322
Industry	136	217	378	Industry	122	173	270
Transport	19	32	56	Transport	18	30	50
Emissions from supply side	86	107	144	Emissions from supply side	180	468	1221
Electricity	82	102	126	Electricity	177	463	1205

Source: Authors' estimates.

Investments

Table 5.2-5 shows our estimated investment in US$ million required to achieve this low carbon transition. As expected, with an increase in energy efficiency and productivity growth, lower carbon emission pathway can be achieved with lower investment.

Table 5.2-5 Cumulative Investment for Base-Run and Policy Scenario 2 (US$ million)

Sector	Base-run		Policy Scenario 2		Additional Investment Required	
	2025-30	2025-50	2025-30	2025-50	2025-30	2025-50
Agriculture	616	2527	639	2608	23	81
Biofuel	84	135	88	152	3	17
Buildings	1725	14337	1725	5299	0	-9038
Cooking (Rural)	488	1696	677	1467	189	-230
Cooking(U)	98	350	93	355	-5	5
Domestic (Resource)	137	406	1600	5123	1464	4717
Electricity	11189	156143	4665	52888	-6523	-103255
Gas	2	11	9	40	7	29

Sector	Base-run		Policy Scenario 2		Additional Investment Required	
	2025-30	2025-50	2025-30	2025-50	2025-30	2025-50
Industry	8	39	41	82	34	43
Transport (Freight)	67	16999	82	23592	16	6594
Transport (Passenger)	9	223	143	286	134	63
Biogas	16079	83111	15990	77897	-89	-5215
Green hydrogen	28930	191819	31097	225539	2167	33721
Total	**59432**	**467796**	**56851**	**395329**	**-2581**	**-72467**
As Percent of Cumulative SDP	**3.34**	**7.34**	**2.21**	**6.51**		

Source: Authors' estimates.

These investment numbers are also subsequently fed into the macro model to check if macro growth numbers and prices change in a significant way. This process is continued till the divergence becomes small. In our case, we find that the numbers are close after a round of feedback and so the process was not continued.

5.3 Adoption of New Technologies

It is observed under two different low carbon scenarios of the State that there are certain sectors in the economy which are the prime movers and can't be compromised to keep the economy growing. In Odisha, heavy industry plays a crucial role in generating revenue for the State as well as employment. Transitioning towards the low carbon economy needs significant shifting of various transition, low-cost fossil fuel based technologies in a phased manner. There are two major options for the State: a) shifting towards green and clean fuel use and b) Rationalization of energy demand growth through efficiency improvement and change in use pattern. Technological intervention is crucial for hard to abate sectors for reduction and elimination of GHG emissions. For the state of Odisha thermal power plants and heavy industries like iron & steel, aluminum, fertilizer. Petrochemicals etc. are key for the State's economic and social sector development including employment. It is observed that shifting towards RE based power does have negative impacts on the sectoral outputs and the economy as a whole. Therefore, new technologies like Carbon Capture & Storage including process utilization could be an option for the State to consider.

Carbon capture, storage, and utilization (CCSU) is an approach designed to capture carbon dioxide emissions originating from industrial flue gas streams. Odisha has a significant industrial base, including steel, power, and other heavy industries. CCUS technologies can be applied to capture CO_2 emissions from these industrial processes, contributing to overall emissions reduction. CCUS offers opportunities to convert captured CO_2 into valuable products like green urea, food and beverage applications, building materials, chemicals, polymers, and enhanced oil recovery, contributing to a circular economy. Utilizing green hydrogen in Odisha's industries as part of Carbon Capture, Utilization, and Storage (CCUS) initiatives can contribute significantly to reducing carbon emissions.

Tata Steel plans to set up a pilot plant in Odisha to produce methanol from blast furnace flue gases, aiming at significant methanol production in India. NALCO in Odisha initiated a project for carbon sequestration through micro-algae cultivation, addressing the issue of greenhouse gas emissions. It is important that the State promotes these technologies with policy and R&D support for faster adoption.

6. Employment Implications of Adopting a Low Carbon Pathway

Odisha is a mineral-rich state, and there is significant export of electricity and other energy-intensive commodities from the State. As a result, a low carbon pathway would have significant policy implications on the economy of the State, especially on employment. An analysis of the implications of environmental policies and targets on employment requires consideration of indirect job creation, especially that arising from the macroeconomic effects of policies (Hillebrand et al. 2006; Markaki et al. 2013; Dordmond et al. 2013; Duscha et al. 2016). Employment absorption in different energy sectors are different and, thus, transition to low carbon pathway would have an impact on direct employment generation in the energy sector. Moreover, power generation requires inputs from mining, manufacture, energy, plastics, transport services and others, and the pattern of linkage differs across different fossil fuel-based and non-fossil fuel-based industries, so we have estimated the economy-wide implications on employment by capturing the inter-linkage of industries. Additionally, since the policy emphasis is on greater reliance on the renewable energy sector, there would be additional employment generation from manufacturing and installation of renewable power plants like solar photovoltaic or wind power plants in Policy scenario 2. In this section, we estimate the employment generation projection of policy scenario 2 for Odisha. This is viewed in relation to the baseline scenario to understand the employment consequences of a low carbon pathway in Odisha.

6.1 Employment Effects

According to data from the Periodic Labour Force Survey (PLFS), the unemployment rate, which is estimated as the percentage of unemployed persons in the labour force, was 6.0 for Odisha in 2021-22, which is higher than the all-India average of 4.1 for the age group of 15 years and above, as per the usual status (ps+ss). In this study, employment coefficients are generated using PLFS data. In the usual status (ps+ss) approach in PLFS data, the estimates of unemployment rates are based on usual status considering principal and subsidiary statuses together. Estimates for the labour force under this approach includes (a) persons who either worked or were seeking/available for work for a relatively long part of 365 days preceding the date of survey, and (b) persons from among the remaining population who had worked at least 30 days during the reference period of 365 days preceding the date of the survey. Estimates are adjusted for inflation and growth in labour productivity over the years.

We differentiate between jobs by capturing the 'proximity' of a created job in a sector vis-à-vis other sectors depending on how directly it can be attributed to a certain final energy demand. 'Direct jobs' refer to jobs that are directly related to core activities, such as operation and maintenance of a power plant. These jobs, along with jobs that are related to supply and support of the energy industry at a secondary level (indirect jobs), and jobs led by household spending based on income earned from the direct and indirect effects (induced effects) are included in total employment. Since sectors in the economy are linked through forward and backward linkages, indirect jobs capture jobs that are created to support the respective energy industry for extraction and processing of raw material, manufacturing, construction and so on to support the operation and maintenance of power plants. Total jobs, thus, are the aggregate of all types of jobs, which include direct, indirect, and induced jobs from operation and maintenance of power plants. Additionally, the study estimates the required employment absorption for manufacturing and installation of new renewable power plants.

Our results show that direct employment from operation and maintenance of power plants would be affected by the shift towards green energy in 2050, since the coal mining and coal electricity sectors are still major providers of employment in the State. A major part of output from these sectors is also exported. With green transition, direct employment is these sectors would reduce, and employment in renewable energy sector would increase, but as a result the net effect on direct employment generated from operation and maintenance of power plants would still be negative, which amounts to a reduction of 83,000 direct employment in the energy sector by the year 2050 (Figure 6.1-1). However, this would not have a negative effect on total employment. Through the interlinkage of renewable energy with other sectors of the economy, the economy as a whole is not facing employment shrinkage as a result of transition to green energy. Total employment from operation and maintenance of power plants, which captures the direct, indirect and induced employment generated from all sectors including the energy sector, is expected to provide 8.6 million more employment under policy scenario 2 at 2050 compared to the baseline scenario (Figure 6.1-2).

Figure 6.1-1 **Direct Employment in Energy Sector from Operation and Maintenance**

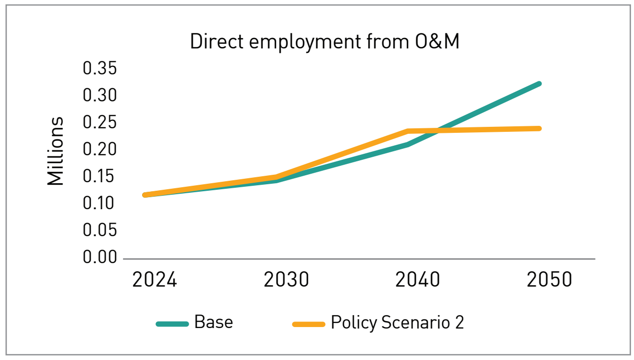
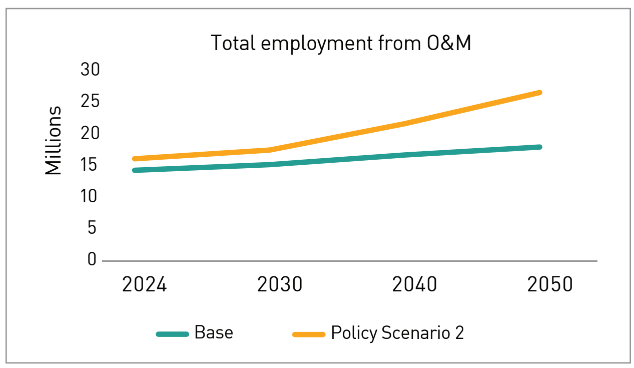
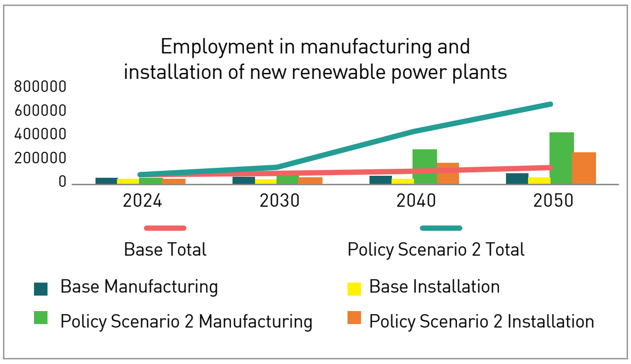


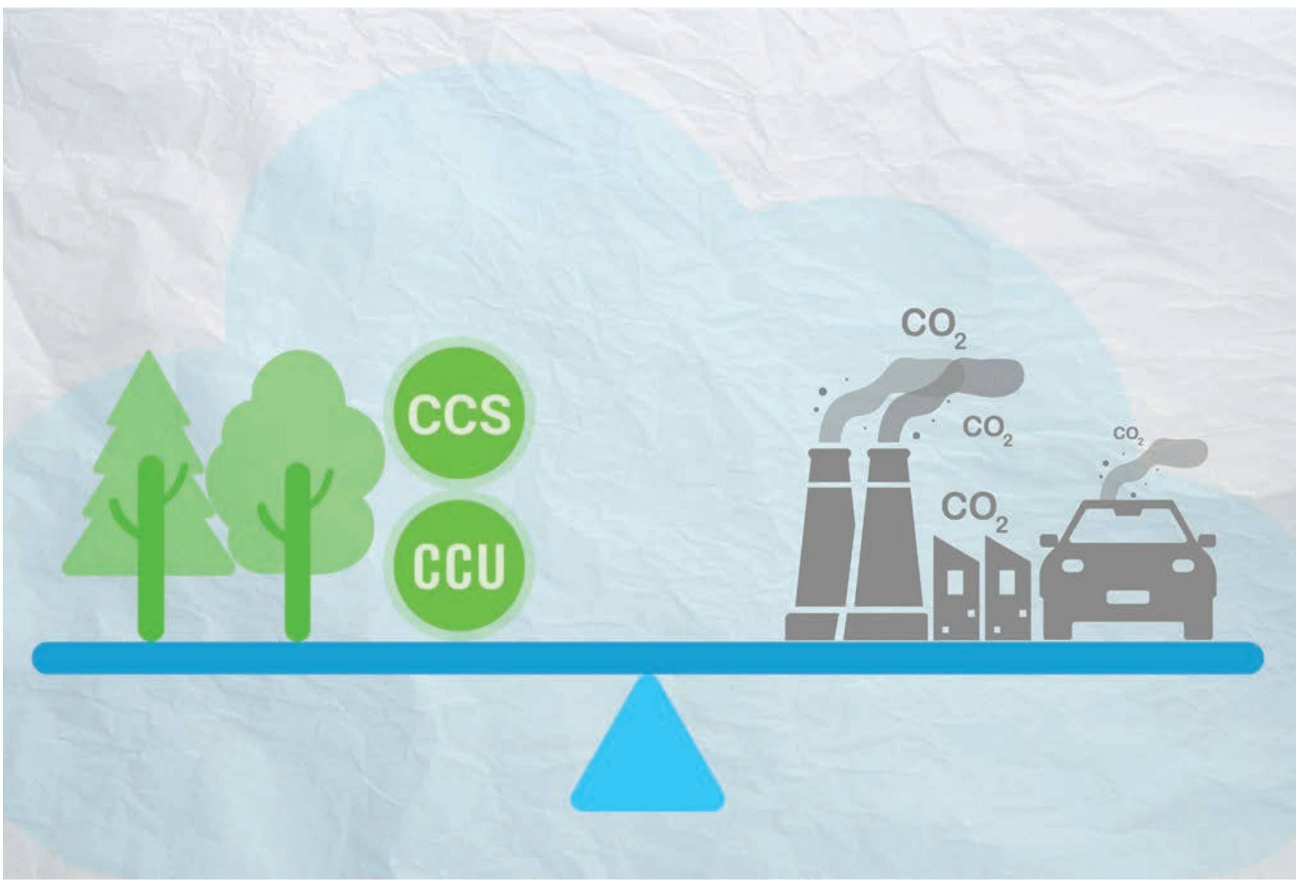
Figure 6.1-2 **Total (Direct, Indirect and Induced Together) Employment in Energy Sector from Operation and Maintenance**



Investment on renewable energy not only increases employment generated from operation and maintenance, but also from manufacturing and installation of new power plants. For this, the median values of direct employment factors for the main phases of deployment for wind and PV are utilised from Cameron and Zwaan (2015), and the estimates show that there would be significant addition in employment in Policy scenario 2 for both manufacturing and installation of power plants. This scenario is expected to generate additional 0.5 million employment in Odisha in 2050 compared to the baseline scenario (Figure 6.1-3).

