THE ENERGY REPORT – KERALA

100% RENEWABLE ENERGY BY 2050

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The Energy Report – Kerala:
100% Renewable Energy by 2050

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Acronym	Definition
AD	Anaerobic Digestion
ADAK	Agency for Development of Aquaculture. Kerala
ANERT	Agency for Non-conventional Energy and Rural Technology
ASI	Annual Survey of Industries
AT	Alternate Technology
BAT	Best Available Technology
BAU	Business-As-Usual
BEE	Bureau of Energy Efficiency
BIPV	Building Integrated PV
BOO	Build-Own-Operate (PPP Model)
BOOT	Build-Own-Operate-Transfer (PPP Model)
BPT	Best Process Technology
BTKM	Billion Tonnes Kilometers
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
CARB	California Air Resources Board
CCSP	Centre for Climate and Sustainability Policy, WISE
CEA	Central Electricity Authority, India
CECRE	Control Centre of Renewable Energies, Spain
CERC	Central Electricity Regulatory Commission
CEEF	Cost Effective and Environment Friendly
CESS	Centre for Earth Sciences Study, Thiruvanthapuram, Kerala
CFL	Compact Fluorescent Lamp
CGS	Central Generating Station
CII	Confederation of Indian Industry
CMFRI	Central Marine Fisheries Research Institute
CNG	Compressed Natural Gas
COSTFORD	Centre of Science and Technology for Rural Development
CPP	Captive Power Plant
CPWD	Central Public Works Department
CRB	CRISIL Research Bulletin
CRISIL	Credit Rating Information Services of India limited
CS	Carrier Substitution
CSP	Concentrated Solar Power
CSR	Corporate Social Responsibility
CTCRI	Central Tuber Crop Research Institute
CTU	Central Transmission Utility
CUF	Capacity Utilization Factor

Acronym	Definition
DLEC	District Level Expert Committees
DNI	Direct Normal Irradiance
EC	Energy Conservation
ECBC	Energy Conservation Building Code
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EEZ	Exclusive Economic Zone
EMC	Energy Management Centre, Thiruvanthapuram, Kerala
EMD	Earnest Money Deposit
EPS	Electric Power Survey
ERC	Electricity Regulatory Commission
ESCO	Energy Services Company
ESMAP	Energy Sector Management Assistance Programme
ESTAP	Energy Technology Systems Analysis Program
FAO	Food and Agriculture organization
FIT	Feed-in Tariff
FO	Furnace Oil
FPC	Flat Plate Collector
FTL	Fluorescent Tube Lights
FYP	Five Year Plan
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiance
GIS	Geographic Information System
GLS	General Lighting System
GPCL	Gujarat Power Corporation Limited
GSDP	Gross State Domestic Product
HCV	Heavy Commercial Vehicle
HEP	Hydro Electric Project
HSDO	High Speed Diesel Oil
HVAC	High Volume Air Conditioner
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPP	Independent Power Producer
ISRO	Indian Space Research Organization
ITES	Information Technology Enabled Services
IWT	Inland Water Transportation
KESNIK	Kerala State Nirmithi Kendra
KIDCO	Kerala Irrigation Infrastructure Development Corporation
KINFRA	Kerala Industrial Infrastructure Development Corporation
KSEB	Kerala State Electricity Board
KSERC	Kerala State Electricity Regulatory Commission
KSIDC	Kerala State Industrial Development Corporation

Acronym	Definition
KSINC	Kerala Shipping and Inland Navigation Corporation Limited
KSRTC	Kerala State Road Transport Corporation
LBNL	Lawrence Berkeley National Laboratory
LCV	Light Commercial Vehicle
LDO	Light Diesel Oil
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LNG	Liquefied Natural Gas
LPD	Liters Per day
LPG	Liquefied Petroleum Gas
LSHS	Low Sulfur Heavy Stock
LSHSD	Low Sulfur High Speed Diesel
LTD	Limited
LULC	Land Use Land Cover
MCA	Multi-Criteria Analysis
MEDA	Maharashtra Energy Development Agency
MNRE	Ministry of New and Renewable Energy, India
MOCA	Ministry of Civil Aviation
MOSPI	Ministry of Statistics and Program Implementation
MOU	Memorandum of Understanding
MPCE	Monthly Per Capita Expenditure
MSME	Micro, Small and Medium Enterprises
MSW	Municipal Solid Waste
MW	Megawatt
NASA	National Aeronautics and Space Administration
NATPAC	National Transportation Planning and Research Centre
NEERI	National Environmental Engineering Research Institute
NEMMP	National Electric Mobility Mission Plan
NHPC	National Hydro Power Corporation
NPC	National Productivity Council
NRDC	Natural Resources Defense Council
NREL	National Renewable Energy Laboratory
NRSC	National Remote Sensing Centre
NSSO	National Sample Survey Organization
NTPC	National Thermal Power Corporation Limited
ODC	Oxygen Depolarized Cathodes
OPEX	Operational Expenditure
OWC	Oscillating Water Column
PAT	Perform, Achieve and Trade
PCY	Per Capita Income
PEUM	Partial End Use Methodology
PKM	Passenger Kilometer

Acronym	Definition
PLF	Plant Load Factor
PPP	Public Private Partnership
PV	Photo Voltaic
PWC	Pricewaterhouse Coopers
PWD	Public works Department
RDF	Refused Derived Fuel
RE	Renewable Energy
REC	Renewable Energy Certificate
RPO	Renewable Purchase Obligation
RTP	Rapid Thermal Processing
SEA	Super Efficient Appliances
SEEP	Super Efficient Equipment Program
SEZ	Special Economic Zone
SHEP	Small Hydro Electric Project
SHP	Small Hydro Power
SLDC	State Load Dispatch Center
SPO	Solar Purchase Obligation
SWH	Solar Water Heaters
SWHS	Solar Water Heating System
SWTD	State Water Transport Department
TERI	The Energy Research Institute
TJ	Tera Joule
TOE	Tonnes of Oil Equivalent
TOR	Terms of Reference
UEC	Unit Energy Consumption
UNEP	United Nations Environment Program
VAT	Value Added Tax
WBREDA	West Bengal Renewable Energy Development Agency
WISE	World Institute of Sustainable Energy
WPD	Wind Power Density
WPI	Wholesale Price Index
WWF	World Wide Fund for Nature

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EXECUTIVE SUMMARY

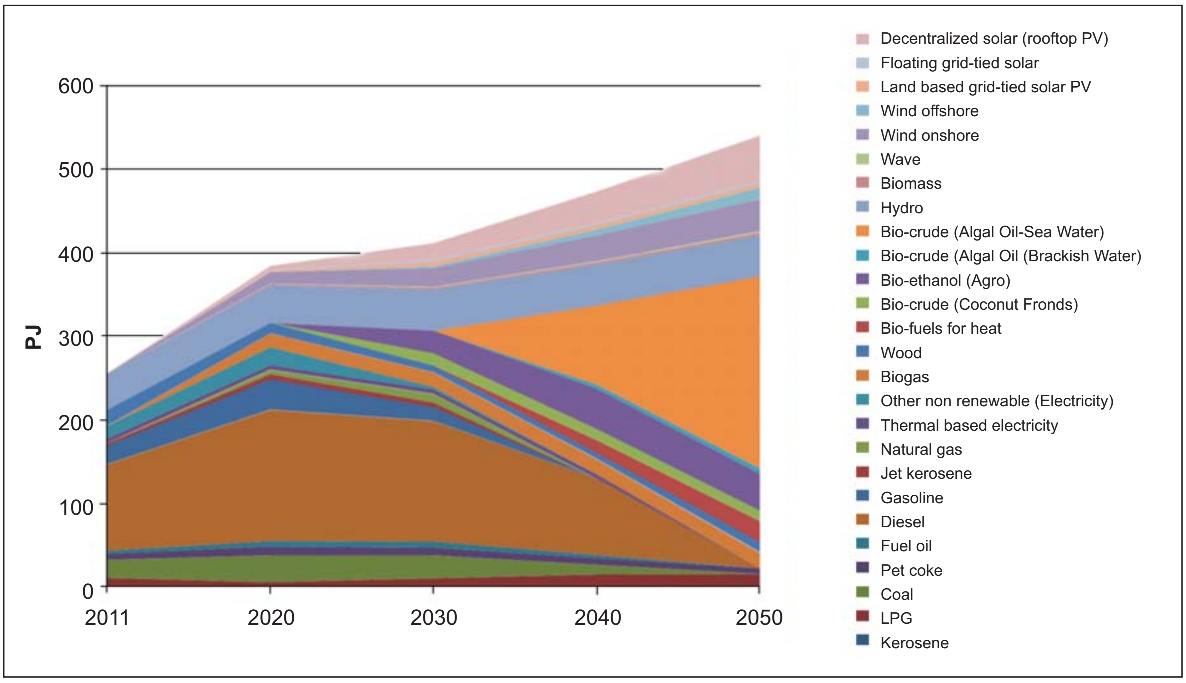
This project is an attempt to model the energy requirement (across power, transport, agriculture, industry, domestic and commercial sectors) of Kerala up to 2050 in order to assess the feasibility of meeting 100 per cent of the state's energy demand with renewable sources.

The approach to the study involves four steps:

a. Assessing renewable energy (RE) supply potential over the projection time frame
b. Modelling of a business-as–usual (BAU) demand scenario
c. Modelling of a curtailed demand scenario to assess maximum potential for demand reduction through focused measures in energy conservation (EC), energy efficiency (EE) and carrier substitution (CS). Carrier substitution is considered when the end use activity is transferred from one energy carrier to another (for example, from transport fuel to electricity, diesel pumps to electric or solar pumps, etc)
d. Matching the supply options with curtailed demand across energy carriers for electricity, heat and transport fuels.

The central finding of the study is that Kerala can meet over 95 per cent of its energy demand with renewable sources by 2050. The following figure shows the final supply sources that can effect this transformation.

Figure A: Supply Sources for Final Energy Scenario



The key highlights of this scenario are:

- 100 per cent electricity requirements for the state can be met with RE. The main resources are onshore and offshore wind, grid-tied and decentralized/off-grid solar, large and small hydro, biomass and wave energy.
- 100 per cent of transport fuel requirements can be met by second and third generation biofuels. Considering the state of biomass to liquid and algal oil based technologies, and related technology access issues, it is assumed that these technologies will be available only by 2030. Sea based algal oil is emerging to be the main fuel supply option of the future. This assumption is consistent with past studies and the global energy report[1], which has assessed commercial availability of these algal based biofuel technologies by 2030.
- Over 70% of the total heating requirements (both for cooking and industrial processes) are met by biogas, wood and surplus biofuels.

The other key findings of the report are covered subsequently.

Renewable Supply Potential

Table A below shows the assessed RE potential of the state.

Table A: Summary of RE Potential of Kerala by 2050

Technology	Supply Potential (2050)	Remarks
Electricity	**Billion Units**	**MW (CUF)**
Grid Tied Solar PV (Wasteland)	5.99	4,273 (16%)
Grid Tied Solar PV (Grassland)	3.56	2,543 (16%)
Floating PV Panels	5.39	3,845 (16%)
Rooftop PV (Domestic)	18.33	13,079 (16%)
Rooftop PV (Institutional)	25.32	18,066 (16%)
Solar Water Pumping		304 (400 hrs)
Onshore Wind (Farmland) (WPD> 200)	5.98	3,103 (22%)
Onshore Wind (No Farmland) (WPD>300)	0.86	447 (22%)
Onshore Wind (Plantations) (WPD>200)	8.60	4,465 (22%)
Offshore Wind (WPD >250)	29.4	13,447 (25%)
Biomass Gasification	0.21	37.2 (65%)
Biomass Combustion	0.62	101 (70%)
Existing Hydro (Large and Small)	11.2	1,998 (65%)
Small Hydro	2.55	583 (50%)
Wave	0.37	420 (10%)
Total	**107**	

Continued...

[1] WWF International. 2011. *The Energy Report: 100% Renewable Energy by 2050*. Avenue du Mont-Blanc, Switzerland.

Continued...

Heat	TJ (Max)	
Biomass Combustion	12,206	
Biogas	18,600	
Total	**30,806**	
Fuels	**TOE (Max)**	
Bio-Crude	296,539	
Bio-Gasoline	15,520,075	
Total	**15,816,614**	

The potential of grid-tied wind and solar energy was assessed using geographical information system (GIS). For the analysis, stringent land use and land availability criteria are considered in addition to standard technical constraints. Off-grid potential assessment is a tabulated exercise. Bioenergy assessment assesses biomass residue availability based on anticipated future trends in agricultural use. The biofuel potential assessment is based on assessed technology parameters of biomass to liquid technologies and algal oil based biofuel processing. Hydro potential assessment is based on the understanding that the only prospective new potential seems to be small hydro power. Wave energy potential estimation is based on assessment done in past studies.