Figure 6.1-3 **Employment in Manufacturing and Installation of New Renewable Power Plants**





7. Concluding Remarks

As India embarks on the journey of green transition to fulfill its nationally determined target of net zero by 2070, states gear up their climate action strategies. Geographically located at the head of the Bay of Bengal, Odisha has its coastal stretch vulnerable to floods and cyclones. The frequency and intensity of these extreme weather events have increased due to climate change. Since the coastal population of Odisha is dependent on agriculture, fishing, and forestry, they become vulnerable to such extreme events. Naturally endowed with rich mineral and coal deposits, Odisha has many energy-intensive industries like iron and steel, and that contribute to large emissions from the industry sector. Odisha has a higher per capita emission than the national average.

Odisha is one of the few states of India which is surplus in electricity production: More than 90 per cent of Odisha's electricity comes from coal. Of this, 82.4 per cent of the produced electricity is consumed within the State and the remaining 17.6 per cent is exported to other states. Clearly, selling electricity is a source of revenue for the State. To keep up the pace of growth and development for the states and to meet the aspirations of the people, the State requires to continue generating electricity. It will not be prudent to import electricity from other states to reduce emissions within the state boundary. Moreover, the State has large potential of renewable electricity and, thus, it makes sense to augment the capacity of renewable electricity. Also, green hydrogen is the future fuel of the many energy-intensive industries and the government of Odisha has already made a start in this direction by announcing policy incentives and a policy ecosystem.

This transition involves the adoption of some technologies with their underlying financial costs. Hence, it is crucial to understand the fiscal burden vis-à-vis the benefits of each policy intervention as an alternative low carbon pathway. Only by incorporating the behavioural aspects of economic agents and relevant energy technological innovations interplaying with the markets and prices in the economic system can a coherent energy transition pathway be developed. Accordingly, this report has undertaken the integrated modelling approach with the primary objective of quantifying the gains and losses of low carbon transition and their financial implications.

The integrated modelling approach involves soft linking of the macroeconomic top-down CGE model and bottom-up (MESSAGEix) energy model. The top-down macroeconomic CGE model used for integration is a multi-sectoral, multi-regional (Odisha, Rest of India and Rest of World) variant of the GTAP power model that has a detailed power sector.

The CGE model produces forecasts of sectoral output and prices for the business-as-usual and two policy scenarios. These CGE results are fed as exogenous input demand projections into the MESSAGEix model which is an energy optimisation model. These projected demands are met by supplies subjected to least cost optimisations along with policy constraints (such as environmental, resource, and capacity constraints. The model provides technology-based decisions in each of its sectors in terms of cutting down of emissions and the cost of implementing those pathways in a given period. The integrated model is a recursively dynamic model with multiple periods to simulate changes as per policy targets for the short, medium and long term for the low carbon pathway of the Government of India.

In this report, we have undertaken two policy scenarios. (i) 50 per cent of the existing potential of renewable electricity by various modes is achieved in Odisha and the rest of India by the terminal year of our model run (2050) by dampening the growth of fossil electricity through taxation, which is distributed to the renewable electricity as a revenue neutral subsidy. (ii) concomitantly, energy efficiency in all energy sectors is increased to the tune of 1.5 per cent per annum along with 1 per cent total productivity growth per annum in all sectors of Odisha and India's economy. Our assumption on the growth rates of the two parameters are very reasonable and India is achieving much more improvement on these parameters over the years.

The key message that comes out of our simulation is that energy transition towards renewable energy will not take place without complementarity support polices towards this sector. There is a need for the government to play a key role in effecting the change. Also, it is pragmatic to augment the capacity of renewable capacity as far as possible. Since Odisha has high coal deposits and the presence of other minerals, the dependence on fossil fuel will continue to be high in the energy/ fuel mix. The role of carbon capture and storage is a technology that Odisha need to invest in. The investment in green hydrogen makes sense for the State since energy-intensive industries will grow due to the location of mines in the State. Also, it is important to focus on improving energy efficiency in all sectors. This not only reduces emissions and also helps the economy by being more productive. All Indian state governments are taking proactive steps to increase energy efficiency in their states. Thus, Odisha needs to take the lead in this area, or else the State will lose its competitive edge.

Our observation is that energy transition may be a win-win situation in the sense that growth and employment creation may be positive with suitable policy intervention.

It must be mentioned that the study has focused only on the energy sector. The developed model may be used in future to focus on the economic implication of other polices, such as carbon sequestration.

Annex A1. Review of Odisha Climate and Energy Policies

A1. Introduction

Odisha, a coastal state of Eastern India, experiences a high number of natural disasters, like cyclones, drought, flash flood, coastal flooding etc. These climate change-led disasters affect the livelihood of the coastal population, which is significantly dependent on agriculture, forestry, fishery, etc. The incidence of high poverty and the significant presence of indigenous communities who are primarily dependent on natural resources make the State extremely vulnerable to climate change. Their limited capability to cope with the adverse effects of climate change increases the vulnerability of these households. The economic impact of climate change on agriculture in the coastal zone of the State is significant (Mishra & Sahu 2014; Mishra et al. 2016; Paltasingh & Goyari 2015). The effect of climate change on public health in terms of severity, frequency, and spread of vector-borne diseases also cannot be ignored (Karmakar & Pradhan 2020). Studies suggest that the factors like annual income, access to irrigation, access to credit facility and landholding size of the farming households play a crucial role in the household's capability of adapting (Sahu & Mishra 2013). In cyclone-prone areas, factors like demographic characteristics, distance from cyclone shelter, unemployment, adequate toilet facilities, frequency and impact of flood and cyclone, and lack of logistics support during cyclone etc. determine the vulnerability of the population in the region and the development of adequate coping mechanism is essential to reduce their vulnerability (Yadav & Barve 2017). The following sections discuss the economy, emission profile, and energy mix of the State and the climate policies adopted.

A2. State of the Economy

Odisha is situated in eastern India, with the geographical area of 1,55,707 square km. As per Census 2011, the population of Odisha was 4.2 crore, which is 3.47 per cent of India. Population density in Odisha was 270 per square km (Census 2011), which is lower than the national average (382); decadal growth rate of 2001-2011 in Odisha (14.05) is also much less than that of India (17.7); and the urbanisation rate is much lower in Odisha (16.7 %) compared to the national average (31.16 %) in 2011. As per the Multi-dimensional Poverty Index 2023, Odisha's poverty level was 15.96 per cent against the national average of 14.96 per cent and per capita net state domestic product at constant prices with 2011-12 base in Odisha is Rs 79,607 in 2021-22, which is lower than the national average (Rs 91,481).

Like other states, the Odisha economy was affected by Covid-19 and the economy experienced negative growth. The Odisha Economic Survey 2022-23 reported that gross state value added (GSVA) at constant prices in Odisha slumped to -4 per cent in 2020-21 but made a quick recovery, and the growth rate of GSVA at constant prices was reported to be 9.5

per cent in 2021-22 and 7 per cent in 2022-23. The share of the primary sector (agriculture and allied activities, and mining and quarrying) in GSVA at constant prices in Odisha is 27 per cent, for the secondary sector (manufacturing, electricity, gas and water supply, construction) it is 35 per cent and the tertiary sector (trade, repair, hotels and restaurants, transport, storage and communication, financial, real estate, ownership of dwelling, professional services, public administration, other services) was 38 per cent in 2022-23. The detailed sectoral composition and sector-wise growth rate for 2017-18 to 2022-23 is provided in Table A1-1.

Table A1-1 **Growth Rate of Gross State Value Added by Economic Activity at Constant Prices and Sectoral Composition (2017-18 to 2022-23) (%)**

Economic Activity	Growth Rate of Gross State Value Added by Economic Activity (at constant prices)						Share of Sectors in Gross State Value Added (at constant prices)					
	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
Crops	-20	9	19	9	-2	5	7	7	9	10	9	9
Livestock	8	11	5	0	10	2	2	2	2	2	2	2
Forestry and logging	-8	7	9	3	2	5	2	2	2	3	2	2
Fishing and aquaculture	17	9	9	4	15	13	2	2	2	2	2	2
Mining and quarrying	-9	10	-4	-12	22	7	12	12	11	10	11	11
Manufacturing	21	19	-12	6	9	5	24	26	23	25	25	25
Electricity, gas, water supply	-1	-8	3	6	8	7	4	3	3	3	3	3
Construction	8	4	0	-11	10	6	8	7	7	7	7	7
Trade & repair services	10	8	7	-21	11	15	10	10	10	8	9	9
Hotels & restaurants	8	10	7	-56	63	37	1	1	1	0	1	1
Railways	7	0	0	-13	4	11	1	1	1	1	1	1
Road transport	9	-14	-1	-29	7	7	4	3	3	2	2	2
Water transport	17	26	6	-6	1	10	0	0	0	0	0	0
Air transport	18	-39	64	-46	75	58	0	0	0	0	0	0
Services incidental to transport	34	-12	8	-13	7	8	0	0	0	0	0	0
Storage	2	12	3	-1	5	5	0	0	0	0	0	0
Communication	-5	-3	15	2	5	3	2	1	2	2	2	2
Financial services	8	5	9	5	8	8	4	3	4	4	4	4
Real estate, etc.*	6	2	1	-4	7	7	7	7	7	7	7	7
Public administration	6	7	16	-1	7	2	5	5	5	5	5	5

Source: Odisha Economic Survey 2020-21.

Notes:

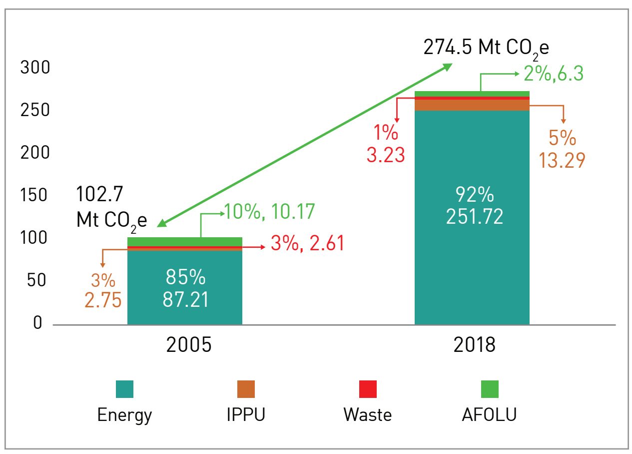
1. Estimates for the years correspond to 2017-18 and 2018-19 (Actual), 2019-20 (3rd RE), 2020-21 (2nd RE), 2021-22 (1st RE), 2022-23 (A).
2. *Refers to real estate, ownership of dwelling, & professional services.

As per the Odisha Economic Review for 2022-23, land use pattern shows that 37 per cent of the land comes under forest area. Net area sown is 35 per cent of the total geographical area. The major crops are paddy, sugarcane, pulses, maize, and groundnut. During 2021-22, the total irrigation potential created (IPC) was 46.3 lakh hectares for kharif crops, and 20.6 lakh hectares for rabi crops. Fishery is an important sector in Odisha and in 2021-22, 255,000 million tons of fish was exported from the State. The share of the industry sector in the Odisha economy is larger than that of India because of the large mining and quarrying sector in Odisha, which accounts for 11 per cent of GSVA in 2022-23. Odisha produces 100 per cent of the chromite, 73 per cent of the bauxite, 53 per cent of the iron ore, 24 per cent of the coal and 20 per cent of the manganese produced in India (Economic Review 2022-23). The manufacturing sector is also large; it has a share of 25 per cent of the GSVA in Odisha. Bal et al. (2015) point out that Odisha's registered manufacturing sector witnessed 17 per cent annual growth rate between 2002-13. Organised manufacturing output was largely driven by basic metal and alloys, followed by food products, chemical and chemical products, and non-metallic mineral products. The State exported products worth Rs 127,498 crore in 2021-22, which mainly consisted of metallurgical, engineering, chemical and allied, minerals, and marine products. Odisha has a number of power plants and during 2021-22, 3,827 MW of power was available for consumption from all sources that stood at 47 per cent of total contracted capacity. The services sector is not only important for the growth of the economy (38 per cent share in GSVA in 2022-23), but it also provided employment to 24.4 per cent of workers in Odisha in 2020-21 as estimated from PLFS data.

A3. Emission Profile and Energy Mix for Odisha

Though Odisha has the share of 3.47 per cent population in India, net GHG emission from Odisha was 9.3 per cent of the country in 2018 (GHG Platform India[6] 2022). Net emission from Odisha in 2018 is 274.54 Mt CO_2e. In per capita terms, net emission from Odisha (6.15 tCO_2e per capita) is higher than that of the national average (2.24 tCO_2e per capita). A report by GHG Platform India 2022 found that overall emission in Odisha has increased at a compound annual growth rate (CAGR) of 7.85 per cent, from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e in 2018; this was based on emissions from the energy sector (fuel combustion from public electricity generation, transport, captive power plants, industries, agriculture, commercial, and residential categories and fugitive emissions from fuel production), the Agriculture, Forestry and Other Land Use (AFOLU) sector; Industrial Processes and Product Use (IPPU) and Waste sectors.

Figure A1-1 **Sector-wise Contribution (Mt CO_2e) in Emission and Percentage Share (%) in Overall GHG Emissions (excluding AFOLU Sector) in Odisha in 2005 and 2018**



Source: GHG Platform India.

[6]The GHG Platform India is a civil society initiative that provides an independent estimation and analysis of India's Greenhouse Gas (GHG) emissions across key sectors, namely, energy, IPPU, AFOLU, and waste. The platform comprises the following from civil society: Council on Energy, Environment and Water (CEEW), International Maize and Wheat Improvement Center (CIMMYT), Center for Study of Science, Technology and Policy (CSTEP), ICLEI - Local Governments for Sustainability, and Vasudha Foundation.

Both in 2005 and in 2018, the energy sector was the major contributor of emission in Odisha (85 per cent in 2005 and 92 per cent in 2018) (Figure A1-1). Emissions from this sector increased almost three times from 87.21 MtCO_2e in 2005 to 251.72 MTCO_2e in 2018. Within the energy sector, the majority of emissions came from industries (52 per cent), captive power plants (22 per cent), public electricity generation (19 per cent) and transport (4 per cent) in 2018. Emissions from coal were the major contributor to emissions in Odisha. The Industrial processes and product use (IPPU) sector caused 5 per cent of the total economy-wide emissions in Odisha in 2018, and emission from this sector is mainly driven by the production of iron and steel, cement, and aluminum. The agriculture, forestry and other land use (AFOLU) sector has a share of 2 per cent in total emissions, but net emission from this sector declined from 10.17 Mt CO_2e in 2005 to 6.30 Mt CO_2e in 2018. Excluding the land sub-sector, the major contributor to emissions from IPPU are rice cultivation (45 per cent) and enteric fermentation (42 per cent). Emission from the waste sector was mainly driven by domestic wastewater (60 per cent), industrial wastewater (34 per cent) and solid waste disposal (6 per cent) in 2018 in Odisha. Within industrial wastewater, the pulp and paper industry had the maximum share in emissions (68 per cent) in 2018 in Odisha. Large mining and the industrial sector in Odisha have been major sources of emission.

However, Odisha, with rich mineral sources, generates revenue from coal and lignite, and oil and natural gas (Box A1-1). Moreover, 0.47 per cent of workers (Usually Working Persons [PS+SS] in 2020-21) were engaged in the mining and quarrying sector and 0.45 per cent of workers work in electricity, gas, water supply and other utility services. Shifting to renewable energy sources might affect the revenue sources and might hamper employment in these sectors.

Box A1-1

- State-level revenue from oil and natural gas is estimated to be Rs 5,687 croresin Odisha in 2020-21, which is 11.8 per cent of the State's own revenue. This revenue from oil and natural gas is generated from value-added tax (VAT), octroi, entry tax, duties including electricity duty (tax revenue), royalty, and dividend (non-tax revenue).

- State-level revenue from coal and lignite is estimated to be Rs 2,952 crore in Odisha in 2020-21, which is 6.1 per cent of the State's own revenue. This revenue from coal and lignite includes State GST, integrated GST, VAT, royalty, additional royalty including the District Mineral Fund (DMF), royalty for the National Mineral Exploration Trust (NMET), and dividend.

Source: Bhandari, L. and Dwivedi, A. (2022). Critical Challenges in Realising the Energy Transition: An Overview of Indian States. *CSEP Working Paper 41.*

A3.1 Trend of Supply and Demand Scenario of Power Sector

The State's share in installed capacity of all power projects (including share of power from central and other sources) was 8,107.1 MW in 2021-22 (12,328.19 MW in 2023) compared to 8,018.3 MW in 2020-21, registering an increase of 1.1 per cent. In the six years between 2015-16 and 2021-22, it increased by 45 per cent.

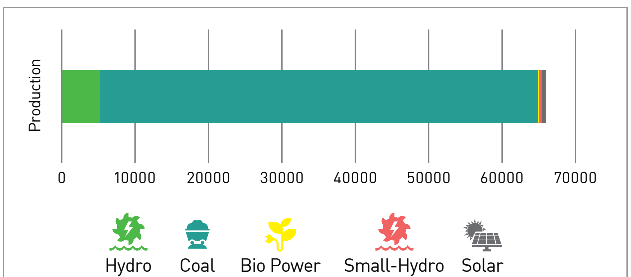
As of 2020-21, the installed capacity of renewable power by Grid Corporation of Odisha (GRIDCO) from various units was 1,159.10 MW, of which 100.15 MW is from small hydro-electric projects, 781.85 MW from solar projects, 20 MW from bio-mass power projects, and 275.10 MW from wind sources.

The estimated demand for power increased to 3,088 MW in 2021-22 from 2,934 MW in 2015-16, an increase of 5.3 per cent. The State remained power surplus during the years from 2018-19 to 2021-22.

A3.2 Odisha's Energy Mix

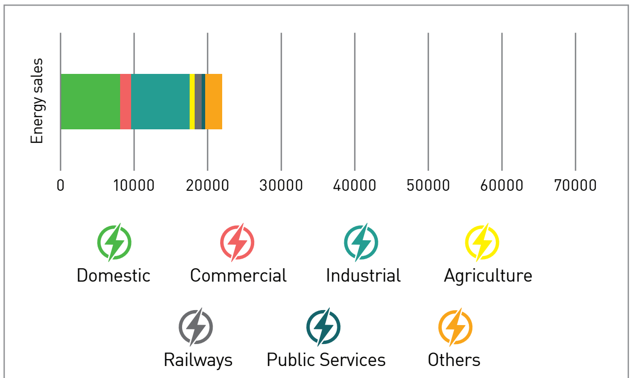
The high level of emissions in Odisha is caused by high dependence on coal (90 per cent) as a source of power generation in the State (in 2021-22)[7]. Other sources of power generation are hydro (8 per cent), small hydro (1 per cent), and solar (1 per cent) (Figure A1-2). According to Central Electricity Authority's (CEA) data, 31 per cent of the installed capacity is with the private sector in Odisha, 37 per cent with central sector and 32 per cent with the state sector. However, energy sales within Odisha in aggregate terms (21,949.76 MU in 2021-22), is much lower than that of generation (65,973.8 MU in 2021-22) because the State is a power-surplus state. The major consumers of power in Odisha are the domestic (37 per cent) and industrial (36 per cent) sectors (Figure A1-3).

Figure A1-2 **Power Generation from different Sources in Odisha in 2021-22 (MU)**



Source: https://vasudhapower.in/generation

Figure A1-3 **Power Sales across Sectors in Odisha in 2021-22 (MU)**



Source: https://vasudhapower.in/demand

The combined consumption by the domestic and industry sectors is more than 70 per cent of the total power consumption of the State. Domestic consumption has been rising steadily from 2010-11 due to massive investments in the rural electrification sector. Industrial power consumption grew by 30 per cent in 2021-22 over the previous year.

The irrigation and agriculture sectors have witnessed the fastest growth in energy consumption between 2016-17 and 2021-22 followed by the railways, public lighting, and public waterworks. Industry has witnessed the least growth rate in power consumption followed by the commercial sector and the domestic sector.

Abhishek and Goel (2021) mention that for renewable energy development, the major challenges are land acquisition and opportunity costs involved with renewable energy development. Odisha's RE rich sites are mainly in forest areas or on agricultural land, so it is quite difficult for the State to establish a large-scale solar power sector. Also, Odisha's installed capacity is more for captive power plants than for utility power plants; captive capacities are generally smaller and have higher specific emission levels than utility power plants. Transmission and distribution losses are also a major concern in the power sector in Odisha.

[7] Power Generation in India-Data, Analysis & Mapping (vasudhapower.in) accessed on 28th February 2023.

A4. Odisha's Plan for Energy Transition

At the outset, to promote energy conservation in industries, Perform, Achieve & Trade (PAT) is implemented. This includes 75 energy-intensive industries notified as Designated Consumers (DC) and utility-based DSM programmes carried out for all DISCOMs. Odisha Energy Conservation Building Code was notified to promote the construction of energy-efficient buildings.

According to the Odisha Renewable Energy Policy 2022, Odisha has recognised the huge potential for renewable energy in the State. It is offering exemption on duty and surcharges, along with other benefits. Renewable energy capacity of 10,000 megawatt, or 10 gigawatts, is targeted by 2030. The document was framed to accelerate the adoption of clean energy alternatives, decarbonise the energy sector, and harness the clean energy potential of the State. The policy is applicable for large hydro, small hydro, ground-mounted solar, rooftop solar, floating solar, canal-top solar, wind, biomass, energy storage, waste-to-energy, and green hydrogen/green ammonia projects or any other renewable energy technology and new initiatives/ pilot projects. The document discusses issues related to a general framework for identification and award of RE projects, exemptions and incentives, allotment of land, bidding criteria of projects, sale of power, mode of operation, concession period etc.

A total of 1,159.10 MW of renewable energy was installed by GRIDCO in various units as of 2020–2021; of this, 100.15 MW came from minor hydroelectric projects, 781.85 MW from solar projects, 20 MW from biomass power projects, and 275.10 MW from wind sources. During 2021-22, the contracted capacity of renewable power by GRIDCO from various RE projects was 1,433.7 MW.

The Odisha Renewable Energy Policy (OREP), 2022 aims at maximising the development of RE potential in the State and make Odisha a hub for the production of green hydrogen and green ammonia.

Odisha has planned to mitigate climate change in the energy sector through the following:

i) Meet 20 per cent of energy demand from RE other than hydro by 2026.
ii) Meet 50 per cent of its energy requirements from green sources other than hydro by 2030.
iii) Adopt 20 per cent of battery-operated vehicles by 2030.
iv) Green hydrogen and green ammonia: The State government recognises the importance of green hydrogen and ammonia in transitioning to renewable energy. Odisha is considering creating hubs for industries like petrochemicals, fertilisers, steel, and city gas distribution, and incentivising them to produce green hydrogen so as to gear up the renewable energy system of the State.

The following initiatives are envisaged under the Energy Transition Plan;

i) Implementation of ECBC and ECO-NIWAS SAMHITA in all ULBs
ii) Push for EV-charging infrastructure in major cities
iii) Municipal Energy Efficient Programme (MEEP)
iv) Energy Accounting in DISCOMS
v) Biomass co-firing in thermal power plants
vi) Promotion of energy-efficient appliances
vii) Feeder segregation under PM-KUSUM
viii) Energy efficiency activities in MSMEs.

The following are the major initiatives on various renewable sources:

A4.1 Solar (Rooftop and Land-based)

Odisha's renewable energy mix is dominated by solar energy. The government of Odisha is earnestly exploring different sources of clean energy to meet its increasing energy demand, diversify sources of energy, and address potential climate change issues. With about 280-300 days of sunshine a year and a global horizontal solar resource average of about 4.5-5.0 KW/h/m2/day, Odisha has good potential for solar power generation.

A4.2 Rooftop Solar Programme

The Odisha Renewable Energy Development Agency (OREDA) is the State nodal agency for the promotion of renewable energy and aims to enhance the proliferation of rooftop solar within the State for projects less than 1 MW. It has undertaken several measures and plans to assist consumers and utilities in Odisha with large-scale implementation of the rooftop solar programme. The government of Odisha will promote grid-connected rooftop solar PV projects to be set up on public buildings, domestic buildings, and commercial and industrial establishments. All government buildings with available roof space will be encouraged to set up rooftop solar facilities. Ministry of New and Renewable Energy (MNRE) has sanctioned 4 MW solar rooftop project on non-residential government. buildings in the twin city of Cuttack-Bhubaneswar through PPP mode. A total of 199 buildings have been identified (126 in Bhubaneswar and 73 in Cuttack) for rooftop installations.

A4.3 Off-grid Solar Rooftop Power Plant

Off-grid solar power plants are installed where grid power has not reached or is not reliable. It is primarily focused on providing energy access solutions in rural and remote areas. Such plants are mainly aimed at providing electricity to schools, hostels, police stations, hospitals, panchayats, and other public service institutions. So far, a cumulative capacity of 7.71 MW off-grid rooftop solar plants has been installed typically with individual capacities ranging from 0.5 KW to 30 KW (OREDA).

A4.4 Land-based Solar Parks

The Odisha Renewable Policy 2022 aims to promote solar parks that have a minimum capacity of 25 MW to reduce the cost of generation. A solar park is a dedicated area earmarked for the development of solar power projects.

Odisha has shown interest in the development of solar parks under the MNRE scheme. MNRE has allocated an 1,000 MW solar park to Odisha for development under its solar park scheme. Approximately 4,000 acres of land have been identified at Balasore, Bhogari, and Bhhanga and land identification across the other districts is also under progress.

A4.5 Land-based Non-park Solar Projects (>1 MW)

The minimum capacity for projects under this category would be 1 MW. The State will promote the setting up of these projects for the below purposes:

- Sale of power to GRIDCO at a tariff discovered through a competitive bidding process.
- Captive use within and outside the State.
- Sale of power within and outside the State through open access.

A4.6 Floating Solar

Floating solar reduces approximately 2 per cent in evaporation resulting in more water availability for irrigation and hydropower generation. Odisha has vast stretches of water bodies and multiple reservoirs that can be used to set up large-scale floating solar projects/parks in the State. The government of Odisha through its RE Policy aims to facilitate the development of floating solar projects. In the first phase, the State has prepared a pre-feasibility report (PFR) for more than 5,000 MW floating solar potential.

NHPC Limited has invited bids for the engineering, procurement & construction (EPC) of a 300 MW floating solar power project and a 220 KV transmission line at Rengali Reservoir in Angul, Odisha.

A4.7 Solar Pump Drinking Water

This system energises existing tubewells in remote/ un-served areas and ensures piped drinking water supply. An1 horsepower (HP) solar pump is installed, the water is lifted and stored in an overhead tank of 5,000 litres and supplied through stand posts in suitable locations. These systems have been installed in the State through various central and state schemes. In this year, these systems will be installed under the Jal Jeevan Mission (JJM) scheme. So far 13,219 solar drinking water pumps have been installed in the State and many projects are at the installation stage.

A4.8 Solar Pump for Irrigation

The programme is largely implemented in remote unelectrified areas where energising bore-wells through grid power is not possible or uneconomical. The solar pump installed on the farmer's field is a standalone type with a capacity of 3 or 5 HP. From this financial year 2020-21, standalone solar pumps should be implemented through a central government scheme, Kisan Urja Suraksha Evam Utthaan Mahaabhiyan (KUSUM). During this year, the target is to install 5,000 solar pumps of capacity 1 HP to 7.5 HP.