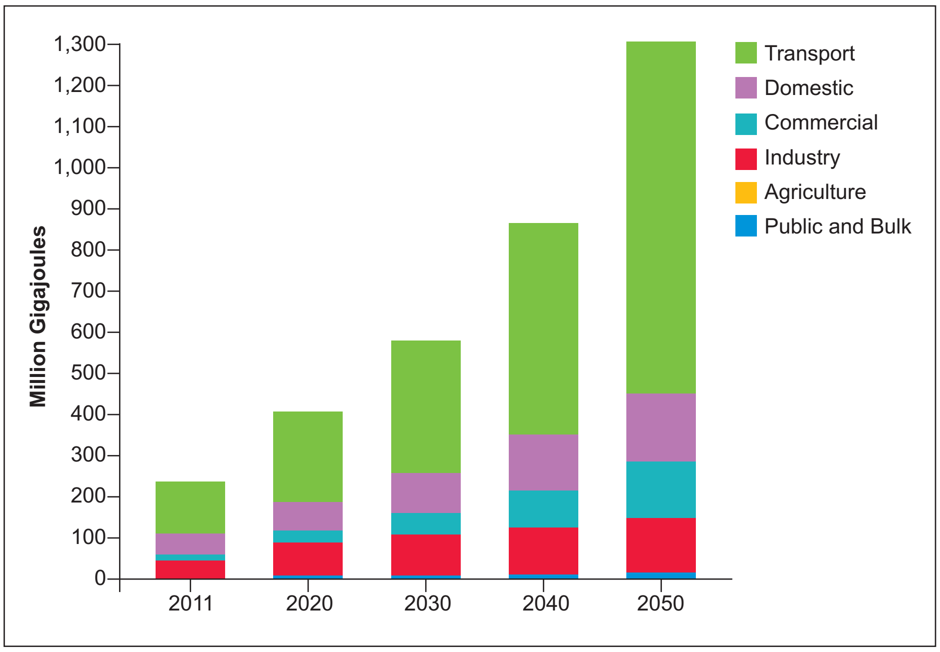
Business-as-Usual Demand Projections

The BAU demand projections for Kerala indicate that the transport sector accounts for little over 50 per cent of the total energy demand of the state in the base year 2011. This is very atypical and unexpected, but validation of derived fuel demand data (from a bottom up assessment) with actual fuel use seems to indicate a good match. The BAU projections indicate an increase of about 5.5 times in total energy from 2011 to 2050. For the transport sector, the increase during this period is almost 7 times. Table B and Figure B summarize the result of the BAU demand projections:

Table B: Energy Demand for the BAU Scenario

State Energy Demand (PJ) - BAU	2011	2020	2030	2040	2050
Transport	128.2	225.2	329.3	520.9	853.5
Domestic	54.4	66.7	94.5	131	169.3
Commercial	12.2	27	53	88.7	134.1
Industry	48.3	75.5	90	104.8	119.7
Agriculture	2	2.2	2.5	2.7	2.8
Public and Bulk	2.6	4.1	6.8	10.5	15.1
Total	**247.7**	**400.8**	**576.2**	**858.6**	**1294.5**

Figure B:
Sectoral Energy
Demand Projections
(BAU Scenario)



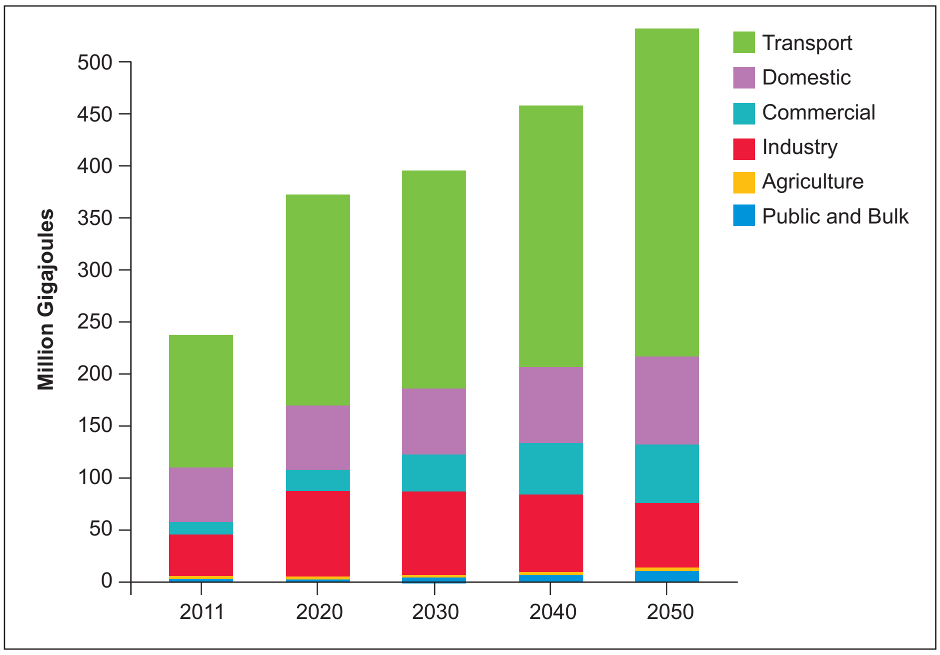
Curtailed Demand Projections

In contrast, the curtailed demand scenario indicates an increase of 2.2 times over the projection period. The curtailed demand was assessed after factoring in aggressive interventions in the BAU scenario. These interventions did not assume any reduction in economic output (or growth) but only assumed a reduction in energy intensity and better resource optimization. In economic terms, these interventions represented alternatives that effectively decoupled economic growth (GDP) from energy resource use. Table C and Figure C summarize the result of the curtailed demand scenario:

Table C:
Energy Demand
for the Curtailed
Demand Scenario

Curtailed Energy Demand (PJ)	2011	2020	2030	2040	2050
Transport	128.2	204.8	208.8	253.3	313.7
Domestic	54.4	63.4	63.9	73.3	87.7
Commercial	12.2	20.6	36	49.2	54.1
Industry	40	81	79.3	73.9	63
Agriculture	2	2	1.8	1.8	1.8
Public and Bulk	2.6	3	5.1	8	11.6
Total	**239.4**	**374.8**	**395.1**	**459.5**	**531.8**

Figure C: Sectoral Energy Demand Projections (Curtailed Demand Scenario)



On a broad level, the project findings indicate that while the existing pattern of growth (BAU growth) would lead to overdependence on fossil fuels, aggressive interventions in energy efficiency, energy conservation and carrier substitution can curtail demand significantly. More importantly, the curtailed demand scenario has the potential to drastically reduce the state's dependence of fossil fuels to achieve a near 100 per cent RE supply by 2050.

PART I

INTRODUCTION

1. INTRODUCTION AND OVERVIEW

In 2011, WWF International published *The Energy Report: 100% Renewable Energy by 2050* that outlines the possibility of powering the world entirely by renewable energy by the middle of this century. As a follow up to the global study, WWF-India intended to undertake a similar study for the state of Kerala. The broad objectives of the state-level study were:

(i) To develop a state-specific report (*The Energy Report: 100% Renewable Energy for Kerala by 2050*) that provides a vision of a 100 per cent renewable and sustainable energy supply for the state by 2050.

(ii) To develop technical scenarios for switching over to 100 per cent RE by accounting for energy requirement in key sectors and associated costs; scenarios to address energy access issues.

(iii) To use the WWF International report as a reference point, with appropriate and relevant modifications for the state.

1.1 BRIEF OVERVIEW OF THE STUDY METHODOLOGY

The following narrative summarizes the methodology used for the study.

STEP 1: Estimation of the existing state of energy share in terms of fuel carriers – electricity, heat and fuels – by identifying key consumption sectors based on historical and present consumption patterns

Energy share is calculated across energy carrier streams: electricity, fuels and heat. The category 'fuels' includes all fuel use for non-heat and non-electricity end-uses (e.g., transportation, diesel pumps, etc) only. The end-use heat requirement met by industrial and other fuels is considered as heat demand.

Energy Carrier		
Electricity	Heat	Fuels

The energy report considers three main consumption sectors – industry, buildings and transport. However, based on data availability, six consumption sectors are studied for mapping their historical and present energy requirements. Table 1.1 shows a list of focus sectors that are studied along with the expected energy carriers that are utilized for end-use activities.

Table 1.1: Focus Sectors for Demand Estimation

Focus Sectors for Demand Estimation	Electricity	Heat	Fuel
Domestic	■	■	
Commercial (IT and Tourism)	■	■	
Public Utilities	■		
Industry	■	■	
Agriculture	■		■
Transportation	■		■

STEP 2: Developing a curtailed demand scenario for identified sectors up to 2050 assuming a three-point intervention – energy conservation (EC), energy efficiency (EE) and carrier substitution (CS)

An energy demand scenario up to 2050 for all the focus sectors is plotted based on a business-as-usual (BAU) growth and standard assumption. This demand scenario for each sector is then built-down, based on identified interventions in EC, EE and CS, considering appropriate timelines for substitution initiations and reduction quantum. *Carrier substitution will mainly emphasize a shift from typically less efficient energy carriers like fuels and heat to more efficient energy carriers like electricity*. For example, for the transport sector, CS will include change from 'fuel-based transportation' to 'electric vehicles', i.e., a shift from carrier 'fuel' to carrier 'electricity'. In line with *The Energy Report,* timelines to introduce interventions and the quantum of interventions will be decided on the technology and market maturity of the proposed intervention. Table 1.2 briefly summarizes some of the identified interventions for each focus sectors.

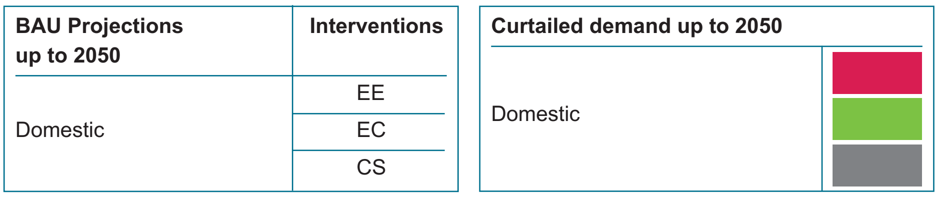
Table 1.2: Elaboration of End-use Activities and Identified Interventions for Focus Sectors

Focus Sectors	End-use activities	Indicative Interventions
Domestic (Residential)	Lighting Local cooling Electronic Load cooking Water pumping	Efficient lighting and star rated white goods. EC Climate responsive building design to conserve energy Solar intervention - roof top PV, water heating, cooking Soil stabilization techniques in building construction. Use of solar and biomass energy for cooking Rain water harvesting
Commercial (Shops, Malls, IT parks, Tourism)	Lighting Space Cooling Cooking Electronic load	Efficient lighting, white goods and motors Solar intervention - roof top PV, water heating, cooking Energy efficient building material and design Recycling and reclamation of waste material for construction Rain water harvesting
Industry (Large and MSMEs)	Lighting Space Heating/Cooling Process Heating/Cooling Pumping	Process improvement DSM measures Efficient lighting solutions Use of efficient motors EC through reduction in idle processes Solar intervention - roof top PV, water heating Substitution of heat source (From fuels to biomass) Substitution of energy carrier (Electricity to renewable heat)
Utilities (Municipalities, Government offices, Industrial Development parks)	Lighting Space Cooling Pumping	Efficient lighting Use of efficient motors EC through reduction in load DSM Solar intervention - roof top PV, water heating

Focus Sectors	End-use activities	Indicative Interventions
Agriculture (Crops and plantations)	Fertilizer application Water pumping	Organic Agriculture Efficient water use Solar water pumping
Transport (Road, Rail, Water, Air)	Passenger Freight	Migration to mass transport Modal shift to a less energy intensive transport mode Energy carrier shift from petrol based vehicles to electric vehicles Localization of supply and demand

Post-intervention energy demand will be mapped in terms of energy carriers. This process is represented for one focus sector diagrammatically in Figure 1.1 below.

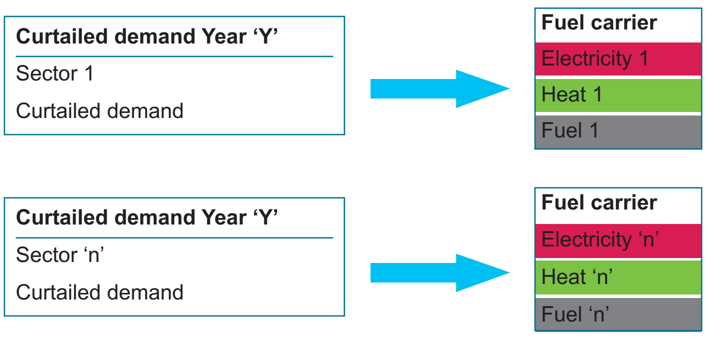
Figure 1.1: Derivation of Curtailed Demand in Terms of Energy Carriers



STEP 3: Aggregation of curtailed demand up to 2050 for the sectors in terms of primary energy sources – electricity, heat and fuels

The curtailed demand for all the identified sectors is then aggregated and converted into the curtailed energy demand in terms of fuel carriers – electricity, heat and fuels. Figure 1.2 below shows this process diagrammatically.

Figure 1.2: Aggregating Total Demand for all Sectors in Terms of Energy Carriers



Total energy demand for 'n' sectors in terms of energy carriers – electricity, heat and fuels – is represented by

Total electricity demand in Year Y = ${}^{1}\Sigma_{n}$ Electricity

Total heat demand in Year Y = ${}^{1}\Sigma_{n'}$ Heat

Total fuel demand in Year Y= ${}^{1}\Sigma_{n}$ Fuel

STEP 4: Identifying renewable energy supply options by assessing technical and implementable resource potential

In line with *The Energy Report,* potential of all the possible RE supply options, including onshore and offshore wind, grid-tied and off-grid solar photo voltaic (PV), grid-tied and off-grid solar thermal (electricity), solar thermal (heat), large and small hydro, ocean energy (wave and tidal), bioenergy including biomass combustion (electricity and heat), biomass gasification (electricity and heat), bio-methanation (electricity and heat), and biofuels including land-based energy plantations and algae-based fuels, are assessed. The potential assessment of grid-tied wind and solar power is done using geographic information system (GIS).

The potential assessment methodology considers aspects related to specific land use patterns and technology constraints in Kerala, and excludes all the areas that may be environmentally sensitive or technically challenging. In addition, conservative parameters are also employed for assessing the availability of land and surface water area for bioenergy to ensure sustainability of resource availability.

STEP 5: Estimation of supply energy scenario in terms of energy carriers

The energy supply potential for each RE supply technology is mapped across the projection period by assuming suitable technology deployment rates. For new technologies that are at pilot stage or are yet to achieve commercial maturity, technology kick-in time and penetration level have been decided on case-to-case basis depending on the expected commercial development / expert interaction or on available literature analysis.

The year-wise supply potential for all technologies is then aggregated in terms of the energy carriers – electricity, heat and fuels.

STEP 6: Matching demand with supply by maximizing renewables (implementable potential) and minimizing fossil fuel use

Based on demand in terms of energy carriers as estimated in STEP 3, carrier-wise supply allocation is done on an annual basis. The annual demand is compared with the annual supply potential and all demand-driven sources are allocated first followed by supply-driven sources like wind, solar and wave power. For example, for the energy carrier fuel, if the total demand in any year is 'Y' units, then this is first matched with the total RE supply potential of energy carrier 'fuels' as estimated in Step 5. If the supply potential is less than the demand 'Y', then the unmet 'fuels' demand is deemed to be met through the most environment friendly mix of existing 'fossil-fuels'.

STEP 7: Assessment of policy imperatives and state financing requirements for the transition

Preliminary assessment of sectoral policies and public sector capital expenditure (CAPEX) and differential operational expenditure (OPEX) requirements (wherever possible) for implementing proposed interventions and strategies are also carried out.

1.2 OVERVIEW OF THE STATE'S DEMOGRAPHICS

Kerala forms the southwest tip of India, covering about 38,863 km^2 (3.8 million hectares) comprising about 1.18 per cent of India's land area. It has a long coastline of about 580 km, looking into the Arabian Sea.

Kerala has three distinct geographical divisions. The highlands, which slope down from the Western Ghats; the midland plains lying between the highlands and the lowlands, and made of undulating hills and valleys; and the lowlands comprising mostly coastal areas. Despite being small, Kerala is blessed with numerous water bodies comprising small rivers, rivulets and lakes.

The highlands, close to the ghats, comprise steep mountains and deep valleys, covered with dense forests. Forty-one rivers out of a total of 44 originate from here. In the midland plains of the central region, the valleys have been developed as paddy fields and the elevated lands and hill slopes are converted into estates of rubber, fruit trees and other cash crops like pepper, areca nut and tapioca. Tea and coffee estates have also cropped up in the high ranges during the last two centuries.

The lowlands, mainly the coastal belt, are comparatively plain and comprise extensive paddy fields, thick groves of coconut trees and backwaters.

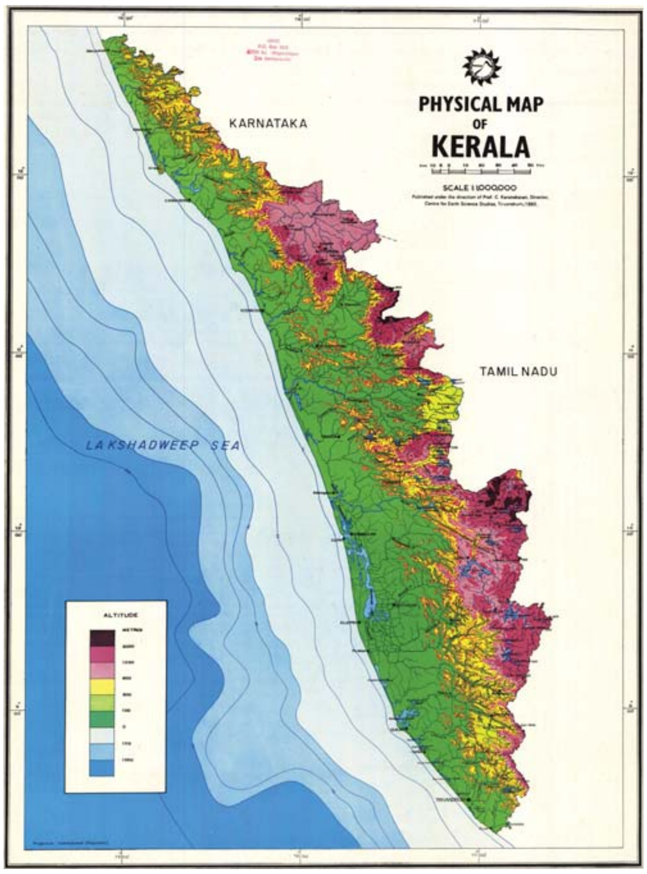
Kerala is also very rich from an ecological perspective. It has a total forest area of over 10,815 km (1.08 million hectares) covering 28 per cent of total land area. The forest cover of Kerala is spread over the Western Ghats, which is considered to be very rich in ecological diversity and is among the world's 18 biodiversity hot spots.

Administratively, Kerala has 14 districts and 63 talukas with a population of about 33.3 million (3.3 crore), out of which about 15.93 million (1.59 crore) live in urban areas. Considering the small size of the state, this population figure translates into a population density of 859 persons/km^2, which is among the highest in India. Figures 1.3 and 1.4 show the political and the physical map of Kerala respectively.

Figure 1.3: Political Map of Kerala: Districts[2]

[2] http://www.prokerala.com/kerala/maps/kerala-population-map.html.

Figure 1.4: Physical Map of Kerala[3]



Kerala came into existence in 1956 after the integration of the Malayalam-speaking former princely states of Travancore, Cochin and the Malabar district of the British constituted province of Madras. The freedom movement in Kerala saw increasing participation of farmers and workers as early as in 1920's, bringing the concept of mass participation very early in the political landscape. This grassroots-level participation was also the precursor to powerful left-wing politics that facilitated decentralization of authority and became a key to many social and economic reforms in the post-independence era. This political philosophy has been perhaps the biggest enabler of the present socio-economic fabric of the state.

Today Kerala represents, in many ways, an alternative development model where high human development indicators are decoupled from key economic indicators like industrial growth. Kerala is considered to have pioneered the approach towards the decentralization of development and governance, and has achieved significant milestones in literacy, healthcare, population control and poverty alleviation without ascribing to the tenets of industrial economy. In this sense, Kerala represents a set of contradictions that are antithetical to the conventional principles of development economics. Even though Kerala's model has been appreciated across the world for its high Human Development Index (HDI) score, problems remain with respect to energy supply, employment generation and food production, which require a fresh approach towards the development of the economy.

[3] http://annyann.blogspot.in/2011/11/dam-999-realistic-mullaperiyar.html.

2. BRIEF OVERVIEW OF CURRENT STATUS OF THE STATE'S ENERGY AND ENERGY RELATED SECTORS

This chapter provides a brief overview of key sectors that are related to energy. Most of the studies on energy use in the state primarily focus on electricity and very little emphasis is given to direct and indirect use of energy. In contrast, this study attempts to cover a variety of energy uses across sectors. The brief overview covered in this chapter forms the basis for subsequent analysis and assumptions that go into making future energy demand projections for the state.

2.1 POWER

The growth of the power sector in Kerala has been very lopsided. At present, the state's power mix is dominated by hydro (71 per cent of the installed capacity of 2,857 MW as on 31 March 2011). Historically, hydro power has been the major energy source for the state. Table 2.1 shows the trend of increase in installed capacity over the years.

Table 2.1: Growth in Installed Capacity in Kerala (Year-wise)[4]

Year	Installed Capacity in MW			
	Hydel	Thermal (Incl. IPPs)	Wind	Total
1980-81	1,012	0	0	1,012
1990-91	1,477	0	0	1,477
1999-2000	1,743	594	2	2,339
2005-06	1,850	592	2	2,443
2010-11	1,995	617	35	2,647
2011-12	2,001	617	35	2,654

According to the Kerala State Electricity Board's (KSEB's) website, total installed generation capacity of Kerala as on 31 October 2012 was about 2,867 MW comprising 2,041 MW of hydro, 791 MW of thermal and about 35 MW of wind

[4] Application for approval of the Aggregate Revenue Requirement and Expected Revenue from Charges for the year 2013-14.
http://www.erckerala.org/userFiles/634932411702810000_OP.2%20ARR-ERC%20&Tariff%20petition%20of%20KSEB%202013-14%20(corrected).zip.

power. In addition, Kerala also gets an allocation of about 1,030 MW from central generating stations (thermal and nuclear). However, the situation is bound to change in the future with the state projecting additional generation requirement of about 1,000 MW during 12th five year plan period due to the scarcity of good hydro sites and large-scale environmental opposition against new hydro projects.

In order to meet the energy requirement of the state, KSEB proposes to add about 248 MW of new hydel capacity (with 741.85 MU annual generation), about 300 MW of solar PV and 200 MW of wind power on BOO (build-own-operate) basis during 12th plan period. It is learnt that the state has signed an MOU with National Thermal Power Corporation Limited (NTPC) to develop the proposed 200 MW wind capacity. In addition, the state is also planning to develop thermal projects using gas / liquefied national gas (LNG). However, these projects are at a very preliminary stage.

At present about 55 per cent of the peak demand and 35 per cent of the energy requirement is being met from hydel plants whose energy availability projection is based on normal monsoon. However, environmental deterioration of rivers due to deforestation in the catchments and extensive sand mining along with erratic monsoon have resulted in reduction of reservoir levels, significantly curtailing the hydro generation capacity of the state.

On the supply side, out of the total installed capacity of 2,873 MW during 2011-12, hydel contributed the major share of 2,045 MW (71 per cent), while 793 MW was contributed by thermal projects including the one by NTPC at Kayamkulam (Kerala's dedicated thermal station) and Kanjikode wind farm at Palakkad has contributed 2 MW. Wind energy from IPP is 33 MW. Additional capacity generated during 2011-12 was only 15 MW (0.53 per cent) that is 2,873 MW in 2011-12 against 2,858 MW in 2010-11. Table 2.2 below indicates the break-up of the installed power capacity in the state. Table 2.3 shows the break-up of hydro capacity for the state.

Table 2.2: Installed Capacity as on 31 October 2012

Source	Installed Capacity (MW)
KSEB	
Hydro Electric Power Plants	1,997.8
Thermal Power Plants	234.6
Wind Plants	2.03
Sub Total:	**2,234.4**
NTPC/IPP/ CPP in the State	
Small Hydro Electric Power Plants (IPP & captive)	43
Thermal Power Plants (IPP)	198.93
Wind Plants	32.85
NTPC Kayamkualm	359.6
Sub Total:	**633**
Total MW in Kerala	**2,872**

Table 2.3: Break-up of Hydro Capacity in the State

KSEB Plants (Large Hydro)				
Sr. No	Name of HEP	Installed Capacity		Total Capacity
		No of Units	MW	(MW)
1	Idukki	6	130	780
2	Sabarigiri	6	5 x 55 MW + 60 MW	335
3	Idamalayar	2	37.5	75
4	Sholayar	3	18	54
5	Pallivasal	6	3 x 4.5 MW + 3 x 8 MW	37.5
6	Kuttiyadi	6	3 x 25 MW + 3 x 50 MW	225
7	Panniar	2	15	30
8	Neriamangalam	4	3 x 17.55 MW + 25 MW	77.65
9	Lower Periyar	3	60	180
10	Poringalkuthu & PLBE	5	4 x 8 MW +16 MW	48
11	Sengulam	4	12	48
12	Kakkad	2	25	50
	Sub Total (HEP)	**49 Nos**		**1,940.2**
KSEB Plants (Small Hydro)				
13	Kallada	2	7.5	15
14	Peppara	1	3	3
15	Malankara	3	3.5	10.5
16	Madupatty	1	2	2
17	Malampuzha	1	2.5	2.5
18	Lower Meenmutty	3	1 x 0.5 MW +2 x 1.5 MW	3.5
19	Chembukadavu - 1	3	0.9	2.7
20	Chembukadavu - 2	3	1.25	3.75
21	Urumi -1	3	1.25	3.75
22	Urumi -2	3	0.8	2.4
23	Kuttiyadi Tailrace	3	1.25	3.75
24	Poozhithode SHEP	3	1.6	4.8
	Sub Total (SHEP)	**29 Nos**		**57.65**
	Total (Large + Small Hydro)	**78 Nos**		**1,998**
IPP (Small Hydro)				
25	Maniyar (CPP)	3	4	12
26	Kuthungal (CPP)	3	7	21
27	Ullunkal (IPP)	2	3.5	7
	Sub total	**8 Nos**		**41**
			Total Hydro	**2,039**

In terms of energy, the statistics provided in the Table 2.4 below are a good reflection of the power situation in the state.