A4.9 Solar Lanterns

The programme envisages proper illumination and extended working hours for rural artisans through the provision of solar lanterns. The programme has been sponsored by the Directorates of Textile & Handlooms and Cottage Industries and Handicrafts since 2013-14. So far, 83,400 solar lanterns have been distributed to rural weavers and artisans.

A4.10 Solar Street Lighting System

To provide street illumination in remote areas where grid electricity is not feasible or economical, standalone solar street lighting systems are being provided. These street lights have a capacity of 7W to 15W (luminary) and are also in 4x24W (minimast light) applications. So far, more than 18,000 standalone solar street lights have been installed in the State.

A4.11 Solar Water Heater

This system can provide hot water using solar energy. This can reduce a large amount of grid electricity consumption. So far, more than 26,000 litres per day (LPD) of solar water heaters have been installed in the State.

A4.12 Other Policy measures

- *Support for the Promotion of Distributed Solar Generation*

Distributed solar generation facilities can meet energy needs in remote areas in a sustainable manner. Feeder solarisation can be done using guidelines or schemes. Feeder-level solar power plants can be installed for agriculture feeders and connected to distribution substations. Technologically advanced solutions like agri PV can maximise land utilisation and generate local, decentralised solar energy. Solar energy use for livelihood activities should be encouraged.

Solar-based EV Charging Stations

- The government of Odisha envisions further reducing the carbon footprint of electric vehicles (EVs) by providing access to cheap and clean solar electricity for EV charging.
- The nodal agency in consultation with OERC, OREDA, and DISCOMs will propose appropriate mechanisms to avail of solar power for EV charging under non-park solar and rooftop solar mechanisms.
- Solar installations for EV charging on government land shall be eligible for 50 per cent concession on land lease payment for the first 50 MW of installation under the non-park solar category during the policy period.

Konark Solarisation

- The Ministry of New & Renewable Energy, Government of India announced the implementation of the scheme for 100 per cent solarisation of the Konark Sun Temple and Konark town, Odisha on 19 May 2020.

- The scheme aims to 100 per cent solarise the Konark Sun Temple and the town through grid-connected and off-grid projects, fulfilling households' electricity needs with solar energy. Implementing 10 MW projects and various off-grid applications such as solar trees, E-rickshaws, charging stations for E-rickshaws, and solar drinking water kiosks.
- Konark is being developed as a solar city as well as a net zero city. Under this solar city initiative, apart from complete illumination of Konark Sun Temple, the town has been provided with solar streetlights, solar drinking water, kiosks, rooftop solar power plants, solar power EV charging stations etc. Under the net zero initiative, a 10 MW solar power plant is being installed to offset the grid power being supplied to the town.

A5. Climate Policies in Odisha

The government of Odisha has taken several steps to promote adaptation and mitigation strategies to cope with the adverse effects of climate change. Odisha was one of the states that initiated developing a climate action plan in India in 2010. By 2022, two documents on Odisha Climate Change Action Plan (CCAP) for the years 2010-2015 and 2018-23 have been published. They identified 11 sectoral missions such as agriculture, coast and disaster, energy, fisheries and animal resources, forests, health, industries, mining, transport, urban and water resources. Besides, action has been taken in various areas to mitigate emission.

Apart from these, the Odisha Climate Budget 2022-23 has identified state climate policy goals (as outlined in CCAP document) that support the target of national commitment to COP-26. It shows that for each of the targets set at the national level, several steps were taken across different sectors. A Phased Climate Change Impact Appraisal (CCIA) analysis was conducted to assess the two main dimensions of programme-level linkage to climate change: (1) Climate Change Relevance Share (CCRS)- How benefits from development programmes additionally contribute to improving resilience to climate change; and (2) Climate Change Sensitivity Share (CCSS)- How programme benefits are likely to be impacted by climate change itself in the absence of climate change-specific planning interventions. The results show that sectors like water resources, energy, agriculture, and panchayati raj are of both high climate sensitivity and climate relevance, i.e., they retain benefits with positive climate sensitivity and climate-proof benefits with negative sensitivity. Sectors like forestry, urban development, coasts and disaster management are of low climate sensitivity and high climate relevance, which means climate change benefits accrue with relatively less impact (or loss) from climate risks (low hanging fruits). Sectors like fisheries & animal resource development are associated with high climate sensitivity and low climate relevance, i.e., design changes are required to enhance climate resilience and also more climate proofing effort to insure against welfare losses from climate hazards in the case of negative sensitivity and in the case of positive sensitivity, enhancing climate resilience would reap dual benefits. Sectors like rural development, health, and transport are of both low climate sensitivity and low climate relevance. For these sectors, regular monitoring and review are required to explore the future scope for mainstreaming climate concerns and allocations in these sectors need to be evaluated.

Below, we discuss various sector-specific priorities and initiatives in relation to climate change in Odisha, as outlined in the Climate Action Plan document[8].

A5.1 Agriculture

Agriculture, which has a significant share in Odisha's GDP and employment, is extremely vulnerable to climate change. The agriculture sector in Odisha is primarily rain-fed; change in intensity and frequency of rainfall due to climate change can potentially hamper agricultural production and factors like pest attack and disease outbreaks are also influenced by climate variability.

[8]The list is not exhaustive.

Box A1-2

- Odisha is one of the largest producers of rice in India. The other crops cultivated are pulses, oil seeds, cotton, jute, and sugarcane. Cuttack, Dhenkanal, Baleshwar and Sambalpur are the major agricultural hubs of the State.
- Agriculture, livestock, forestry and fishing has 18.50 per cen share in the workforce in Odisha in 2020-21 (46.5% for All-India). There were 41,03,989 cultivators (main and marginal) and 67,39,993 agricultural labour (main and marginal) in Odisha in 2021.
- The share of agriculture and allied activities in gross value added was 15 per cent in Odisha in 2022-23 (advance estimates).
- From 2016-17 to 2020-21, the utilisation of irrigation in terms of area increased from 34.09 lakh hectares to 42.51 lakh hectares. During 2021-22, 150,048.6 quintals of seeds have been supplied by the Odisha State Seeds Corporation (OSSC) to 1,947 PACS and Large Area Multi-Purpose Societies (LAMPCS) for distribution to farmers.
- Yields of important crops in Odisha in the year of 2020-21 are:
    - Rice: 2,173 kg/hectare (All-India: 2,713 kg/hectare)
    - Wheat: 1,604 kg/hectare (All-India: 3,464 kg/hectare)
    - Pulses: 535 kg/hectare (All-India: 892 kg/hectare)
    - Oilseeds: 801 kg/hectare (All-India: 1,254 kg/hectare)

  Per cent of consumption of electricity for agricultural purposes: 2.80 per cent in 2019-20 in Odisha (All-India: 20.08%)
- Cropping intensity in Odisha is 113.0 in 2018-19 while the same for all-India is 141.6.
- 29 per cent of area under principal crops in Odisha was irrigated during 2018-19.
- According to land use pattern in Odisha, 37 per cent of total area is covered by forest.

Along with the National Mission on Sustainable Agriculture, Odisha has outlined some targets to improve adaptation and mitigation responses to climate change for the sector. In agriculture, the areas of emphasis at the state-level are rapid screening and strategy assessment of the State Agriculture Policy, promotion of best practices on climate change, capacity building, livelihood-focused, people-centric integrated watershed development in rain-fed areas, perennial fruit plantation, water use-efficient micro irrigation methods and individual /community farm ponds, monitoring and surveillance, sustainable soil, water and crop management, studying crop tolerance /resistance, climate-linked research studies. Policies are designed to discourage the indiscriminate conversion of agricultural land, to promote cropping mix and revision of the crop calendar in disaster-prone areas, to provide training on climate-resilient indigenous farming practices, screening of germplasm for multiple stress resistance/tolerance, etc. The activities for the sector in Odisha by priority level are listed below.

High priority

- Continued investment in integrated watershed development programmes in climate-sensitive areas and ensuring replication across Odisha (livelihood-based).
- Rapid screening and strategy assessment & seed improvement.
- Capacity building of extension personnel & farmers.
- Improved monitoring/ surveillance; then devise new farming techniques.
- Continued liaison work with National Mission on Sustainable Agriculture.
- Use of training hubs to disseminate information on climate change.
- Establish institutional delivery mechanisms to promote best practices on climate change adaptation in rain-fed farming conditions.
- Capacity building and technical support for better management of land and water to adapt to climatic risks.

- Development of micro-irrigation and individual/community farm ponds.
- Emphasis on shade net house/poly house & mulching.
- Increased area under perennial fruit plantation.
- Impact analysis of climate change on major crops in Odisha.
- Breeding studies on major crops for tolerance/resistance to high temperature, submergence and drought under elevated carbon dioxide.
- Development of sustainable soil, water and crop management practices.
- Preparedness to tackle emerging scenarios of pests.
- Increased production of rice seeds to meet requirement under various weather scenarios.
- Climate risk management services.

Medium priority

- Create awareness among farmers.
- Revisit agronomic practices of major crops.
- Conduct a study to determine implications of climate changes on small and marginal farmers of rain-fed areas.
- Establish a climate change resource centre network.
- Promote low carbon technologies in climate-sensitive watershed areas.
- Popularise environment-friendly crop resources.
- Increased crop diversification.
- Promote organic agriculture.
- Popularise agro-forestry models.
- Screen and value add to resilient species from local agrobiodiversity.
- Screen available crop production technologies that are suitable as potential adaptation and mitigation measures through modelling.
- Examine the performance of situation-specific contingent measures in crop production.
- Identify suitable rice varieties for vulnerable coastal areas.
- Standardise crop and soil management practices for vulnerable.

Low priority

- Train farmers in water efficiency.

A5.2 Fisheries and Animal Resources

Fisheries and animal husbandry provide livelihood to a significant section of the population in Odisha. Being dependent on water, fisheries are affected by climate change-induced hazards. Livestock living on concentrated feeds create significant amounts of methane emission. In the fisheries and animal resources sector, areas of emphasis were vaccination, deworming and early disease warning system, green fodder, pasture development and grazing, training on fodder production, fodder conservation, rotational grazing, rain water harvest technology, methane gas harvesting technology, biogas tanks management, conservation of local hardy animals, gobar gas tanks/packing to cylinders, easy and handy methane harvest at farmers' point, enhancing disease early warning systems with climate change considerations, use of biotechnology and skilled animal breeding for development of better adapted species, capacity building of livestock keepers, research on disease early warning system relevant to livestock, impact of climate change on inland and coastal aquaculture, development of infrastructure for early warning systems in coastal areas for fishermen, etc. The activities for the sector in Odisha according to priority level are listed below.

High priority

- Scientific animal health management.
- Capacity building of livestock keepers.
- Better waste management.

- Research on easy methane harvest technology.
- Research on disease early warning system.
- Loss of livelihood due to ban and climate change related implications on fishery livelihood.
- Impact of extreme climate events due to climate change.
- Protection of fisheries' infrastructure and assets.
- Fishing methods and gears.
- Health and sanitation in coastal areas.
- Fishermen's welfare activities.

Medium priority

- Improved feeding management.
- Breeding management.
- Study on climate change and catch of marine fish.

A5.3 Forest Management

The forestry sector is important both from the adaptation and mitigation perspectives relating to climate change. Protection of forestry along with afforestation and reforestation measures not only helps build carbon stocks and sinks, but also acts as a measure for water and soil conservation. The key steps that are prioritised in the CCAP document are mainly reforestation and afforestation activities in degraded forest areas, protection of present forest stocks, planting on non-forest land to protect coastal zones from storm and cyclone impacts, suitable species mix, nurturing existing mangrove cover along the coast, assessing fire management strategies, integration with watersheds and water resource management, supporting community users, studying the impact of climate change on indigenous tree species, assessing threats to biodiversity and wildlife, knowledge on climate change science and policy developments, capacity building of panchayati raj institutions/ communities/ JFM institutions etc.

For afforestation, the State has implanted several programmes including afforestation in 11,225.30 ha area under Artificial Regeneration (AR) plantation, and 99,143 ha under Assisted Natural Regeneration (ANR), and 4,616.60 Row Kilo Metres (RKM) under avenue plantation. To conserve the perennial flow of the Mahanadi River, the Green Mahanadi Mission was launched in 2018-19 to increase water availability and to improve livelihoods. Under this programme, 75 lakh seedlings (18 months old) were raised for planting and distribution for the 2023 planting season. The Medicinal Plants Knowledge Centre at Bhubaneswar was established to enhance knowledge about medicinal plant species and 314 species of medicinal plants were planted in 314 plots. The Elephant Corridor Scheme was launched to prevent elephant deaths due to electrocution.

The Compensatory Afforestation Fund Management & Planning Authority (CAMPA) was formed for conservation, protection, regeneration, and management of existing natural forests, wildlife and their habitats, and raising site-specific compensatory afforestation. The State is encouraging eco-tourism to provide an alternate source of livelihood for forest-dependent communities. During 2021-2022, 47 eco-tourism destinations across 18 districts have been developed with 366 rooms accommodating 769 eco-tourists during night stays.

To protect the habitat of wildlife in protected areas, the government took initiatives like relocation of villages from critical protected areas. During December 2021, 42 families of village Lambipali were relocated outside Debrigarh Sanctuary. Funds have been provided to relocate Asanbahal village of Satkosia (WL) Sanctuary, Baliamba village of Khalasuni (WL) Sanctuary, and Jamunagarh village of Similipal Tiger Reserve.

Other forest-related activities included the establishment of 16 bamboo nurseries and the development of bamboo plantations in 496.19 ha of farmers' land through 649 farmers under the Odisha Bamboo Development Agency (OBDA). The Odisha Forest Development Corporation Limited (OFDC) promotes the trade of timber/firewood, processed and phal kendu leaves, cashew nuts and rubber; the collection and trade of sal seed directly or through raw material procurers (RMP); oversees regulation of firewood (long bamboo) and other small timbers distribution to local people, monitors bamboo operations directly or through RMP, and the processing and trade of honey and a few non-timber forest items to provide livelihoods to forest-dependent communities.