Table 2.4: Key Operational Statistics of KSEB

Generation & Sale of Energy		
1	Generation Capacity (As on 31.3.2012)	2,874.78 MW
2	Connected Load	17,518.42 MW
3	Maximum Demand	3,348 MW
4	KSEB's own generating stations	8,303.43 MU
5	Independent power producers (IPP)	715.66 MU
6	Captive power producers (CPP)	88.35 MU
7	Import (CGS, UI, Traders, etc.)	9,927.20 MU
8	Others	125.96 MU
9	Ex. Bus Energy	19,160.60 MU
10	External Sales	201.1 MU
11	Aux. Consumption	13.54 MU
12	Net System Input Energy For Sale	18,946.29 MU
13	Units Sold	16,181.63 MU
14	Consolidated T&D Losses	15.65%
15	Consumer Strength (By end 2012-13)	106.9 Lakhs
16	Per Capita Consumption	502 kWh

The above table suggests that KSEB's own generation accounts for about 44 per cent of the total energy sold, while 52 per cent comes from central generating stations, traders and UI pool, often at higher prices.

On the consumption side, the bulk of electricity is consumed by domestic consumers. Table 2.5 summarizes the energy consumption categories for power.

Table 2.5: Energy Consumption Profile for Various Sectors Across Years (All values in MU)[5]

Category	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Domestic	4,668.35	5,213.15	5,602.85	5,931.27	6,559	6,877.83	7,705.86
Commercial	1,470.53	1,676.9	1,885.12	2,080.37	2,486	2,707.95	3,007.84
Industry	2,236.16	2,370.37	2,444.89	2,341.75	2,514.09	2,569.55	2,692.82
Agriculture	199.11	229.6	239.78	233.98	265	239.56	294.29
Utilities	207.78	228.74	248.56	294.32	303	265.68	294.26
Transport (Rail)	57.94	72.16	109.26	142.07	165	156.39	154.49
Others	1,429.91	1,540.08	1,519.39	1,390.56	1,679	1,730.94	1,830.97
Total	**10,269.77**	**11,331**	**12,049.85**	**12,414.32**	**13,971.09**	**14,547.9**	**15,980.53**

[5] Ibid.

Figure 2.1: Consumer Category-wise Breakup of Electricity Consumption in 2011-12

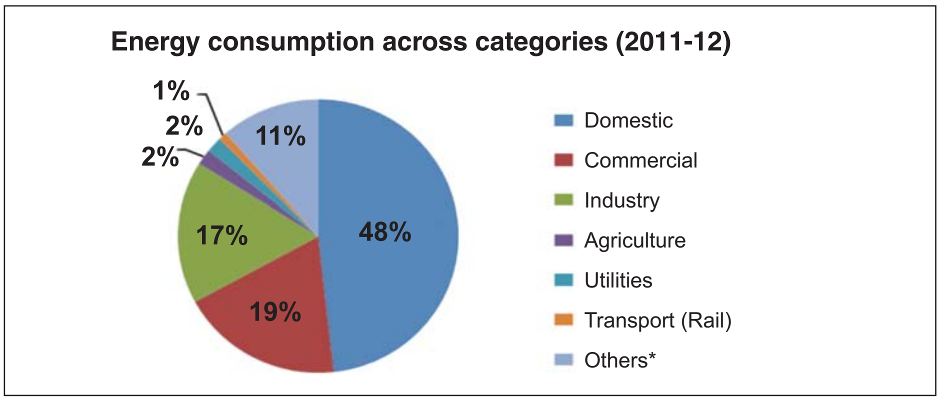


Figure 2.1 shows the sector-wise breakup of energy consumption in percentage terms for 2011-12 in terms of a pie chart.

Past trend in consumption indicates a very high growth in the demand for energy in the domestic and commercial sectors, which together account for about 67 per cent of the total energy consumption. Considering the rapid pace of urbanization, increasing affluence and a fast growing services sector, the possibilities of the demand letting up in these sectors seems to be remote. In fact, according to the Central Electricity Authority's (CEA's) Eighteenth Electric Power Survey (EPS) demand projections for the state indicate an increase in this share to about 70 per cent by 2021-22 (13.72 BU for domestic and 7.2 BU for commercial sectors out of the total estimated demand of 29.7 BU).

In this scenario, the best measure for the state could perhaps be an aggressive and planned transition to renewable sources. According to the Ministry of New and Renewable Energy (MNRE), the non conventional energy potential of the state includes wind potential of around 1,000 MW, biomass potential of around 762 MW and small hydro power (SHP) potential of around 704 MW. While for other RE technologies like solar, offshore wind, biofuels and ocean, no comprehensive potential assessment exercise has been done till date.

Part II of this report tries to reassess the potential of renewable resources in the state in a more comprehensive manner.

2.1.2 Policies, Legislations and Regulations

Some of the key power sector policies including renewable policies and regulations are covered in brief here

Kerala Small Hydro Power Policy 2012

The 'Kerala Small Hydro Policy 2012' envisages a targeted 150 MW SHP capacity addition during the plan period 2013-17 with the help of private sector participation. The current policy is notified almost a decade after conducting the first round of competitive bidding process for allotment of SHP projects to private investors during 2003-04, when the anticipated SHP capacity addition was not achieved.

The Kerala SHP policy 2012 has stringent approval and permission requirements, and specifies a built-own-operate-transfer (BOOT) period of 30 years from the date of allotment of the SHP project. The policy provides for construction of evacuation line beyond the interconnection point by the SHP investor, but such cost is allowed to be included as part of the capital cost. The total financial support provided under this policy is about Rs 12,000/kW for projects above 100 kW and up to 1000 kW and Rs 1.20 Crores (for 1st MW + Rs 20 lakh for each additional MW) for projects above 1 MW and up to 25 MW.

ANERT: 10,000 Roof-top Solar Power Plants Scheme 2012-13

Kerala has become the first Indian state to create a very ambitious project to generate over 10 MW of solar power from 10,000 roof-top solar power systems of 1 kWp each. Any household with 15 m^2 of sunny rooftop area can register for this programme.

For an approximate system cost of Rs 250,000, central financial assistance of up to 30 per cent of the system costs and a state assistance of Rs 39,000 per system is made available as subsidy under this policy.

ANERT: Kerala Draft Solar Policy 2013

The Draft Solar Policy was announced in February 2013 and was expected to be put in effect by 1 April 2013. The main objective of the policy was to increase the installed capacity of the solar sector in the state to 500 MW by 2017 and 1,500 MW by 2030.

Some of the strategies identified to achieve the policy objectives are as follows:

1. **Financing:** For off grid systems the solar policy seeks to ensure bank finance at attractive rates. The government itself would initiate a programme by which all public buildings are provided with generation facilities using appropriate technology options. For grid connected systems in non-government buildings / premises, the incentives shall be on the basis of net metering, feed-in tariff and Renewable Energy Certificate mechanism, and appropriate tariff system by following due procedures. Grid connected systems will be promoted for domestic consumers in a phased manner after formulating grid connection standards for Low Tension distribution in line with the solar policy. Regarding PV and public place installations a wider community ownership model with direct financial stake by the public will be encouraged.

2. **Legal and regulatory framework:** The state will support the formulation of a regulatory environment, legally enforcing use of electricity from solar sources. A tariff incentive for consumers opting for solar generation shall be offered, in addition to incentives for people's representatives / panchayats for promoting solar installations and street light optimization. Incentive schemes for conversion of existing inverter installations to solar, solar procurement obligation (SPO), will be mandated for commercial consumers. All new domestic buildings having a floor area of more than 2,000 ft^2 should install solar water heater and solar PV system. About 5 per cent of the energy usage for common amenities should be from solar in residential flats. Use of solar water heating system shall be made mandatory for star hotels, hospitals, residential complexes, etc.

3. **Procurement Policy on Grid Connected Solar Plant:** KSEB will have first right of refusal for the power from plants established in private lands / premises, except in cases of self / captive use. In such cases the sale of power to KSEB shall be as per tariff decided by KSERC or at the pooled cost of the power purchase of the utility or net metering.

4. Reservation of land for the renewable projects.

ANERT: Solar Thermal Programme 2011-12

The main activities under the Solar Thermal Programme 2011-12 are implementation and propagation of solar thermal devices, like solar water heating systems and solar drying systems in the state. The supporting mechanisms involve a mix of state and central based (MNRE) subsidy.

Kerala State Electricity Regulatory Commission (Renewable Purchase Obligation and Its Compliance) Regulations, 2010

As per this regulation, every obligated entity shall purchase not less than 3 per cent of its consumption of energy from RE sources under the Renewable Purchase Obligation (RPO) from 2010 with annual increase of 10 per cent over the base value of 3 per cent per year up to a maximum RPO limit of 10 per cent.

2.2 TRANSPORT

Kerala, being a long and narrow coastal state with high population density, has enormous problems in land allocation for transportation corridors. The eastern length of the state is under forest cover and spans over mountainous terrain, making it infeasible for the development of a North-South corridor due to both cost and environmental considerations. The coastal plain region of Kerala already has two parallel corridors – road and rail. Kerala is one of the few states where all the four modes of transport (road, rail, water and air) are available and are actually used. However, road transport accounts for a bulk of passenger and freight traffic.

The total length of the roads in Kerala is 151,652km.[6] Table 2.6 shows jurisdiction wise distribution of road length in 2010-11 in Kerala.

Table 2.6: Agency-wise Distribution of Road Length in Kerala in 2010-11

S.No	Department	State Road Length (Km)	Percentage
1	Panchayats	104,257	68.748
2	PWD (R&B)	23,242	15.32
3	Municipalities	8,917	5.88
4	Corporations	6,644	4.381
5	Forest	4,075	2.689
6	Irrigation	2,664	1.757
7	CPWD (NH)	1,542	1.006
8	Others (Railway, KSEB)	3,28	0.216
	Total	**151,652**	**100**

[6] State Planning Board, Kerala. 2012. *Economic Review* 2011. Thiruvananthapuram, Kerala. Chapter 11 – Transport.

The table clearly suggests that almost 69 per cent of the road length service (panchayat areas) may be dominated by passenger transport rather than freight transport. In the road transportation sector, most of these vehicles have registered more than 5 per cent compound annual growth rate (CAGR) over a period of 2000-01 to 2011-12. Not surprisingly cars have shown the highest CAGR of 14.26 per cent, followed by three wheelers and tempos for goods carriage, which witnessed a CAGR of 13.57 per cent between 2000-01 and 2011-12. Two wheelers (motor cycles / scooters) have shown a CAGR of 12.3 per cent, while omni buses have shown 10.73 per cent CAGR. The lowest CAGR of 0.52 per cent has been recorded by jeeps.

In terms of vehicle penetration, from 2000-01 to 2011-12, the number of cars per 1,000 persons have increased from 8 to 36 cars, while the number of two wheelers increased from 36 to 123 motor cycles / scooters. Interestingly, two wheelers and cars account for more than 60 per cent of the share of total registered vehicles. The Table 2.7 below shows the increase in vehicle penetration over the past years.

Table 2.7: Number of Vehicles per 1,000 Persons

Categories	2000-01	2011-12
Four wheelers and above	4.46	9.64
Three wheelers and tempos	0.99	3.84
Stage carriages	0.38	0.79
Contract carriages and omni buses	1.27	3.71
Cars	8.89	36.69
Taxi cars	2.38	5.25
Jeeps	2.19	2.2
Autorickshaws	7.8	17.2
Motor cycles	36.17	123.45
Tractors and tillers	0.4	0.4
Trailers	0.05	0.07

Source: Motor Vehicles Department, Kerala, http://www.keralamvd.gov.in

Kerala's railway operation is carried out by three railway divisions, viz., Thiruvananthapuram, Palakkad and Madurai. Total railway route in Kerala is about 1,257 km;[7] 1.95 per cent of India's total railway route of 64,600 km. According to information available on the Indian railways website, the state railways is 51 per cent electrified (as against the national railways electrification of 31 percent).[8] According to financial statement and operational statistics of the Indian railways, Kerala's railway passenger traffic has increased from 9.55 to 21.11 billion km, with a CAGR of 8.25 per cent between 2001-02 and 2011-12. The state's railway freight traffic increased from 2.41 to 7.18 billion net tonnes km between 2001-02 and 2011-12, with a CAGR of 11.55 per cent.[9]

[7] Ibid.

[8] Website of the Indian Railways, government of India. http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,366,532,565

[9] Planning Commission. 2007. *Report of the Working Group on Transport for 11th and 12th Five Year Plan*. Government of India. New Delhi, India.