The activities for the sector in Odisha according to the priority level are listed below.

High priority

- Increase reforestation and afforestation activities in degraded forest areas.
- Protect existing forest stocks to act as carbon sink with stronger conservation.
- Cover bald hills with suitable species mix.
- Increase and protect existing mangrove cover along the coast.
- Assess additional threats to biodiversity and wildlife. This includes forest consolidation, linking forest fragmentations, habitat development, and mitigation of human-wild animal conflicts.
- Access updated knowledge on climate change science and policy developments and make this available for frontline staff and forest managers and policymakers. Bring in trainers to develop modules for forest training institutes.
- Monitor carbon stock and biodiversity at regular intervals.

Medium priority

- Increase planting on non-forest land and promote agro-forestry and farm forestry.
- Assess fire management strategies.
- Improve tree planting and forest management to work further in watersheds and with integrated water resources management to increase water storage, reduce surface flow and soil erosion; to assess where tree planting could provide protection in flood-prone areas.
- Work to establish new systems to support community users. Aim to create new marketing structures for users of traditional forest products to improve incomes and livelihoods to reduce pressures on forest destruction.
- Undertake studies on indigenous tree species to assess their vulnerability to climate change. Develop heat-resistant genotypes in trees.
- Build capacity of panchayati raj institutions/ communities/JFM institutions to adapt to climate change.

Low priority

Decrease people's dependence on firewood and timber and increase the use of improved stoves (chullahs) and wood substitutes.

A5.4 Biodiversity Management

Chilika Development Authority initiated de-siltation of the lead channel through dredging to protect the ecosystem there. The Centre for Environmental Studies (CES) under the Department of Forest, Environment & Climate Change, Government of Odisha undertakes activities to promote environmental education, awareness, training and research, and disseminate the environmental knowledge through different media platforms like newsletters, books, booklets, posters, leaflets, video clips, mobile apps. The Odisha Biodiversity Board was established to implement legal provisions of the Biological Diversity Act 2002 and Rules 2004. The Regional Plant Resource Centre promotes several innovative research and development activities for bio-prospecting indigenous macro and micro flora for wider usage.

Under Satoyama Initiatives, which is a landscape-based, bio-diversity conservation and management system that facilitates sustainable livelihoods, 10 Eco Development Committees (EDC) were set up in Badrama Wildlife Sanctuaries of the Bamra Wildlife Division and was piloted in 10 villages covering 500 households. Interventions under this program include:

- Micro-plan formulation for each EDC
- Avenue plantation across villages
- Revival of traditional paddy variety (bhajana) in the pilot programme
- Training on bio-fertiliser and bio-insecticide preparation and use
- Establishment of nutri garden through the convergence of 32 households
- Supply of smokeless chullah to all households
- Development of anganwadi centre to make it operational
- Solar fencing for elephant depredation to reduce man-animal conflict
- Fire line construction and community-driven protection of forest from fire
- Construction of pucca road of 1 km through the Rural Development Department, Government of Odisha
- Revival of traditional equipment like belana (thrashing equipment) and dhinki
- Declaration of plastic-free, eco-friendly and open-defecation-free villages.

A5.5 Wildlife Conservation and Protection

Odisha has 19 wildlife sanctuaries, 1 national park, 1 proposed national park, 3 elephant reserves, 2 tiger reserves, 1 proposed tiger reserve, and 14 identified elephant corridors for wildlife conservation. Apart from these, there are 11 zoos and 15 eco-sensitive zones. In addition, 539 eco-development committees (EDCs) have been established, covering 43,455.32 ha of the protected area.

To reduce human-animal conflicts in Odisha, the initiatives include engaging 586 anti-depredation/anti-poaching elephant squads and 115 trackers to prevent depredation by wild animals; trench fencing up to 40 kms; solar fencing along 14.8 kms in depredation-prone localities; awareness creation with the help of VSS/EDC members, NGOs, and school students; engaging 2,785 gaja saathis in 557 villages; compensation of Rs 2,099.66 lakh to animal attack victims in 2021-22; and setting up a 24x7 toll-free number to address human-animal conflicts.

Initiatives regarding habitat development of wild animals include the creation of 86 new water bodies, 5 water harvesting structures (WHS) and renovation of 47 water bodies, plantation of 9,000 fruit-bearing plants, fodder plantation in 10 ha of land around water bodies, wildlife corridor rejuvenation in 25 ha, and mangrove plantation on 150 ha in the coastal districts of Puri and Kendrapada.

A5.6 Water Conservation, Air and Water Pollution, and Health Management

Emphasis is being given for the conservation of water resources, under which more than 15,000 check dams have been built across various nallahs in the State. During 2020, Rs 11,760 crore was approved for construction of in-stream storage structures (ISS) in different rivers. Thirty ISS projects have already been taken up and 16 more are proposed in different rivers.

The CHHATA (Community Harnessing & Harvesting Rainwater Artificially from Terrace to Aquifer) scheme for ground water recharge in water-stressed areas covering 52 blocks and 27 urban local bodies (ULBs) has been launched. ARUA (Artificial Recharge to Underground Aquifer) has also been launched to improve the ground water table through the construction of recharge shafts.

The State Pollution Control Board (SPCB), Odisha works on monitoring emissions from industries and mines; surveillance for ambient air quality check; collection, storage, treatment, and disposal of hazardous and biomedical wastes, monitoring ground water quality, etc.

Health is a major area of emphasis because climate change is likely to change the disease pattern of vector-borne diseases like malaria and dengue and can also trigger water-borne diseases, apart from pollution and health hazards after extreme events. So, the CCAP emphasises capacity building of the health sector, consideration of climate change in the State health policy, managing vector-borne and water-borne diseases, dealing with heat wave conditions, handling physical and psychological impacts due to extreme weather conditions, managing drought, nutrition & food security, malnutrition & food security, research on climate change, air quality and health impacts, food safety, research and studies on climate change and health impacts etc. The activities for the sector in Odisha according to the priority level are listed below.

High priority

- Build capacity of the health sector on climate change on both adaptation and mitigation aspects.
- Integrate climate change considerations in the State health policy.
- Strengthen approaches to manage vector-borne diseases that have worsened due to climate change impacts.
- Undertake measures to manage water-borne diseases that have worsened due to climate change impacts.
- Strengthen approaches to deal with heat wave conditions exacerbated due to climate change.

Medium priority

- Strengthen approaches to deal with physical and psychological impacts due to extreme weather conditions caused by climate change.
- Address drought, nutrition & food security due to increased risk of drought, consequent decline in agriculture, and increased malnutrition & food security.
- Address food safety that is undermined as a result of increased ambient temperatures and extreme events.
- Study the interlinkages between air quality and climate change, and their implications on health.

A5.7 Mining

Odisha is rich in mineral reserves: chromite (96 per cent of India's total reserve), nickel (92 per cent), bauxite (51 per cent), iron ore (33 per cent), manganese ore (43 per cent), and coal (24 per cent). Mining is a major sector in Odisha and it has a significant contribution (8.29 per cent of GSVA in 2021-22 AE) (Odisha Economic Survey 2021-22) in the State's GDP. It provides livelihood to a significant section of the population in some districts in Odisha. But because of the harmful effect of mining on the surrounding surface, air and groundwater, it is environmentally regulated. Major steps for sustainable mining involve: addressing climate issues in the state mineral policy, encouraging efficient energy use in the sector, realising the potential of beneficiation of low-grade minerals, strengthening environmental monitoring by assessing the contribution of both local and global pollutants and suggesting policies to address the issue, installing protection measures for water bodies in mining-intensive areas, increasing carbon sinks by expanding and maintaining green zones, training stakeholders on the clean development mechanism, cleaner production/low carbon/ efficient technologies and climate abatement measures, exploring energy-savings potential in mining, etc. activities for the sector in Odisha according to the priority level are listed below.

High priority

- Draft state mineral policy incorporating climate concerns.

- Conduct a study to determine appropriate policy instruments to promote energy efficiency in mining clusters and mineral transport.
- Conduct a study to identify the potential of beneficiation of low-grade iron ore, manganese, graphite, and chrome ore.
- Conduct a study to explore best practices in metal mining.
- Establish a robust system of environmental monitoring in major mining clusters.
- Protect water harvesting structures, reservoirs, etc. from pollution and restoration of water bodies in mining-intensive areas
- Create and maintain green zones in major mining clusters.
- Strengthen the Directorate of Mines on human resources, technology, and the development of databases.
- Train officials on various aspects of climate change.
- Generate awareness, create capacity, and train mining personnel/lease holders on the benefits of cleaner production.
- Identify areas in the mining process where energy savings and emission reduction can be achieved.
- Protect and restore water harvesting structures in catchments in mining-intensive areas.
- Create a plan for supply of drinking water in the vicinity of mining clusters.

Medium priority

- Prepare regional sustainable mining plans for Joda-Barbil (iron and manganese area), Mayurbhanj iron ore zone, Talcher-Angul Area, Ib-valley area, Sukinda chromite belt, Sundergarh limestone and dolomite belt, eastern ghats bauxite zone.
- Provide incentives for R&D projects in environment-friendly technology development for small mining sector (graphite, granite and other minor minerals).
- Devise a mechanism for green belt development and maintenance in mining clusters.
- Explore cleaner technology and best practices in coal mining.
- Conduct a study to identify cleaner technology for using coal (like coal washing, coal to liquid, etc.) in industrial processes.
- Conduct a study to determine the potential of coal bed methane in the coal fields of Odisha
- Exploring techno-economic viability of capturing coal bed methane for use in industrial sector.
- Carry out a research programme for controlling coalfield fire and subsidence due to underground coal mining.
- Conduct a study to explore the feasibility of nickel extraction from nickeliferous overburden of Sukinda.
- Prepare an action plan to mitigate hexavalent chromium pollution in the streams and ground water of Sukinda valley area.
- Conduct an R&D project for recovery of metallic ore and strategic minerals from tailings.
- Prepare an energy-efficient mineral evacuation plan separately for Joda-Barbil, Sukinda, and Koira areas.
- Institute a system of energy audit in metal mining sector.
- Prepare regional environmental management plans for major mining clusters like Talcher-Angul, Ib valley, Joda- Barbil, Koira, and Sukinda.
- Devise a sensitisation programme for adoption of clean development mechanism (CDM) in the mining sector through seminars and other awareness programmes.
- Identify a host training institute to assess the training needs of related agencies and prepare training modules.
- Establish a training and research institute on climate change.

- Strengthen the Centre for Environmental Studies to build capacity to carry out R&D projects in climate change mitigation and adaptation.
- Impart training on energy efficiency in haulage, transport, pumping system, motors, process heating, compressed air system etc.
- Develop a methodology to measure, monitor, and verify the amount of carbon sequestered by plantation programmes in the mining sector.
- Develop emission intensity targets for different mining sectors.
- Carry out regional hydro-geological survey for major mining clusters of Joda-Barbil, Koira, Talcher-Angul, Ib valley, Sukinda valley area, Sundergarh limestone and dolomite belt, and eastern ghats bauxite zone.
- Devise a mechanism to implement a system of compensatory water harvesting and storage around mining clusters by the concerned mines.
- Create an environmental restoration fund by contribution from mining houses.
- Construct rest shelters with plantations in mining areas to provide shelter during heat wave conditions.

Low priority

- Prepare a coal evacuation plan separately for Talcher coalfield and Ib-valley coalfield.
- Prepare an action plan for reclamation and rehabilitation of old abandoned mines.

A5.8 Industry

One of the major objectives of the Industrial Policy Resolution 2022 for Odisha is to encourage environment-friendly industrial practices and ensure industrial development. For optimal use of resources and to prevent environmental degradation, the government is committed to ensure compliance with environmental standards and to support the development of sustainable industrial infrastructure.

As industry is an integral part of the development system, reduction in emission without compromising industrial growth and development of climate-resilient industrial system are the major goals in the (CCAP). Key priority areas in the industry sector are aligning policies and plans with climate concerns, assessment of GHG profiles of major industrial clusters, conducting a heat island study for Talcher and Jharsuguda areas, raising awareness and training of stakeholders, compensatory water harvesting, restructuring institutional arrangement and strengthening OSDMA (Odisha State Disaster Management Authority), promoting research on energy efficiency, recovery, recycling and reuse of waste material, emission standards for thermal power plants etc. The activities for the sector in Odisha according to the priority level are listed below.

High priority

- Integrate climate concerns in Intellectual Property Right (IPR).
- Formulate industrial cluster policy for minimum carbon footprint.
- Carry out a study to determine appropriate policy instruments to promote energy and material efficiency in industrial clusters.
- Incorporate climate change concerns in the draft SEZ policy.
- Integrate climate concerns in steel and mining policy.
- Prepare GHG profile of major industrial clusters and introduce a system of GHG auditing for major industrial sectors.
- Conduct heat island study for Angul-Talcher and Jharsuguda-Ib valley areas.
- Identify a host training institute to assess the training needs of related agencies and prepare training modules.
- Train officials of industries department, Directorate of Industries, etc. on various aspects of climate change.
- Impart training to MSME sector on climate change risk and mitigation.

- Streamline institutional arrangement for disaster management in coastal industrial belts like Paradeep, Dhamra, and Gopalpur.
- Strengthen OSDMA with training and equipment for technical disaster management.
- Carry out an energy efficiency study for integrated steel plant and sponge iron plants and explore the scope of waste heat utilisation.
- Institute a comprehensive study on processing and utilisation of discharge from sponge iron plants.
- Discourage accumulation of fly ash in thermal power plants and institute a cess on accumulated fly ash.
- Set emission targets for thermal power plants.