Water transportation in Kerala uses both inland and coastal routes. Kerala has 590 km of coastline and 17 intermediate and non-major ports, in addition to the largest port at Cochin. Compared to the road network, the total length of inland waterways is around 1,687 km.[10] The Kollam-Kottapuram stretch of West Coast Canal along with Champakara and Udyogmandal canals (205 km) in Kerala is one of the three national waterways declared by the government of India. In Kerala, coastal movement has grown at a CAGR of 1.25 per cent during the period 2001-2010.[11] However, inland water transportation (IWT) system remains the main mode for passenger movement by water. Kerala has 1,687 km of inland water transport route network which consists of national waterway number 3.[12] State Water Transport Department (SWTD) and Kerala Shipping and Inland Navigation Corporation Ltd. (KSINC) are engaged in inland water transportation. However, KSINC no longer offers passenger services and is now only involved in freight movement and operates more than 10 barges for movement of bulk and liquid cargo through the inland waterways of the state. On the other hand, the bulk of passenger services is carried out by the SWTD. The SWTD operates 81 passenger boats spread across 14 stations, covering 7,900 km per day. Districts covered by passenger ferry service are: Ernakulam, Alappuzha, Kottayam, Kollam and Kannur.[13]

There are three international airports in Kerala at Cochin, Calicut and Thiruvananthapuram. The total flights (both domestic and international) operated from Kerala increased from 44,033 in 2007 to 82,010 in 2012; while domestic flight operations in Kerala have increased from 22,710 to 42,296 between 2007 and 2012.[14] At the same time, Kerala's share in India's domestic flights has also increased from 2.6 per cent in 2007 to 3.99 per cent in 2009.

2.2.1 Energy Use in Transport

No data on energy use in the transport sector are available and hence a comprehensive bottom-up assessment is done in Part 3 of this report.

2.2.2 Policies, Legislations and Regulations

The *Draft Transport Policy for Kerala* prepared by the National Transportation Planning and Research Centre (NATPAC), Thiruvananthapuram has been submitted to the Transport Department, government of Kerala in 2011. The main thrust of the policy was to increase the share of public transportation and discourage the huge growth of private vehicle based transportation.

The vision of the policy was "shaping a modern, efficient, economical and safe transportation system, connecting various growth regions in the state, to meet the

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[10] State Planning Board. 2012. *Economic Review 2011.* Government of Kerala. Thiruvananthapuram, Kerala. Chapter 11.
[11] Deloitte. 2011. *Preparation of Strategy Road Map cum Action Plan for Development of Coastal Shipping in Kerala.* Submitted to the Directorate of Ports, government of Kerala. Deloitte Touche Tohmatsu India Private Limited, Valiyathura.
[12] NATPAC. 2011. *Draft Transport Policy for Kerala.* Submitted to the Transport Department, government of Kerala. National Transportation Planning and Research Centre. Thiruvananthapuram, Kerala.
[13] State Planning Board. 2012. *Economic Review 2011.* Government of Kerala. Thiruvananthapuram, Kerala. Chapter 11.
[14] Ibid.

faster mobility needs of all Keralites by 2025".[15] The overall objective of the draft policy was to evolve schemes to meet, in a phased manner, the requirements of faster mobility, safety, access to social and economic services and minimizing the impact of negative externalities. The major strategies envisaged in the policy to meet the above objective were: providing quality infrastructure support for improving the connectivity and transportation of humans and goods to sustain high growth rate of GDP; developing integrated and multimodal transport system with emphasis on mass rapid transport, such as railways and metros at regional / city level; promoting public transport and requisite quality of service to discourage personalized transport; promoting quality and productivity of goods transportation and infrastructure; and promoting sustainable road transport with special emphasis on energy efficiency, environmental conservation and least negative social impact. Besides this draft transport policy, recently the government of Kerala is also planning to formulate a coastal shipping policy for movement of goods through waterways and government will provide incentives to users.

The highlights of the draft transport policy are given below.

- Share of public transport to increase to 80 per cent by 2025 from the existing 33 per cent.
- Increase in the share of Kerala State Road Transportation Corporation (KSRTC) buses in total stage carriage to 50 per cent by 2025 from present 27 per cent.
- Goods transportation will be done through intermodal freight transportation; the necessary infrastructure will be strengthened, and multi-axle trucks and container transport will be encouraged.
- Discourage use of personalized vehicles from the perspective of road safety, fuel economy and clean environment standard.
- Improve railway connectivity through implementation of high-speed north-south railway corridor, dedicated rail freight corridor and development of multimodal logistics park.
- Promote goods and tourist traffic through inland waterways by linking inland feeder canals with the national waterway no. 3.

2.3 AGRICULTURE

Kerala has been undergoing structural changes in the way agriculture is conducted in the state. Kerala has seen steady decline in the area under cultivation of important food crops namely paddy, pulses and tapioca from the mid-1970s. Out of a gross cropped area of 20.71 lakh ha in 200-11[16] (about 53 per cent of total the geographical area of the state), food crops, comprising rice, pulses and tapioca, occupy only 11.74 per cent of the cropped area. About 18.22 lakh ha (88 per cent of the total cropped area of the state) being used for commercial crops. In 2010-11, the area under food crops reduced further to 8.13 per cent. Table 2.8 gives the area and production of principal crops in Kerala.

[15] NATPAC. 2011. *Draft Transport Policy for Kerala.*
[16] State Planning Board. 2012. *Economic Review 2011.*

Table 2.8: Area and Production of Principal Crops in Kerala

S. No	Crops	Area (ha)		Production (MT)	
		2009-10	2010-11	2009-10	2010-11
1	Rice	234,013	213,185	598,337	522,739
2	Pulses	4,449	3,823	3,390	2,908
3	Pepper	171,489	172,182	28,497	45,267
4	Ginger	5,408	6,088	28,603	33,197
5	Turmeric	2,438	2,391	6,066	6,216
6	Cardamom	41,593	41,242	7,800	7,935
7	Areca nut	99,188	99,834	116,763	99,909
8	Banana	51,275	58,671	406,242	483,667
9	Other Plantains	47,802	49,129	338,546	353,772
10	Cashew nut	48,972	43,848	35,818	34,752
11	Tapioca	74,856	72,284	2,525,384	2,360,081
12	Coconut	778,618	770,473	5,667	5,287
13	Coffee	84,796	84,931	59,250	65,650
14	Tea	36,845	36,965	57,810	57,107
15	Rubber	525,408	534,230	745,510	770,580

Source: State Planning Board. 2012. *Economic Review 2011*. Chapter 6 - Agriculture and Allied Sectors. 124-25pp.

2.3.1 Energy Use in Agriculture

Electricity consumption in the agriculture sector constitutes 2 per cent of the total electricity consumed in the state in 2007-08. Annual electricity sale to the agriculture sector constitutes 0.24 BU in 2007-08. One of the major areas of energy consumption in the agricultural sector is water pumping. The population of agricultural pump-sets is around 4.3 lakh, accounting for an annual consumption of 0.24 BU. Another area of major energy use in agriculture is fertilizers. Nitrogen, Phosphorous and Potassium fertilizers generally termed as NPK fertilizers are the predominant fertilizers used in Kerala and the quantity consumed in the year 2009-10 was 264.89 lakh.[17]

2.3.2 Policies, Legislations and Regulations

The draft agriculture development policy of Kerala, drawn by a drafting committee, was submitted to the government on 11 July 2013. The policy provides a vision through which Kerala's agriculture should be guided.

Some of the major highlights of the draft policy are:

- Farm lands should not be put for any use other than farming activities, and the purchase of farmlands should be restricted for cultivators only.
- Identification and immediate utilization of cultivable wastes.

[17] State Planning Board. 2012. *Economic Review 2011*. Chapter 6 – Agriculture and Allied Sectors.

- Initiation of water budgeting on a watershed basis.
- Popularization of micro-irrigation technology.
- Water harvesting measures to be put in place: farm ponds and *thalakkualams,* use of sub-surface dykes for ground water recharge, etc.
- Encourage custom hiring operation for tractors, power tillers and farm machinery through training, financial incentives, subsidized loans and adequate financing to allow procurement of high capacity equipments by custom operators to ensure sufficient turn over and income.
- Financial incentive for replacement of inefficient equipments in place of improved tools and implements.
- Exemption from import duty and value added tax (VAT) for agricultural machineries and implements.
- Use of solar, wind and hybrid technology based high-volume output pumps along the bunds of these *padasekaharams*.

2.4 INDUSTRY

The manufacturing sector in Kerala is typically limited to a few cement, mining and chemicals manufacturing units under both private and state ownership. Table 2.9 below shows the number of key manufacturing units in the state in terms of sectors.

Table 2.9: Key Manufacturing Units in Kerala in Different Manufacturing Sectors

Sr. No.	Sector	No. of Units
1	Chemical	6
2	Ceramics & Refractories	2
3	Development & Infrastructure	3
4	Electrical Equipments	4
5	Electronics	3
6	Engineering	6
7	Textiles	7
8	Traditional & Welfare	5
9	Wood & Agro based	1
	Total	**37**

Out of the total manufacturing units in the state, there are only about eight units comprising four sectors that are large-scale in operation. Table 2.10 captures large scale manufacturing units in the state.[18]

According to the *Economic Review 2011,* the contribution of the manufacturing sector to gross state domestic product (GSDP) at constant and current prices in 2010-11, was 8.28 per cent and 9 per cent respectively.[19]

[18] State Planning Board. 2012. *Economic Review 2011.* Chapter 7 – Industry and Allied Sectors. p. 3.
[19] Ibid.

Table 2.10: Designated Large Industrial Consumers in Kerala

Industrial sector	Designated Consumer in Kerala
Cement	Malabar Cement Ltd.
Chlor-Alkali	Travancore Cochin Chemicals Ltd.
Paper & Pulp	Hindustan News Print Ltd.
Fertilizer	The Fertilizer and Chemicals Travancore Ltd.
Textiles	GTN Textiles Ltd. Patspin India Ltd. Sri Asoka Textiles Ltd. The Western Indian Cottons Ltd.

Kerala has also developed significantly in the services sector, which is dominated by IT and ITES. The state has Technopark at Thiruvananthapuram and Infopark at Kochi. A cyberpark at Kozhikode is under construction. In addition, the state also has many private IT parks such as Smart City-Kochi, L&T Park-Kochi, Leela Info Park Trivandrum, Brigade Park, Kochi and Muthoot Pappachan Technopolis, Kochi. Some of the key private players in the services sector are Tata Consultancy Services, Infosys, iGATE Patni and RR Donnelley India Outsource Pvt. Ltd.

However, in terms of numbers, the bulk of industry in Kerala state is mainly agro-based and comprises traditional industries like cashew, coir, handloom, handicrafts and khadi. These industrial units are typically small but large in numbers. According to the *Economic Review 2011,* the total number of functional micro, small and medium enterprises (MSME) registered in Kerala was 194,908 as on March 2011. With a total investment of US$ 1.9 billion, these units employ 941,981 people and produce goods and services worth US$ 35.98 billion.[20]

The following narrative tries to capture the brief statistics on key-industry sectors

Coir Industry: The coir Industry is the largest agro-based traditional cottage industry in Kerala. The industry accounts for 95 per cent of the total coir and coir products produced in India. It provides livelihood to nearly 3.50 lakh people. Almost 80 per cent of coir factories in the state are in the Alappuzha district. The state has three coir parks, two at Alappuzha and one at Perumon, in Kollam. The USA is the largest importer of coir products from India followed by the Netherlands, the UK, Germany, Italy, Spain, etc.

Handloom Industry: Kerala's textile industry comprises traditional handloom industry, such as weaving and spinning. The handloom industry in Kerala employs about 100,000 people. The industry is mainly concentrated in Thiruvananthapuram and Kannur districts, and in some parts of Kozhikode, Palakkad, Thrissur, Ernakulam, Kollam and Kasaragod. The Industry is dominated by the cooperative sector, which covers 94 per cent of total looms. The remaining six per cent of handloom units are owned by industrial entrepreneurs. The overall production of handloom cloth by the handloom industry was 25.55 million metres in 2010-11, valued at US$ 40.0 million.

Powerloom Industry: The four integrated power loom cooperative societies in the state are at Calicut, Wayanad, Neyyattinkara and Kottayam. There were 4,120

[20] Ibid. p. 7.

power looms in the state in 2009-10, of which 844 looms were in the cooperative sector. In 2009-10, the production of cloth through power loom societies was 38.10 lakh metres, with a productivity of about 4,514 meter/loom.

Cashew industry: Kerala has a long tradition both in cashew cultivation and cashew nut processing. The production of raw cashew nuts in Kerala witnessed an upward trend; in increased from 66,000 MT to 71,000 MT between 2009-10 and 2010-11.

Mining: Kerala is endowed with a number of mineral deposits, such as heavy mineral sands (ilmenite, rutile, zircon, monazite, sillimanite), gold, iron ore, bauxite, graphite, china clay, fire clay, tile and brick clay, silica sand, lignite, limestone, lime shell, dimension stone (granite), gemstones, magnesite, steatite, etc. However, large scale mining activities are confined mainly to a few minerals – heavy mineral sands, china clay and to a lesser extent limestone / lime shell, silica sand and granite. In fact, heavy mineral sand and china clay contribute more than 90 per cent of the total value of major mineral production in the state. However, 75 per cent of the mineral revenue comes from minor minerals.

Food processing: The food processing industry in Kerala is considered as priority sector and is growing at a very fast pace. The industry has a lot of potential for future growth and possibilities of generating employment at a very high. Kerala Industrial Infrastructural Development Corporation (KINFRA) has already set up about 7 food theme based parks. Additionally various industrial units are also established to suit the specific need of the food processing industry.

2.4.1 Energy Use in Industry

Even though the figures for electricity use in the food processing industry are available, no comprehensive data on industry heat requirements exist. *Part III of this study attempts to assess the Industrial heat demand in the food processing industry*.