Medium priority

- Provide incentives for R&D in climate-resilient technology development.
- Devise a mechanism for green belt development and maintenance for industrial clusters.
- Prepare a SEA framework to be used as templates for policy making in cross-sectoral issues like energy policy, water plan, tourism policy, and agro processing policy.
- Set emission targets for thermal power, iron & steel, aluminium, and cement sectors.
- Establish a monitoring network for GHG emission in major industrial clusters.
- Provide a subsidy on consultancy charges to MSME for adopting CDM.
- Establish a network with research.
- Introduce a programme for mandatory water and wastewater audit in water-intensive industries like thermal power, iron & steel, sponge iron, and educational institutes like IITs, IMMT etc.
- Revise water charges and incentivise water efficiency to ensure efficient water management for industrial consumption.
- Promote water harvesting and storage in industrial clusters.
- Establish and monitor pollution prevention plans in industrial clusters.
- Create adequate green zones and water bodies in industrial clusters.
- Establish a network with DMI, Bhopal, OSDMA and coastal industrial houses.
- Reclaim coastal low-lying areas with scientific disposal of fly ash of thermal power plants.
- Conduct technology assessment and explore alternatives for steelmaking to minimise carbon footprint.
- Set emission targets for iron & steel sector.
- Conduct technology assessment and explore alternatives for power generation to minimise use of water and coal.
- Conduct an energy efficiency study for ferro-alloy sector in Odisha.
- Carry out a material and energy audit in aluminium industries of Odisha.
- Carry out a material and energy audit in cement industries of Odisha.
- Institute a comprehensive study on processing and use of spent pot lines from aluminium smelters.

Low priority

- Study the impact of climate change on supply-side capacity of food processing industries.
- Study the feasibility of establishing and operating bio-methanation process for food processing cluster in PPP mode.
- Install centralised solar heating system in food processing cluster to supply hot water.
- Prepare regional environmental management plans for major industrial clusters.
- Establish a system for empanelling CDM consultants.
- Establish a training and research institute on climate change.

- Strengthen the Centre for Environmental Studies to build capacity to carry out R&D projects in climate change mitigation and adaptation.
- Establish a mechanism to ensure that coastal industries incorporate extreme climate conditions during the structural design phase.
- Develop a coastal green belt in Paradeep and Dhamra.
- Generate awareness, create capacity, and train industrial personnel on the benefits of cleaner production.
- Set up a demonstration project for carbon capture and storage in the thermal power sector.
- Develop a mechanism to use waste plastics, rubbers, tires, and other carbonaceous waste material for co-processing in cement kilns.
- Carry out a material and energy audit of the paper industries of Odisha.
- Set emission targets for the cement, paper, aluminium, and cement sectors

A5.9 Energy

With growing demand for energy, energy production is also increasing in Odisha. The share of hydel power would be decreasing in total power generation, and there would be substantial pressure on the local environment and natural resources. In the energy sector, the areas that needed intervention are clean coal approaches, capacity building/ restructuring of the energy department, reduction in transmission & distribution losses, promoting demand-side management & energy efficiency, fly ash utilisation and emission reduction from power plants, promotion of small and medium hydel plants, utilising biomass potential, grid-based wind power generation, increasing solar power generation, biogas and manure management, etc.

On the renewable energy front, there is potential for increasing electricity generation by about 2,400 MW from medium-scale hydropower (90-150 MW per unit), 150-200 MW from small hydropower plants (10-25 MW per unit), 1,40,000 MW from solar PV power, 1,70,000 MW from wind power, 350 MW from bio-mass-based power, 12 MW from municipal solid & 8 MW from liquid waste–based power. At present, around 57 MW is generated from small hydel plants in the State and some pilot projects are done. Under this, the important measures proposed are: All thermal power plants should be obliged to develop solar power at 1 per cent of their power generation capacity, increase in coal-fueled power plant efficiency from 37 per cent to 42 per cent, encouraging gas-based combined cycle power plants where CO_2 emission can be reduced from 0.46 to 0.25 per MWh. There are 42 action points that are listed, among which 10 key priority areas are included for implementation by next five years, with others to be considered in the next phases. The activities for the sector in Odisha according to the priority level are listed below.

High priority

- Study to develop a policy framework for generating cleaner energy through clean coal approaches
- A switch from sub-critical technology to super-critical technology by which coal consumption will reduce from 1 MT to 0.88 MT per MWh and increase plant efficiency from 37 per cent to 42 per cent
- Encourage more gas-based combined cycle power plants where CO_2 emission is 0.46 and which can be reduced.
- Washed coal to be used by IPPs/ CPPs for the generation of power if ash content in coal exceeds 40 per cent.
- Use of fluidised bed boiler and coal gasification. This will utilise the mines' rejects and washery rejects for power generation.
- Import power from neighbouring countries like Bangladesh (rich in gas deposits), Nepal, and Bhutan that have huge hydro potential. Explore the possibility of State/Central PSUs to construct power plants in those countries

with a bilateral agreement to export a large portion of the power to India.

- Implement emerging clean coal technologies through pilot.
- Install equipment at IPPs/CPPs for NOx reduction.
- Adoption of Hg reduction measures like activated carbon injection (ACI) or co-capture with FGD (Flue Gas Desulphurisation).
- SO2 removal from coal/flue gas through dry/wet FGD system
- Install high-efficiency ESPs followed by bag filters in all thermal power plants.
- Implement carbon cap-trade mechanism for TPP with a system of incentive and penalty for lower/higher level of emissions.
- Integrated super-critical (660 MW) IPP Policy (coal washeries, fly ash-based cement, and brick plants). Minimum unit size for the purpose of IPP/MPP should not be less than 300 MW to achieve minimum standards of efficiency.
- Promote merchant power plant in existing industrial units with variable PPA (Power Purchase Agreement) option.
- Revise Renewable Purchase Obligation (RPO) based on the changing load mix and assessment of evacuation infrastructure.
- Functional reorganisation of the energy department to have a coherent road map
- Improve boiler efficiency through combustion optimisation by installing dynamic coal flow balancing system with continuous residual carbon analyser in the boilers.
- Conduct a study to determine state emission intensity.
- Develop State-level energy efficiency standards for various sectors.
- Feasibility study of evacuation corridor
- Augmentation of T&D infrastructure and investment plan
- Implement utility-level DSM measures.
- Awareness generation for energy conservation
- Promote and implement the National Bureau of Energy Efficiency's (BEE) Energy Conservation Building Code (ECBC) for widespread adoption in the State to reduce energy consumption in buildings.
- Increase energy efficiency through optimisation usage pattern and incorporating energy efficiency measures.
- Compile information from studies and initiatives that have been done on fly ash and develop an operational plan including capacity building of concern department.
- Develop an operational plan for the fund that will get revenue for the sale of power that is exported.
- Climate-proofing of proposed power infrastructure proposed in coastal belts (2 ultra-mega power plants)
- Conduct feasibility study for establishment of coal-based thermal power plants along the coast of Odisha, use of saline water, and dedicated rail corridor for coal transportation.
- Small and medium hydel plants
- Maximise harnessing biomass potential in the State through co-gen/ thermal/power plant/gasification to feed the grid as green power. Increase application of Captive Power Plant (CPP) both in grid and stand-alone mode.
- Promote grid-based wind power generation.
- Maximise solar power generation in the State in both PV and thermal routes and increase the penetration of stand-alone solar systems for use by institutions, communities and individuals.
- Develop biogas and manure management.
- Examine the bio-fuel policy in the State and examining linkages with blending infrastructure.
- Train members of working group or their representatives of different departments and organisations on sector-specific climate effects.

Medium priority

- Land bank for gas-based power projects in potential areas to utilise gas find from Mahanadi basin
- Life cycle analysis of existing thermal power plant as per CEA Benchmark and implementation of Renovation and Modernization (R&M) measures to improve efficiency.
- Explore alternate energy sources (tidal, geothermal, run of the river, wind).
- Reduction of T&D losses: Develop an operational plan for a targeted reduction of losses due to pilferage and outdated systems (estimated to be about 40 per cent). The plan should include enhancing present practices for improved load management & implementation.
- For proper energy monitoring, build capacity of energy auditors and strengthen existing energy conservation cell with manpower and infrastructure.

A5.10 Transport

Transport is an energy-consuming sector and contributes largely to the air pollution. High dependence on fossil fuel, inadequate public transport, and increasing population add to the problem. National-level policies focus on the use of CNG/ LNG in cities, promotion of ethanol-blended petrol and bio-diesel as long as there is no conflict with food chains, pricing measures to encourage the purchase of efficient vehicles, and the development of public transport. At the State-level, priority areas are: revising State transport policies (in terms of transport demand management, improved public transport, encouraging cleaner technology, and promoting non-motorised transport); urban development and land use planning with transport planning; promotion of rail transport, especially freight transport; switching to low-carbon fuel; piloting low-carbon green highways; promoting fuel use efficiency and tightening enforcement through training; promoting pedestrian walkways, cycle paths, and non-motorised transport; avenue plantations; assessment of carbon emissions from the transport sector; and promotion and development of inland water transport system. The activities for the sector in Odisha according to the priority level are listed below.

High priority

- Use of alternatives to conventional fuel
- Policy of phasing out old vehicles for emission reduction
- Ensure fuel efficiency (driver’s training).
- Revise State transport policy.
- Introduce Mass Rapid Transport System (MRTS) in suburban areas including electric-operated vehicles, preparation of Detailed Project Report (DPR).
- Protect coastal road infrastructure from sea erosion.
- Green low-carbon footprint highway
- Avenue tree plantation for carbon sequestration
- Integrate urban development and land use planning with transport planning.
- Develop inland waterways/ setting of ports.
- Survey of ambient air quality of towns/cities
- Generate public awareness on road safety and traffic management of carbon emission reduction.
- Encourage transportation of bulk dirty cargo through rail network.
- Strategic study for expanding public transport across the State
- Expand rail network to reduce carbon emissions.
- Carbon emissions estimation from the transport sector

Medium priority

- Strengthen enforcement wing for emission level check-up (burning fuels more efficiently).
- Promote and incentivise the use of non-motorised vehicles.
- Blending of biofuel in auto fuel

A5.11 Urban Planning

Urbanisation is an essential part of economic growth, but it leads to population concentration in a small geographical area leading to an energy-intensive economy and the generation of large quantities of waste. So, there is a requirement for urban planning that ensures efficient management and delivery of basic urban services with climate consideration. Priorities at the State-level include: capacity building of urban local bodies, incorporating climate considerations in water supply and sewerage design, reducing water losses and promoting water conservation measures, preparing climate-friendly municipal solid waste management plan, street lighting using clean development mechanism, climate-responsible master plans for cities, infrastructure facilitating non-motorised transport, overcoming water supply shortage through water harvesting, managing urban storm water flows, etc. The activities for the sector in Odisha according to the priority level are listed below.

High priority

- Capacity building of Urban Local Bodies (ULB) on climate change impacts and preparedness.
- Conduct a techno-economic study on energy-efficient designs and equipment for urban water supply and sewerage schemes in ULBs.
- MSW composting for both energy efficiency and addressing methane generation from waste.
- Conduct a techno-economic study on switching to energy-efficient street lighting and develop a programmatic Clean Development Mechanism (CDM) proposal for implementation by Urban Local Bodies.
- Mandating water assessment and audit.
- Revise the guidelines for preparation of master plan/ City Development Plan (CDP) and prepare an integrated city development plan with land use and transport planning.
- Promote and incentivize the use of non-motorized transport.
- Formulate State-specific Energy Conservation Building Code (ECBC) and revision of Odisha Public Work Department (OPWD) Act in line with ECBC code.
- Develop a promotion plan for energy-efficiency in buildings through the adoption of ECBC code and piloting green buildings in one city.
- Improvements to water harvesting in urban areas with restoration of water tanks and artificial recharge.
- Develop models of urban storm water flows and capacities of existing drainage systems with climate change.
- Commission urban heat island study.
- Coastal road infrastructure.
- Urban tree plantation.
- Transport policy and boat policy.
- Survey on ambient air quality of towns/cities and encouraging use of biofuel, CNG/LPG.
- Generate public awareness on road safety.

Medium priority

- Introduction of BRTS/MRTS and solar or electric-operated vehicles.
- Green low-carbon footprint highway.
- Development of inland water ways/ setting of ports.

A5.12 Coast and Disaster Management

Odisha has an extensive coastline of 480 kms and 36 per cent of the State's population lives in nine coastal districts. The State is affected by cyclones from the Bay of Bengal each year and also by floods in major rivers. For coasts and disasters, the key priorities are: coastal zone management, flood mapping, flood forecasting and downscaled climate change projections modelling, digital elevation model for erosion-prone areas, studying coastal erosion with a focus on coastal settlements and public infrastructure, micro-level vulnerability assessment, flood shelters, multipurpose cyclone shelters, hydrological framework, dredging and river mouth widening to improve flood management, strengthening coastal protection methods, techno-legal regime for construction of disaster-resilient housing and public infrastructure, integrating climate change risk in the State's disaster management policy, integrated training and capacity building protocol, assessment of risks due to lightning and thunderstorms, flash flood management, modelling the impact of sea level rise on coastal ecosystem, analysis of impact of global warming on the biodiversity of the coastal ecosystem with special emphasis on flagship biodiversity species, etc. The Odisha State Disaster Management Authority (OSDMA) deals with risk reduction, relief, restoration, reconstruction, and other measures related to disaster management activities. The activities for the sector in Odisha according to priority level are listed below.

High priority

- Predictions through appropriate modelling to generate different scenarios.
- Generation of flow series and prediction of the changed salinity regime, salinity flushing, upstream breeding migration, impact on lake fishery and biodiversity.
- Prediction of the rate of migration, cross-section based on numerical modelling.
- Study and assessment of population of biodiversity of all genera of invertebrates and vertebrates with emphasis on flagship species such as marine mammals (cetacean species) and sea turtles in coastal waters and estuarine crocodiles, estuarine terrapins, and migratory birds in estuarine as well as tidal-influenced habitat. This will also include the biology, lifecycle, abundance and distribution of the species and habitat conditions.