2.4.2 Policies, Legislations and Regulations

The Kerala government has released the draft Industrial and Commercial Policy 2011 with the vision: "to transform Kerala into a vibrant and dynamic entrepreneurial society with faster, inclusive and sustainable economic growth in order to achieve global standards in every domain."[21]

The major highlights of the draft policy are:

- Encourage establishment of non-polluting, environmental / eco-friendly and employment oriented industries that have the potential to pay wages at par with the living standards of Kerala.
- Promotion of new industrial parks with quality infrastructure like roads, power, water, waste management, etc., and to upgrade the infrastructure facilities in existing development areas / development plots.
- Protect new micro and small industrial units from tariff hikes for a period of three years from the commencement of commercial production.

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[21] Government of Kerala. Draft Industrial and Commercial Policy 2011. http://kerala.gov.in/docs/policies/draftic_policy11.pdf.

- Provide equity assistance to new units in place of state investment subsidy and margin money loan scheme.
- Exemption from payment of earnest money deposit (EMD) and security deposit, and price preference to MSMEs for a period of five years.
- Encourage public private partnership (PPP) in value added products.

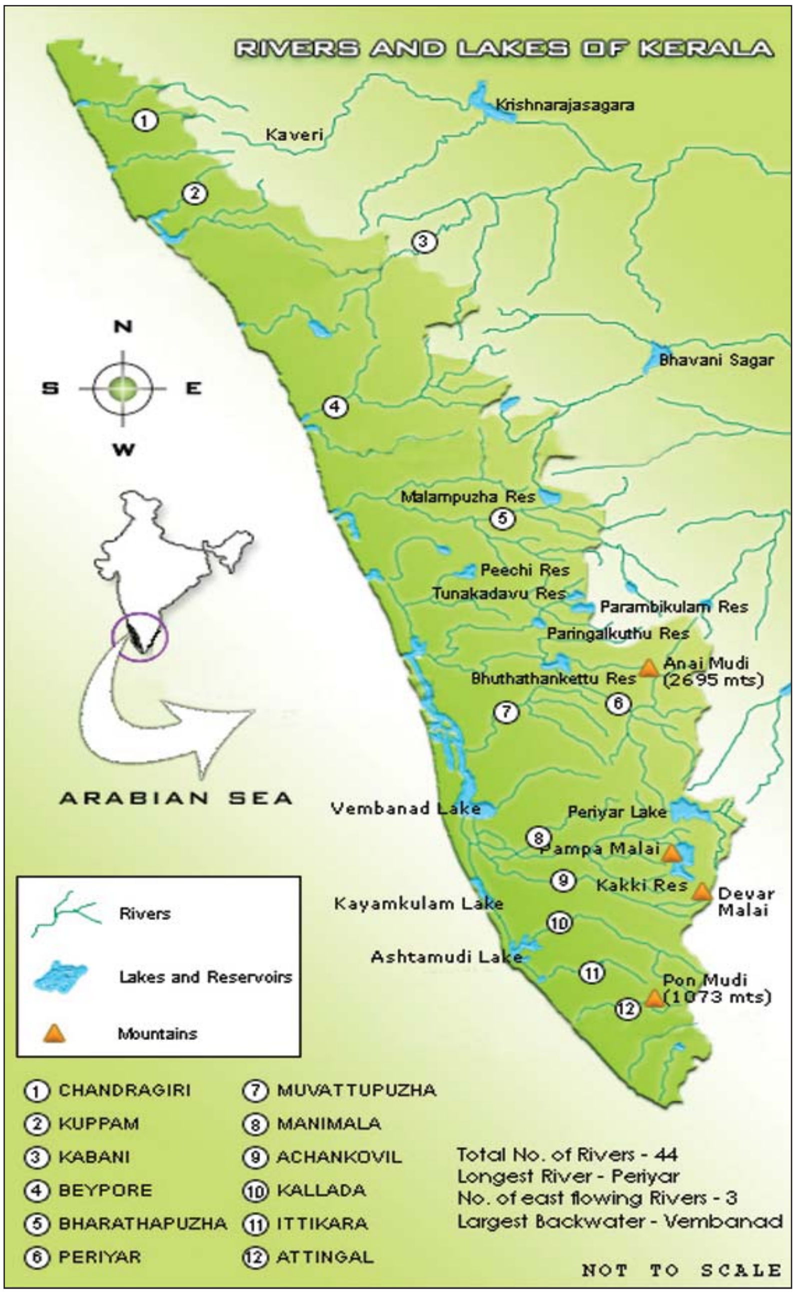
2.5 WATER

Kerala is abundantly blessed with water resources. There are around 44 rivers in Kerala of which 3 are east flowing which form a major source of water resource for the state. Surface irrigation constitute the major chunk of irrigation infrastructure in the state. There are 18 dams in the state intended for irrigation; out of which 14 have storages and the remaining are barrages.

Figure 2.2: Dams in Kerala[22]

[22] http://www.prokerala.com/kerala/maps/kerala-dams.htm.

Figure 2.3: Rivers and Lakes of Kerala[23]



The 44 rivers of Kerala have an average length of 80 km and a watershed area of 700 km^2. Rivers of Kerala are comparatively small and being entirely monsoon-fed, some of them practically turn into rivulets in summer, especially in the high elevation areas.

The average annual rainfall of the state is 3,000 mm, the bulk of which (about 70 per cent) is received during the South-West monsoon which sets in by June and extends up to September. The state also gets rains from the North-East monsoon between October and December. The major portion of the runoff through the rivers takes place during the monsoon season.

[23] http://www.prokerala.com/kerala/maps/kerala-river-map.htm.

Ground Water Resource of Kerala

Groundwater has been the mainstay for meeting the domestic needs of more than 80 per cent of rural and 50 per cent of urban population, besides fulfilling the irrigation needs of around 50 per cent of irrigated agriculture. However, recent surveys and studies indicate an alarming drop in the water level and water quality.

2.5.1 Policies, Legislations and Regulations

The following narrative briefly covers the main policies initiatives of the government of Kerala.

Kerala Water Policy 2008

The Kerala Water Policy[24] was designed with the objectives of integrated and multi-sectoral approach for planning, development and management of water resources; optimal utilization of water resources taking micro watershed as the basic unit of conservation; emphasize the importance of comprehensive watershed conservation and management plan; water quality management and water resources plan; appropriate institutional mechanism and legal measures for sustainable water resource management and development. The policy has defined sector-wise water use priority as domestic, agriculture, power generation, agro-based industrial use, and industrial and commercial use. Watershed based conservation, development and management of water resources has been identified as a necessity for Kerala. A well-defined transparent system of water entitlement has to be established according to the guidelines accepted by the people.

Kerala Ground Water (Control and Regulation) Act, 2002

The Act[25] was enacted in 2002 for the purpose of conservation of ground water and for the regulation and control of its extraction and use in the state. The situation of intense extraction of ground water created several environmental problems and therefore the Act was needed to protect the precious resource. The Act bestows the controlling power in relation to the development of ground water to the State Water Authority. The government, along with the recommendations of the State Water Authority, can notify any area in order to regulate the extraction of ground water. Any indivudual, who need to dig a well or convert the existing well into pumping well in the notified area, has to submit an application to the authority for the grant of a permit for the purpose. Owners of the existing wells in the notified areas also have to apply for a registration. All ground water users in the state require registration with the authority. To protect public drinking water sources, digging of wells within thirty metres of any public drinking water source is prohibited. Depending upon the situation, the authority can change the conditions given in permit or registration and even has the power to cancel the permit or registration previously issues. The Act has penalty provisions for not following the rules framed under the Act.

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[24] Water Resources Department. 2008. *Water Policy 2008.* Government of Kerala. Thiruvananthapuram, Kerala. http://kerala.gov.in/docs/policies/wp_08.pdf.

[25] Kerala Ground Water (Control and Regulation) Act, 2002. http://www.cseindia.org/userfiles/KeralaGWact.pdf.

Kerala Protection of River Banks and Regulation of Removal of Sand Act, 2001

In order to protect the rivers from large scale river sand degrading and to shield the biophysical environment of river systems, the government of Kerala has enacted an Act, namely the Kerala Protection of River Banks and Regulation of Removal of Sand Act, 2001.[26] As per the provisions under the Act, the government establishes district level expert committees (DLEC) under the chairmanship of the district collector, and Kadavu committees under the chairmanship of the President of respective grama panchayat or chairman of respective municipality. The identification of Kadavus of river banks from where sand removal can be permitted and the total quantity of sand that can be removed with due regard to the guidelines of the expert agencies are regulated by DLEC. The Act envisages the preparation and implementation of River Bank Development Plan for the upkeep of the biophysical environment of rivers using River Management Fund.

2.6 BUILDINGS AND MATERIALS

While building and materials do not use energy directly, they have very strong linkages with the overall energy use. Typically, buildings represent invested energy, which may be a magnitude more than that is used by other sectors. But the reasons the actual energy footprints of buildings are not understood are related to the myriad forms in which buildings influence energy use. For example, energy footprint of a building start right from the mining operation at site followed by energy use in raw material transport, in material processing and in final transport and use at site. Interestingly, for buildings, the actual energy footprint extends even beyond the construction phase in the way energy use is spread out within the built enclosure. It is in this context, that buildings and materials are considered as a major energy influencers in this study.

Traditional buildings of Kerala adopted a mixed mode of construction. The stonework was used for plinth and laterite was used for building walls. The roof structure consisted of timber frame which was covered with palm or coconut leaf thatching. Tiles were used only for palaces or temples. The exterior of the laterite walls were either left as it is, or plastered with lime mortar. Mud construction was also one of the most common methods of making cost effective and sustainable habitat in the ancient days in Kerala. Locally available building materials for construction in Kerala were stone, laterite, timber, clay and palm or coconut leaves. Granite availability is restricted mostly to the highlands only and laterite was predominantly used for construction in low lands.

However, from 1960s onwards, there was a considerable change in building material use pattern in Kerala, with traditional building materials like lime, mud, grass, thatch, bamboo, and wood, being replaced with modern materials like burnt bricks, stone, tiles, concrete and other metal sheets.

Many advocates of traditional building methods still work in the state to support and promote traditional building methods that emphasized use of locally available

[26] Kerala Protection of River Banks and Regulation of Removal of Sand Act, 2001. http://www.old.kerala.gov.in/dept_revenue/revenue.pdf.

materials. One early advocate of this movement was Mr. Laurie Baker, a well-known British-born architect, who had settled in Kerala. Based on his principles, alternative technology (AT) initiatives and institutions like Centre of Science and Technology for Rural Development (COSTFORD) and Kerala State Nirmithi Kendra (KESNIK) came up.

COSTFORD: Centre of Science and Technology for Rural Development is involved in promoting construction activities using appropriate building technologies. Its main focus is empowering communities by promoting local level planning and development, and improving the standard of living of people with implementation of appropriate and people-friendly technologies.[27]

KESNIK: The main activities of KESNIK are dissemination of cost effective and environment friendly (CEEF) technology especially by constructing public buildings using this technology; training in alternative housing and building material technologies by effective usage of locally available building materials; providing advice and guidance to the government on emerging housing concepts and policies; implementing CEEF technologies by undertaking construction and consultancy projects. Major activities undertaken by KESNIK are construction and consultancy, production of CEEF materials, building material testing labs and training.[28]

The main features of CEEF are use of: hollow concrete blocks, concrete door and window frames; rubble filler blocks; funicular shell to take up the dead load of the shells; and ferro-cement slabs as wall panel, roofing channel, tiles door shutter and water tank. In addition to the traditional methods, there are other more modern methods (green buildings) in building architecture that focus on reducing the energy footprints of buildings post construction. These are, in general, more oriented towards new materials, passive design features, integrated planning, etc.

2.6.1 Policies

Kerala State Housing Policy 2011[29]

The housing policy takes note of shelter conditions, access to services and livelihood with particular reference to the poor. In order to generate suitable strategies for housing and sustainable development of human settlements, the policy also takes into account the growth pattern of settlements, investment promotion opportunities, environmental concerns, and magnitude of slums and sub-standard housing. The policy further examines the importance of sustainable development in rural and urban structures, and intends to support rural and urban population with suitable access to shelter and services.

The main focus of the *Kerala State Housing Policy 2011* is to provide adequate and affordable housing for all on a rights-based approach. It also intends to address the

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[27] Centre of Science and Technology for Rural Development (COSTFORD). http://www.costford.com.

[28] Kerala State Nirmithi Kendra (KESNIK). http://www.nirmithi.kerala.gov.in/mile.html.

[29] Department of Housing. 2011. *Kerala State Housing Policy 2011.* Government of Kerala. Thiruvananthapuram, Kerala. http://www.kerala.gov.in/docs/policies/drafthpolicy11e.pdf.

concerns of ecology, environment and climatic change, and depletion of natural resources on habitat-based approach. The policy perceives the need for usage of cost-effective, environment-friendly and energy-efficient technology, locally available building materials, and its standardization and acceptance by the general public.

Green Building Policy (2011)

The main objectives of the Green Building Policy[30] are: to conserve natural resources; reduce soil waste; improve air and water quality; protect the ecosystem; reduce consumption of electricity from 40 per cent to 60 per cent by adopting architectural inventions in building designs; encourage use of high efficiency materials; limit all kinds of pollution during the construction and operational phase; use of onsite energy generation by installing solar thermal panel and other sources of non-conventional energy; and employ proper waste management strategies in buildings to minimize the burden on municipal waste management.

The major highlights of the Green Building Policy are:

- Construction of self-sustainable buildings that consume minimum energy, water and other resources.
- Popularize and implement green building concepts, considering the negative impact and exploitation of natural resources caused by conventional building models, both at the construction and operational stages.
- Minimize demand on non-renewable sources and maximize use of efficient construction materials and construction practices.
- Maximize re-use, recycling and utilization of renewable resources.

2.7 THE CASE FOR A TRANSITION TO A RE SCENARIO

Climate change with possibly catastrophic implications has increasingly been identified by leading climate experts as being the most important challenge facing humankind today. Kerala may be threatened by sea level rise as it has a very long coastline, with high population concentration along a narrow belt of land. Kerala is also bordered on the eastern side by the Western Ghats which are internationally recognized as a world biodiversity hotspot. Further, nuclear power projects are opposed by the local people due to high-population density and fragile ecology of the state. Large hydro power development in Kerala has also reached a saturation point, with further development of large hydro projects presumed to have adverse ecological effects.

With respect to use classical fossil fuels for power generation – coal and gas – Kerala is unfavourably situated. With no coal reserves of its own, Kerala will be dependent on domestic coal from the coal bearing states, but overland transportation of coal into Kerala will face severe limitations. Transportation via sea, from the east to west coast will involve multiple modes and trans-shipments, further increasing the cost. Land acquisition for large scale thermal projects will face problems due to shortage of land. Gas supply will face similar constraints,

[30] PWD Architecture Wing. *Green Building Policy (Draft)*. Government of Kerala. http://www.keralapwd.gov.in/keralapwd/eknowledge/Upload/documents/1599.pdf.

ranging from the availability of gas, to access of land for gas pipeline / transportation and gas-based power projects. Finally, the environmental emissions from both types of thermal projects will have to be seriously considered. The emissions from coal-based or gas-based power projects in coastal Kerala will adversely affect both the forests cover as well as the fragile marine ecosystems of the state. It will also add to huge health related concerns for the population. With constraints on inputs, transformation and outputs, the prospects for future fossil-fuel based power generation are also dim.

Many state based studies have assessed the possibilities of meeting the power demand through LNG (this presupposes availability of LNG at low cost) or through installation of state-owned coal generation plants in other states, preferably at pit-head locations. While these strategies, if implemented, will help the state in meeting the demand, they do not consider the potential risks involved in such operations. Even though coal and fossil-fuel-based generation technologies may be low cost options in the short run, they may prove to be high cost options as supply constraints and demand competition come into play. And when they do, it is also important to understand if the proposed plans will indeed be feasible from the perspective of future fuel costs. Lock-in with conventional technologies will expose the state to fuel price volatility over time, which could have disastrous impact on state finances – where on one hand, large state capital would be locked in capital costs and debt repayments for projects that may not deliver low-cost power, while on the other, rising power costs would have an inflationary effect on prices, affecting business growth and economic development.

Given these constraints, Kerala faces a future threat to its energy security. Large scale adoption of renewable resources is possibly one of the best ways to address all the above concerns, leading to a transition to post-fossil-fuel based cleaner, safer, healthier, equitable and sustainable pattern of development. This is particularly important for the state because resource depletion (oil, coal and gas) is occurring at an unprecedented rate globally, accompanied by widespread environmental damages to major ecosystems. Moreover, land acquisition for large conventional projects will always pose a problem in Kerala because such projects require large parcels of land at a single location, which is increasingly difficult in Kerala and may face local opposition. On the other hand, RE projects being modular, have the potential for decentralized and distributed generation, thereby avoiding one of the major issues of conflict in the expansion of energy generation in the state. It is acknowledged that most RE technologies have very low environmental impacts; hence a planned transition to 100 per cent RE for Kerala will be very desirable for the future sustainable development and energy security of the state. The solutions have to come before the state gets technologically locked-in into carbon-based conventional technologies and conventional infrastructure.

Part II of the report highlights the figures of the reassessed RE potential of the state.

PART II

THE CONTEXT, GENERAL OBJECTIVES AND PRINCIPLES OF RE POTENTIAL ASSESSMENT

The common refrain expressed in any discussion on centralized grid-tied RE in Kerala is the lack of availability of land for new projects. It is generally believed that the possibilities of large-scale projects of any kind (even a concentrated thermal power project) are small considering the scarcity of land. While Kerala has one of highest population densities in India, this does not translate into a clear preclusion of land availability. Furthermore, existing RE potential estimates (for wind) assume a certain percentage availability of land for estimating the potential value, which may also not be the right approach.

The aim of the present study is to critically re-assess the RE potential of Kerala. As compared to the existing literature on potential RE assessment in Kerala, the present study is different in respect to two aspects:

- It uses GIS platform linked with multi-criteria analysis (MCA) for assessment of wind (onshore and offshore) and grid-tied solar power (solar PV and concentrated solar power (CSP)). In addition, the study also tries to assess potential for other renewable energy technologies like off-grid solar applications, biomass power and ocean energy using standard tabulated calculations.
- Second, it uses a mix of market information and literature review to arrive at the methodology and the assumptions for the potential assessment exercise.

II.1 WHY GIS?

Considering the ambiguities and differences in the assumptions, it is increasingly obvious that a paper-based exercise for large grid-tied RE potential assessment cannot and will not give a reliable and robust estimate of renewable resource potential. The first step before any real assessment exercise can take place is to understand the assumptions and their underlying rationale. For renewable resources and technology, this assumption set can only be accurately validated with on-site measurements and detailed land surveys. The scope of the project visualizes a GIS-based exercise supported by suitable field and spatial data that not only considers terrain features but also numerical models based on reliable source data for micro-scale assessment. Moreover, such a GIS-based exercise will add tremendous value to the planning process as it will enhance visualization and aid data analysis for varying spatial selections. For the present project, all GIS-based analyses have been executed on the ArcMap 10 platform.

II.2 GIS-BASED RE POTENTIAL ESTIMATION PLAN

The base GIS data has been sourced from various commercial and government sources. The emphasis was on selecting the highest resolution data that met cost and time targets. The following major GIS data layers were used: wind resource, solar resource, land-use and land cover, terrain elevation, administrative and political boundaries, etc. In addition, various thematic layers with features like roads, rivers, railway, transmission lines, etc., have also been included.

The final GIS output includes a map of Kerala with suitable raster and vector layers including land-use, land cover, terrain elevation, administrative boundaries along with gradations and spatial unit-based data values related to wind (onshore) and grid-tied solar potential.

II.3 GIS DATA SETS AND SOURCES

Wind Resource data: Modelled wind resource data is sourced from AWS Truepower, USA, a leading resource-assessment firm. Based on the scope of supply, AWS supplied raster and vector datasets of wind-power density and Weibull *c* and *k* parameters, respectively. The GIS format data was supplied for three hub heights (80 m, 100 m and 120 m) and had a resolution of 200 m × 200 m.

Solar Resource Data: National Renewable Energy Laboratory (NREL) dataset with a resolution of 10 km × 10 km is used.

Land Use data: NRSC-ISRO (National Remote Sensing Centre, Indian Space Research Organisation) 2010-11 land use land cover (LULC) data is used for the analysis because it was the latest data available (2010-11) and had very high resolution of 52.8 m as compared to global datasets. Another important reason for choosing NRSC-ISRO data was that it was government approved and validated by experts attuned to Indian land-use patterns.

Table II.1 provides description and specification of the other datasets used.

Table II.1: Miscellaneous Datasets

No.	Database	Dataset	Base data	Date
1	Shuttle Radar Topography Mission (SRTM) Version 2	90 m × 90 m	NASA satellite	2009
2	Protected areas	World Database on Protected Areas	UNEP	Not known
3	Geographic features (rivers, water bodies)	VMAP 0	National Imagery and Mapping Agency	Not known
4	Administrative boundaries	GADM database of Global Administrative Areas v2	Unknown	2012
5	Infrastructure (roads, railroads, cities, settlements, urban areas)	VMAP 0	National Imagery and Mapping Agency	2000

II.4 GENERAL OVERVIEW OF LITERATURE AND METHODOLOGY

To get a good perspective of the differences in methodology and assumptions, both GIS-based and paper-based resource assessment studies from India and abroad were analysed. The study methodology also relied on a recent GIS-based resource assessment exercise executed for the state of Tamil Nadu by WISE[31] and the technical assumptions and GIS methodology are similar to that used in the earlier report[32].

[31] WISE. 2012. *Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu*. World Institute of Sustainable Energy. Pune, India.
[32] Ibid.

II.5 LAND-AVAILABILITY CONSIDERATIONS

The main consideration before initiating any GIS analysis was exclusion of all non-available geographies. Non-available geographies were categorized either as a geographical extent that are not available for development or as a geographical extent that are not recommended for development.

The geographies that are not available for development included standard geographical features like rivers, other water bodies, protected areas, roads, railroads, cities, settlements, etc. To exclude these features, a proximity criterion was created that excluded a certain extent along the perimeter (called buffering) of all the features and then aggregated these buffered extents to create a common a layer of 'permanent exclusions'. All natural features like rivers and other water bodies, protected areas, and infrastructures like roads, railroads, settlements, airports were excluded from the analysis after buffering. The buffer values used are as specified in Table II.2 and Figure II.1, and indicate the final merged areas that are considered as 'permanent exclusions'.

Figure II.1: Permanent Exclusions

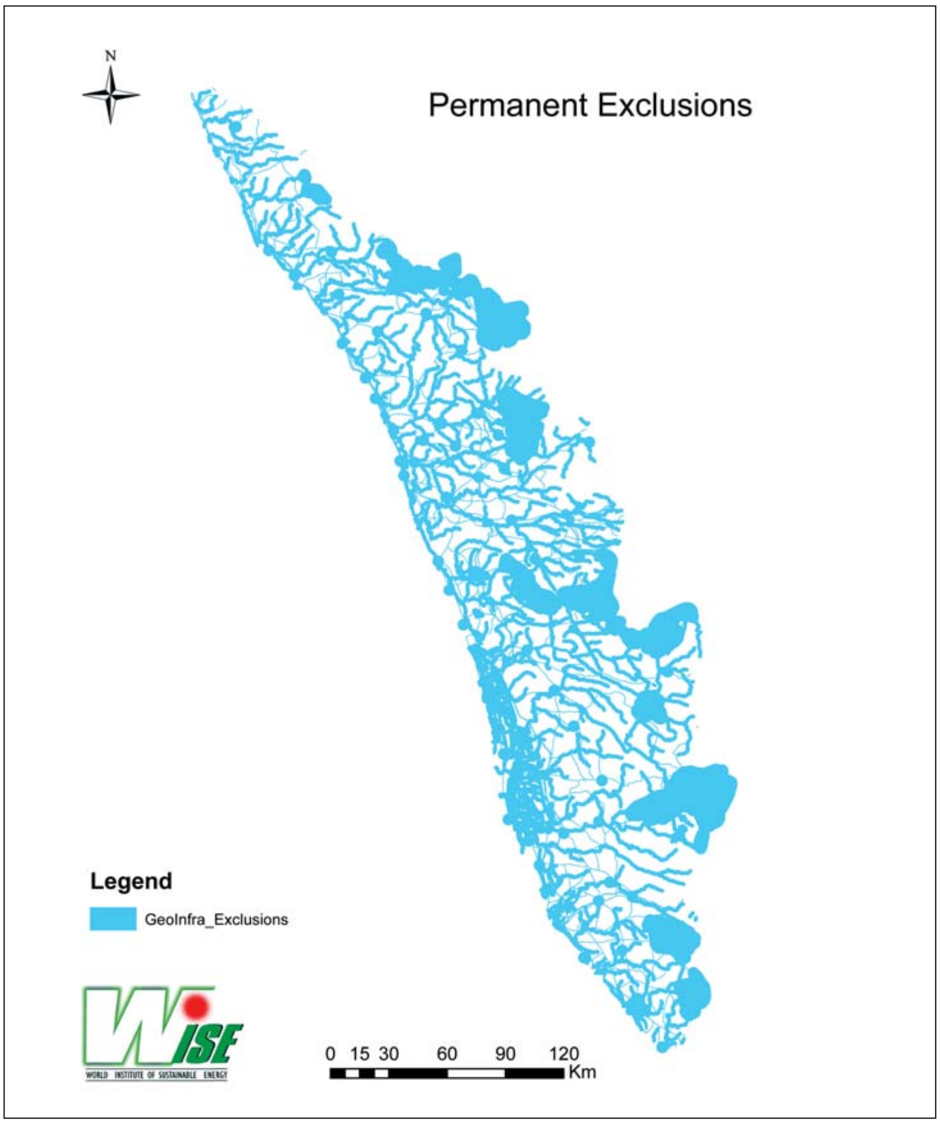


Table II.2: Buffer Values for Features

Feature	Buffer (m)
Environment	
Water bodies	500
River	1,000
Protected areas	3,000
Infrastructure	
Roads	200
Railroads	300
Urban Areas	1,000
Populated Places	3,000
Airports	2,000

The area precluded for analysis because of these permanent exclusions amounts to about 22,131 km^2 (56 per cent) out a total land area of about 38,860 km^2.