Medium priority

- Flood mapping, flood forecasting models, downscaled climate change projections.
- Climate-proofing coastal road infrastructure.
- Capacity building of (ULBs) of the coastal towns on potential climate change impacts.
- Integration of climate change risks into the State disaster management policy.
- Assessment of erosion-prone areas with the help of digital elevation models.
- Strengthening delivery and monitoring systems and preparedness in disaster-prone regions due to rise in sea level.
- Strengthening delivery and monitoring systems of health system preparedness in disaster-prone regions
- District authorities to develop heat wave disaster plans.
- Running drought monitoring and assessment models.
- Study to ascertain long-term sustainability of coastal settlements, vegetation and cropping.
- Survey, identification, mapping, demarcation, fencing and earmarking of non-forest government/ private land in 1-5 km stretch of coastal zone for taking up reforestation & afforestation activities both within and outside sanctuaries.
- Undertake studies on indigenous tree species to assess their vulnerability to climate change. Develop saline-resistant, water logging-resistant, heat-resistant genotypes.
- Capacity building through training of wildlife field functionaries for access to up-dated knowledge on climate change and policy issues in connection with climate change.
- Establishment of rescue centres, equipped with modern facilities so as to cater to the needs of wildlife affected due to climate change.
- With the rise of ambient temperature, erratic rainfall and a more drought-like situation is expected. To cope with the situation, more waterholes for wildlife in protected areas to be created.
- Establishment of conservation breeding centres of land and aquatic wildlife of rare,

threatened and endangered species as well as other targeted species to maintain the gene pool and to re-introduce these species as and when the need arises.

A5.13 Water Resources

Climate change is likely to increase the frequency of extreme events like flood, droughts, and cyclones, which affects water resources. The National Action Plan on Climate Change (NAPCC) aims to ensure integrated water resource management to conserve water, minimise wastage, increase water use efficiency, and ensure equitable distribution both across and within States. State-level priorities include expansion of hydrometry network through the assessment of water availability, extreme events and information for effective water resource planning, development of flood forecasting models, downscaling of global circulation model to the regional scale, increasing water use efficiency in irrigation, improvement in water harvesting structures and drainage systems, maintenance of river health and studying eco-systems environmental flow demand, raising awareness, integrated water resources management, etc. Activities for the sector in Odisha according to priority level are listed below.

High priority

- Expansion of hydrometry network
- Development of flood forecasting models
- Downscaling of global circulation model
- Increasing the water use efficiency, bench marking, and water audit in irrigation projects
- Construction of water harvesting structures, i.e., check-dam to adapt to the climate change scenario
- Provision of fresh water storage structures (major & medium) for enhancement of per capital availability
- Improvement of drainage systems
- Maintaining environmental flow in wetlands
- Awareness raising with Pani Panchayat through farmers' training programme and creation of agro-climatic stations
- Integrated water resources management
- Renovation and improvement of existing storage structures
- New ground water legislation for urban water harvesting
- Consumptive use of surface and ground water
- Regulation of water drawl and wastewater discharge
- Improvement of flood management plan and other extreme events like cyclone, drought, etc.
- Creation of database for ground water resource
- Establishment of academia–department interaction

Medium priority

- Encourage the use of non- conventional water for beneficial uses.
- Inter-basin transfer of water from surplus basin to deficit.

A6. Concluding Remarks

The government of Odisha has taken up several adaptation and mitigation strategies to increase climate resilience, to combat the adverse effects of climate change, and to promote renewable energy sources for power generation. The State created a climate action plan in 2010, but there are still some gaps that need more policy attention.

Erratic weather changes affect crop yields and affect farm income, which can raise food prices. The government needs to devise policy measures to compensate the losses accrued to farmers. A cropping plan needs to be made using both scientific and local knowledge, specific to locations. Based on the recent pattern of rainfall, and temperature fluctuations, information should be disseminated to farmers for appropriate cropping patterns. Climate-resilient crops should be promoted. Odisha's millet mission is a step in the right direction.

Recent years have also witnessed a significant rise in forest fires during the height of summer. Similarly, during cyclones, forests get damaged because these are alien plants. Due to the growth of invasive species in the forest, the habitat and availability of food and fodder and habitat are getting disturbed. Therefore, the planting of local and indigenous species should be promoted.

The State needs to be better prepared for extreme events like cyclones, which are frequent in coastal districts. Farmers should be educated to take precautionary measures to cope with extreme weather conditions. During cyclones and floods, although provisions are made for the evacuation of human beings, no provisions are made for domestic animals, which are a source of livelihood for many farming households. Limited research has been done on the impact of extreme weather on the health and wellbeing of domestic animals.

The education sector gets badly affected during climate-induced disasters such as heavy rainfall, floods, cyclones, and heatwaves. The government announces the closure of schools, for justifiable reasons, during days of heavy rainfall, cyclones, and heatwaves. Although the number of teaching days lost during floods and cyclones is low, teachings days lost due to heatwaves are longer. Alternative teaching and learning methods, such as online teaching, need to be adopted during such times. For these purposes, the necessary infrastructure needs to be created and capacity should be built among teachers. The government may consider rethinking the academic calendar to compensate for losses during natural disasters.

Due to the increase in population, habitations are increasing on the sea coast. The increasing frequency of natural disasters, especially cyclones, floods, and high tides, increases the vulnerability of coastal households. Although coastal zone regulations prohibit any construction within 500 metres of the sea coast, a large number of violations are observed by both business establishments and poor households. Appropriate policy measures should be taken to relocate both groups to safe locations.

Odisha's disproportionate contribution to emissions is largely explained by the large contribution of mining and metal industries. These industries mainly rely on thermal captive power plants that are relatively smaller. There is an urgent need to relook at the policy for captive power plants. In the case of metal industries, captive mining schemes have been discontinued; likewise, the electricity sectors need to be relooked at.

The rise in temperature in summer is pushing households to buy air conditioners in both urban and rural areas. This increases peak time demand significantly. Unable to meet the demands of peak time, distribution companies resort to undeclared power cuts. To meet peak load demand, the State government has entered into an agreement with the government of Madhya Pradesh. The government needs to increase power generation to meet the growing energy demands. The State and national government also need to encourage research on alternative methods of cooling and change the design of buildings to keep houses cool.

The government of Odisha started a climate budget in 2020-21 to track government expenditure for climate change or to support mitigation and adaption actions to address climate change. This is undoubtedly a step in the right direction. Nevertheless, a climate budget should map the financing that reduces the risks of climate change.

Annex A2. Top-down CGE Model

Our top-down energy model is patterned after the GTAP model, designed and developed by the Center for Global Trade Analysis, Purdue University (Hertel 1997). In our model, we consider three regions, namely, Odisha, the rest of India, and the rest of the world.

The GTAP model is impactful in performing a comprehensive evaluation of a policy or regulatory shock. On the production side, the model assumes perfect competition and constant returns to scale. The production for every sector and every region in the model is identified and represented by a Constant Elasticity of Substitution (CES) function. It also works on the basis of Armington assumption and so each firm employs a CES composite of domestic and imported intermediate goods in fixed proportions with endowment factors or value-added commodities like land, labour, capital, and natural resources. On the demand side of the model, total income is distributed following a fixed share across households, government, and savings expenditure. The model captures supply-demand linkages and equates them by accounting for changes in production, consumption, exports, and imports.

There are five factors of production (land, capital, national resources, unskilled labour and skilled labour), three types of domestic institutions (households, enterprises and government).

The behavioural equations in the model dictate production, private consumption, exports, imports, and market-clearing conditions that equate supply with demand. Elasticities determine the substitution between various input and output parameters in the production and consumption behavioural equation.

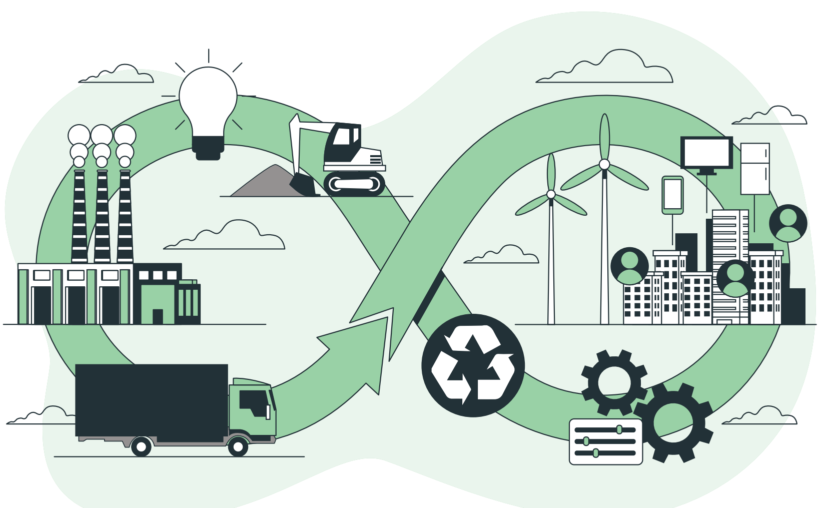


Figure A2-1 **Accounting Structure of the GTAP Model**

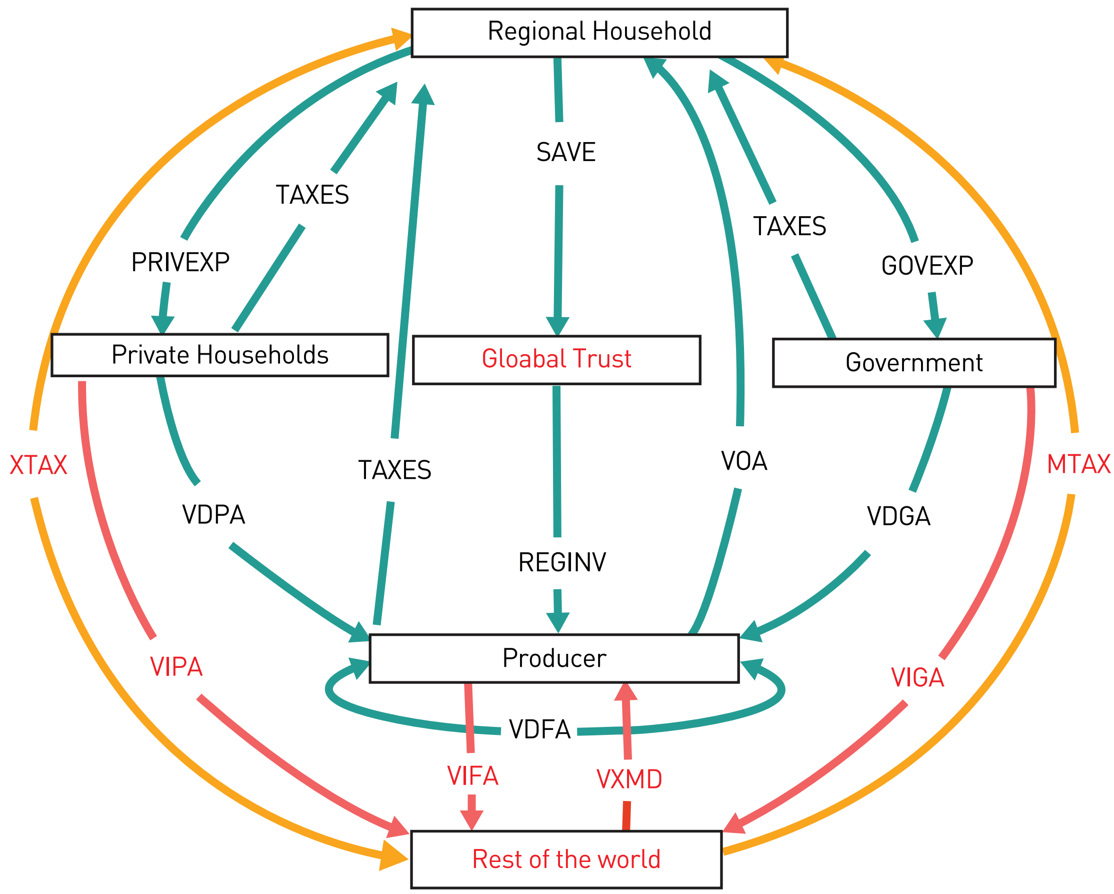
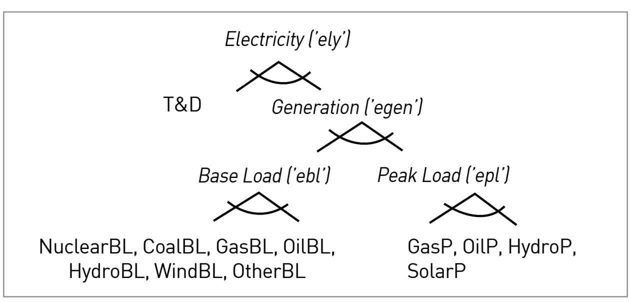


Figure A2-1 offers a simplified outline of the complex GTAP model. Here, the regional household receives factor payments (VOA) from different agents including private households, firms, and the government for the supply of factors like land, labour, and capital. The residual that remains after households' expenditure on private consumption and government consumption is savings. The model is based on the Cobb-Douglas utility function that preserves the share of private consumption and government consumption. Global trust accumulates savings and then distributes them across different regions as investments based on the rate of returns. This becomes a capital input to firms that also use factor inputs (VOA) and intermediate inputs from domestic (VDFA) as well as imported (VIFA) to produce the output. This output caters to the consumption demand of private households (VDPA) and the government (VDGA) and serves as an intermediate input to firms (VDFA). Private households and governments can consume from the domestic output (VDPA/VDGA) as well as from imports (VIPA/VIGA), the consumption of which is governed by the Armington assumption. The international transactions in the figure are marked in red and the domestic transactions are differentiated in blue.

In the standard GTAP model, the electricity sector is present as an aggregate sector in terms of fuel, capital, and other production inputs. However, with policy and technical enhancements across different power generation technologies, it is important to account for power generated from different sources and the substitution between them. The GTAP-Power database extends the standard GTAP database by including transmission and distribution while also accounting for power generated from different sources including solar, wind, gas, oil, coal, nuclear, and hydro. The problem with electricity is that supply must instantly rise to cater to the consumption demand, which in turn varies by, for example, season, work hours, day, and night.

Coal power plants cannot instantly adjust to demand while gas or solar power can during peaks. Also, it is unrealistic to assume that solar or nuclear power can meet all power demands given their operational constraints. Thus, based on their ability to cater to the requirements of the base load (BL) and peak load (P), the power generation sectors are split into base-load and peak-load technologies. The GTAP-Power database disaggregates electricity into 12 sectors with a transmission and distribution sector and 11 other generation sectors based on their sources and capacity to meet consumer demand. There are seven base-load technologies-NuclearBL, CoalBL, GasBL, HydroBL, OilBL, WindBL, and OtherBL- and four peak-load technologies covering GasP, OilP, HydroP, and SolarP (Figure A2-2). Other types of power sources include biofuels, waste, biomass, geothermal, and tidal technologies. Each of these power sources has different fuel efficiencies and demands different investments.

Figure A2-2 **Electric Power Substitution in GTAP E-Power Model**



Source: Peters (2016).

We have constructed a GTAP-Power model comprising of Odisha, the rest of India, and the rest of the world. The model accounts for carbon emissions from the combustion of fossil fuels. Energy commodities in our model include coal, oil, gas, petroleum and coal products, and electricity. The model accounts for inter-fuel substitution and fuel-factor substitution in the production structure.

The construction of the balanced database for GTAP-Power was an extensive exercise. We had to construct an input-output for Odisha and the rest for India using the supply-use table for the year 2021. This also involved collecting State-level data, macroeconomic data for Odisha and India and, of course, electricity generation by modes for Odisha and India. Most of the supplementary information was drawn from official statistics. We used information from official statistics of Directorate General of Commercial Intelligence (DGCIS) to collate data on exports from Odisha/Rest of India and inter-regional trade within India.

Annex A3. Bottom-up Energy (MESSAGEix) Model

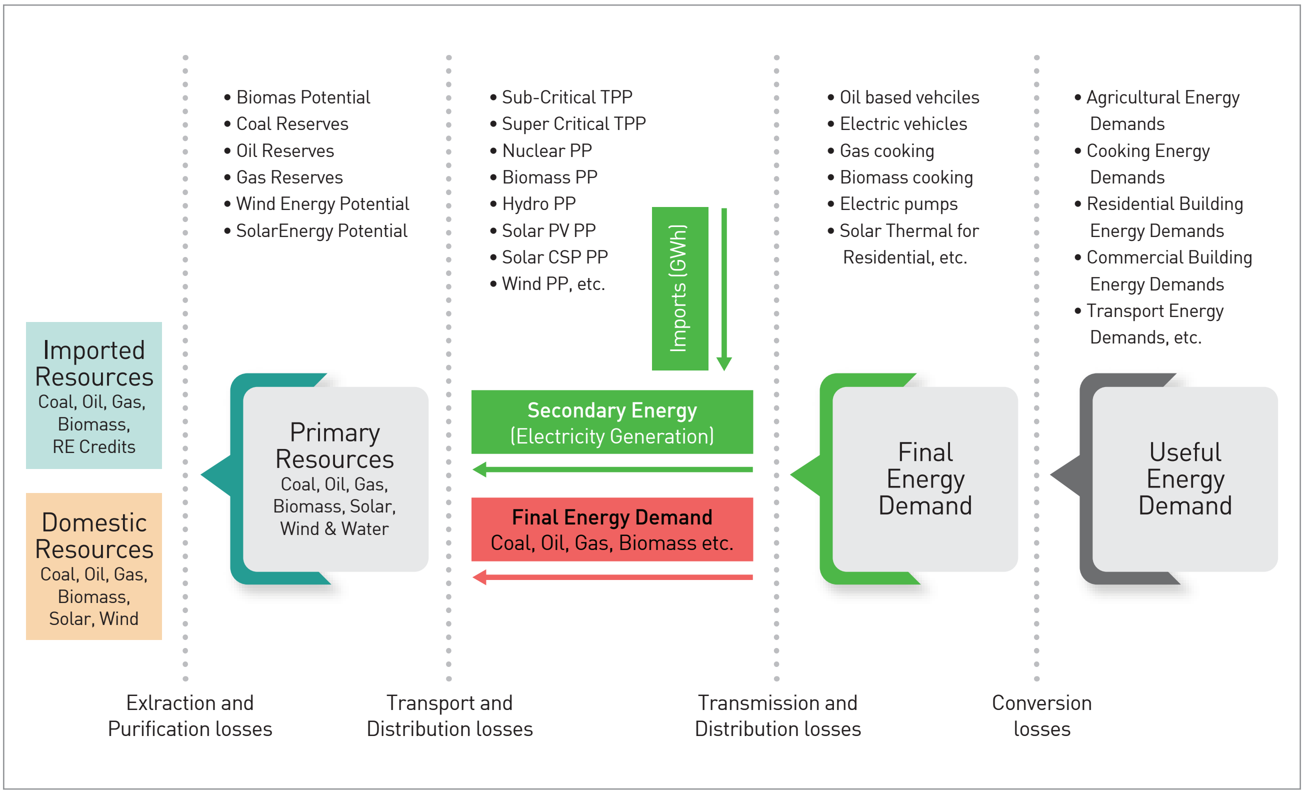
A3.1 Introduction

The MESSAGEix modelling framework was developed by the International Institute for Applied Systems Analysis (IIASA). It is a versatile, open-source, dynamic systems-optimisation model and presents a framework for representing an energy system with all its interdependencies from resource endowments and potentials to extraction rates, imports and exports, generation of electricity and conversion of fuels, transportation, transmission, and distribution, to conversion of energy for end-use demand in the form of heat, light, or kinetic energy. The optimisation model obtains the least-cost solution subject to constraints over pre-defined fixed time periods. The model has been a crucial part of various assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

MESSAGEix is an energy systems optimisation model that optimises the supply side of the model based on the projected energy demand provided as an exogenous input to the model. The model has five major sectors as major energy consumption sectors; residential, commercial, industry, transport and agriculture. The residential sector is further broken down into sub-sectors as appliances and cooking. The growth in energy demand in these sectors is directly linked to the growth of the sectors in terms of economic activity. With these projected demands as input to the model, the model optimises the energy system to the least cost scenario of energy activity in and around policy constraints of environment and resource availability. Optimisation occurs at different levels of energy use from useful energy demand to final, and then to secondary consumption all the way up to primary and resource supply.

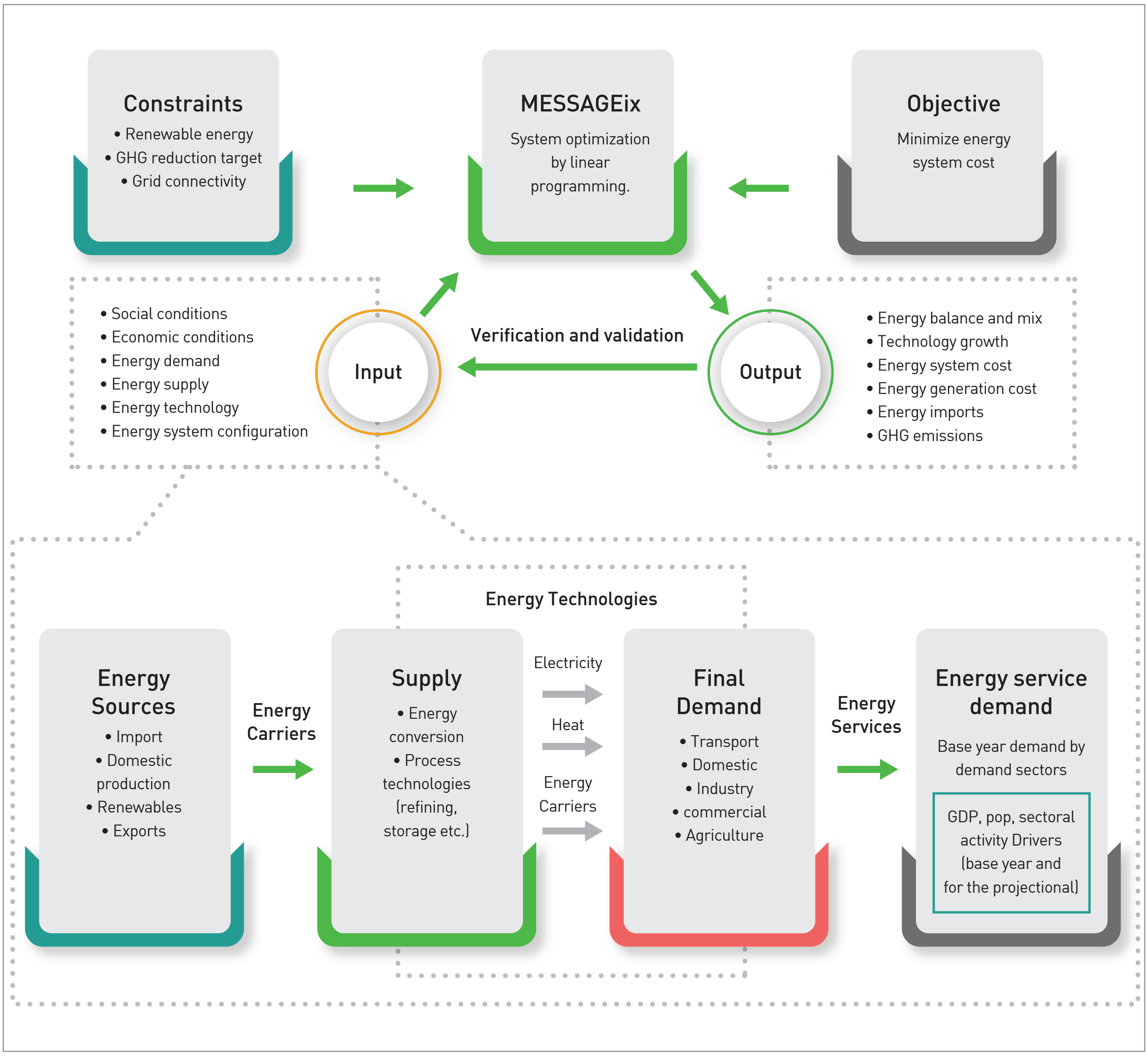
A representation of the model in a general context is shown in the Figure A3-1. It shows the granularity in the model to make a technology-based decision for a low carbon pathway. Total GHG emissions, investments, and electricity generation capacity expansion profile are some of the major outputs from the model. This approach indicates what alternative technology a nation should look at to decide on cutting down emissions and the cost of implementing those pathways. It also helps implement policies that look at better demand management with a shift in fuel mix.

Figure A3-1 Representation of an Energy System Model in MESSAGEix



However, the demand information remains fixed in the model and hence at a time the scenarios can be developed only assuming one case of economic activity. To produce meaningful scenarios, the variation of demand linked with economic activity is required to represent the scenarios at different levels of socio-economic activity and thus a framework with seamless scope of looking at more insightful solutions to climate mitigation becomes key to a more suitable modelling approach where the demands can come from a CGE model (Figure A3-2).

Figure A3-2 Structure of MESSAGEix Model



In short, MESSAGEix is a demand-driven, bottom-up model. The objective is to minimise the energy system's costs to meet given energy demands in the economy over the model horizon.

A3.2 Energy Demand Projection using the IM Framework

MESSAGEix requires demand projections as an exogenous input to the model. Based on these projected demands, the supply side to meet these demands are optimised in the MESSAGEix model at different levels of consumption and supply. Optimisation in MESSAGEix is constrained with least cost optimisation, which means that the optimisation occurs for a least cost systems expansion plan to meet future demands in and around all other policy constraints such as environmental constraints, resource constraints, and capacity constraints. Hence, supply-side information is much relevant because it covers most of the policy aspects. In order to make it more robust in terms of linking the energy model to an economy based on economic performance, the energy demand that should be used in the MESSAGEix model as an input should be derived from a Computable General Equilibrium (CGE) Model.

Here we explain how the projected CGE model outputs at sector level will be used to derive the corresponding sectoral energy demand growth rates using concordance mapping.

A3.2.1 Agriculture Energy Demand

Factors from CGE model outputs

CGE output on 'grains and crop' productivity rate is the key indicator for the agriculture sector. The productivity rate helps determine land use change and change in agricultural tractors and irrigation pumps by increase/decrease in productivity rates.

Derived energy demand from CGE outputs

The factors are then applied to irrigation and land preparation through identification and percentage distribution between surface/ ground water irrigation. Land use change is considered based on long-term historical data based on national statistics.

A3.2.2 Household/Cooking Energy Demand

Factors from CGE

Direct productivity of household demand for electricity and gas supply is obtained and applied to the base year energy demand of both household and cooking.

Derived energy demand from CGE outputs

The base year energy demand is calculated from national accounts and statistics. Cooking activity and its productivity rates are then obtained based on weightage distribution of the fuel utilisation as in its historic trends.

A3.2.3 Commercial Sector Energy Demand

Factors from CGE

Intermediate demand of electricity is directly obtained by deducting household demand of energy commodity from aggregate demand.

Derived energy demand from CGE outputs

The base year energy demand is calculated from national accounts and statistics. Identification and percentage distribution between appliance use and hot-water demand of the sector is based on the growth pattern of the sector.

A3.2.4 Transport (Freight & Passenger) Energy Demand

Factors from CGE

CGE provides direct intermediated growth of 'rail transport, land, air and water transport'.

Derived energy demand from CGE Outputs

Identification of freight and passenger distribution from historical data and current national statistics. Growth parameters are identified based on sectoral demand pattern and then growth rates are directly applied.

A3.2.5 Industrial Energy Demand

Factors from CGE

To identify the growth rate of the industry sector, growth rates are directly sourced from different manufacturing services and other industries modelled in the CGE model. Further, the mean value of all the production growth of manufacturing and other industries from CGE output is calculated which is then directly applied to the calculation of energy demand projection in the industry sector.

Derived energy demand from CGE outputs

Base year energy demand is identified and direct mean growth rates are applied.

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