Similarly, the geographies not recommended for development include certain land-use categories (protected areas, forest land, etc). Established resource-assessment methodologies usually consider only wasteland or grassland as land recommended for development. However, it was felt that wind power potential assessment based on such a criteria would not be consistent and true to the actual ground realities in India where, in many parts, the majority of wind development has happened on agricultural land, where wind turbines installed on footprint basis on farmland area have co-existed with farming. This model of development has evolved especially well in Tamil Nadu because wind rich regions like Tirunelveli, Tiruppur, Coimbatore, Theni, etc. have a predominance of agricultural land.

The fact that wind power has co-existed with farming in Tamil Nadu makes a strong case for the sustainability of the co-existence model, especially in view of the fact that the actual footprint of even new high-capacity turbines is only about three to five acres and the remaining area surrounding the turbine tower and sub-station can be used for farming. In view of the same, non-irrigated farmland and plantations were included as separate scenarios in GIS-based assessment of wind. However, in line with standard practices, irrigated farmland areas were excluded from any potential assessment consideration.

Furthermore, in line with the actual field practices of land use, it was decided to club wasteland and grassland as 'No Farmland' area for wind development. Wind potential assessment has been separately done for three scenarios: farmland (kharif, rabi and current fallow), plantations and no farmland (wasteland and grassland).

Based on the above criteria, the three different scenarios considered for wind power potential assessment are as shown in Table II.3 below.

Table II.3: Land-use Categorization for Wind Power Potential Assessment

LULC Code	Description	Area (km^2)	Percentage Inclusion	Scenarios
2	Kharif only	3,749.08	100	Wind Farmland
3	Rabi only	601.79	100	
6	Current fallow	835.31	100	
7	Plantation/Orchard	16,369.47	100	Wind Plantation
12	Grassland	457.54	100	Wind No Farmland
13	Other wasteland	209.09	100	
1	Built-up	538.05	0	Exclusion
5	Double/Triple	4,244.85	0	
8	Evergreen forest	3,732.68	0	
9	Deciduous forest	6,277.46	0	
10	Scrub/Degraded forest	514.91	0	
15	Scrubland	0.04	0	
16	Water bodies	1,265.59	0	
	Total	**38,795.88**	**57**	

For GIS assessment of grid-tied solar technologies, inclusion of any farmland is not feasible. Furthermore, considering the site-specific requirements of solar projects (clear land without scrub), grassland was included as a separate category. For the final assessment, only two scenarios one with 'other wasteland' and one with 'grassland' were considered. Table II.4 shows the details of the two scenarios.

Table II.4: Land-use Categorization for Grid-tied Solar Power Potential Assessment

LULC Code	Description	Area (km^2)	Percentage Inclusion	Scenarios
12	Grassland	457.54	100	Solar Grassland
13	Other wasteland	209.09	100	Solar Wasteland
1	Built-up	538.05	0	Exclusion
2	Kharif only	3,749.08	0	
3	Rabi only	601.79	0	
5	Double/Triple	4,244.85	0	
6	Current fallow	835.31	0	
7	Plantation/Orchard	16,369.47	0	
8	Evergreen forest	3,732.68	0	
9	Deciduous forest	6,277.46	0	
10	Scrub/Degraded forest	514.91	0	
15	Scrubland	0.04	0	
16	Water bodies	1,265.59	0	
	Total	**38,795.8**	**1.7**	

3. SOLAR POWER POTENTIAL IN KERALA

GIS-based solar resource assessment takes into consideration important factors like topography, vegetation, land-use, which may be crucial factors for identification of areas with solar power potential. Thus, the main intent of the present exercise is not on just providing a figure of solar potential, but also on identifying the exact location and the quality of the resources allowing governments and decision-makers to use the results as policy inputs.

3.1 LAND USE FOR SOLAR POWER

All other categories except 'other wasteland' and 'grassland' were deemed not suitable for solar power plants and hence excluded from the analysis. Table 3.1 recaptures the land-use categorization used for solar potential assessment for grid-tied solar projects.

Table 3.1: Land-use Categorization for Grid-tied Solar Power Potential Assessment

LULC Code	Description	Area (km^2)	Percentage Inclusion	Scenarios
12	Grassland	457.54	100	Solar Grassland
13	Other wasteland	209.09	100	Solar Wasteland
1	Built-up	538.05	0	Exclusion
2	Kharif only	3,749.08	0	
3	Rabi only	601.79	0	
5	Double/Triple	4,244.85	0	
6	Current fallow	835.31	0	
7	Plantation/Orchard	16,369.47	0	
8	Evergreen forest	3,732.68	0	
9	Deciduous forest	6,277.46	0	
10	Scrub/Degraded forest	514.91	0	
15	Scrubland	0.04	0	
16	Water bodies	1,265.59	0	

3.2 SOLAR POWER: METHODOLOGY FOR POTENTIAL ASSESSMENT OF SOLAR POWER

The basic approach for solar potential was to work out the net available area suitable for solar generation after excluding the technical, geographic and social constraint layers. This net area identified for each technology family, namely CSP and solar PV, was then converted into potential, assuming average land utilization factor for each technology family (50 MW/km^2 for solar PV and 35 MW/km^2 for CSP).

Table 3.2: Assumptions for GIS- and MCA-based Solar Potential Assessment for Kerala

Based on detailed literature review and expert validation done in past study,[33] Table 3.2 summarises the assumptions used for assessment for solar PV and CSP technologies.

Parameter	Value	Remarks/sources
Average land requirement (PV)	50 MW/km^2	Based on WISE study*/Industry norm
Minimum GHI (PV)	1,600 kWh/m^2	Based on field interactions
Maximum slope (PV)	5%	Based on industry norm
Minimum contiguous land	5 acres (0.02 km^2)	Assuming minimum scale of 1 MW
Land availability	Wasteland Only Scenario and Grassland Only scenario	
Parameter	**Value**	**Remarks/sources**
Average land requirement (CSP)	35 MW/km^2	Based on WISE study
Minimum DNI (CSP)	1800 kWh/m^2	Based on CEA study (report of sub group II and III)†
Maximum slope (CSP)	3%	Based on industry norm
Minimum contiguous land (CSP)	(0.028 km^2)	Assuming minimum 1 MW size
Land-use availability (CSP)	Wasteland Only Scenario and Grassland Only scenario	

* WISE. 2012. *Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu*. WISE. Pune, India
† CEA. 2010. *Report of Sub-Group II & III on Integration of Solar Systems with Thermal / Hydro Power Stations*. Central Electricity Authority. New Delhi, India. http://www.cea.nic.in/more_upload/solar_sg2_3_report.pdf.

Off-grid assessment methodologies are covered separately in section 3.5.

Figure 3.1: Criteria and Methodology Adopted for CSP Potential Assessment

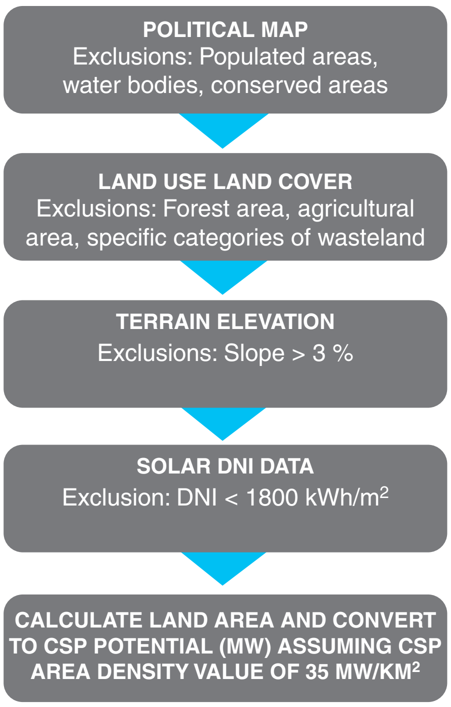
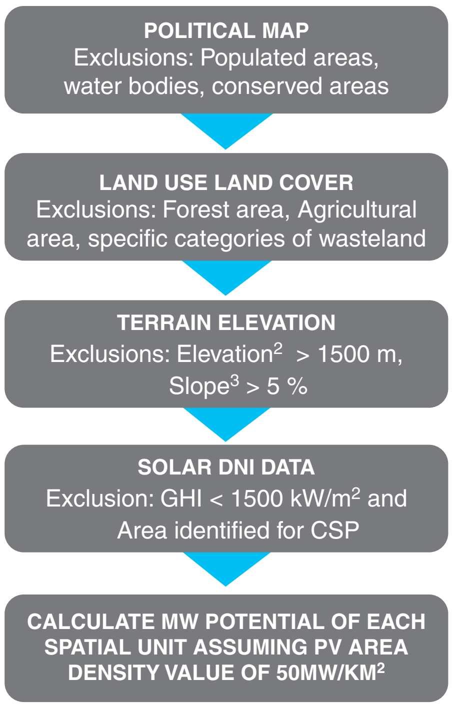


Figure 3.2: Criteria and Methodology Adopted for Solar PV Potential Assessment



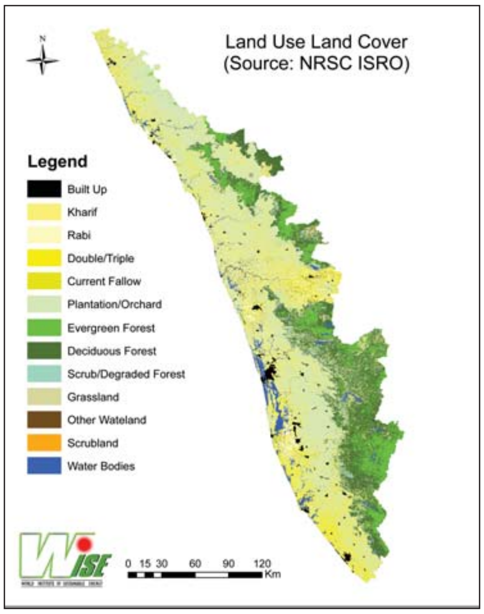
[33] WISE. 2012. *Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu.* WISE, Pune, India.

Based on the finalized methodology, the potential for large-scale grid-tied solar power for both solar PV and solar thermal technologies was analysed using the following resource values and technical constraints.

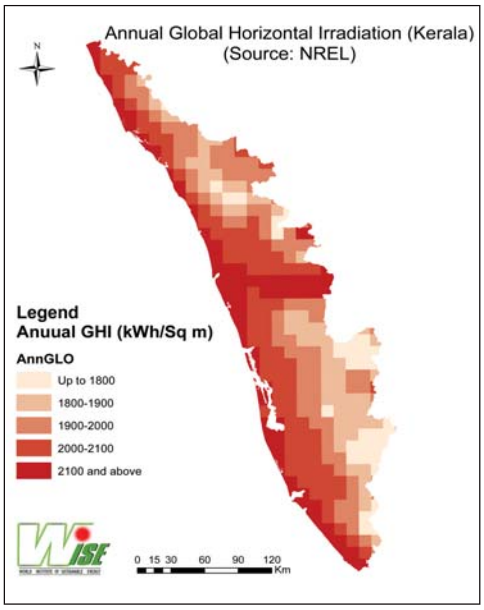
3.3 POTENTIAL OF GRID-TIED SOLAR PV

Figure 3.3 A-C shows the base resource layers of GHI, terrain slope and LULC used in the analysis.

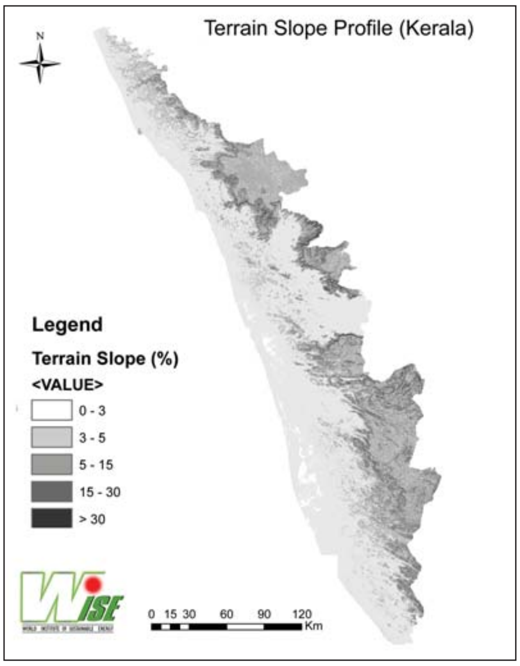
Figure 3.3: GIS Base Resource Layers for Solar PV Potential Analysis



(A)



(B)



(C)

On the basis of the proposed methodology, these three data layers were re-categorized based on the following criteria: land use: wasteland, slope < 5 per cent and GHI > 1,600 kWh/m². The re-categorized layers were then overlaid to arrive at the common overlapping area, which was thereafter overlaid with permanent exclusions (land not available for development) and all common areas were removed from the final consideration. In addition, areas with contiguous land area of less than five acres (0.02 km²), representing a minimum of 1 MW solar PV plant capacity were excluded. The remaining area was assumed as area available for solar PV development and was multiplied by the solar PV density function of 50 MW/km² to arrive at wasteland-based solar PV potential of Kerala. A similar analysis was done separately for assessing grassland based potential.

Figures 3.4 and 3.5 depict PV potential area map for grassland and wasteland categories respectively. Table 3.3 summarises the total potential areas for grassland and wasteland categories.

Figure 3.4: Potential of Solar PV – Grassland

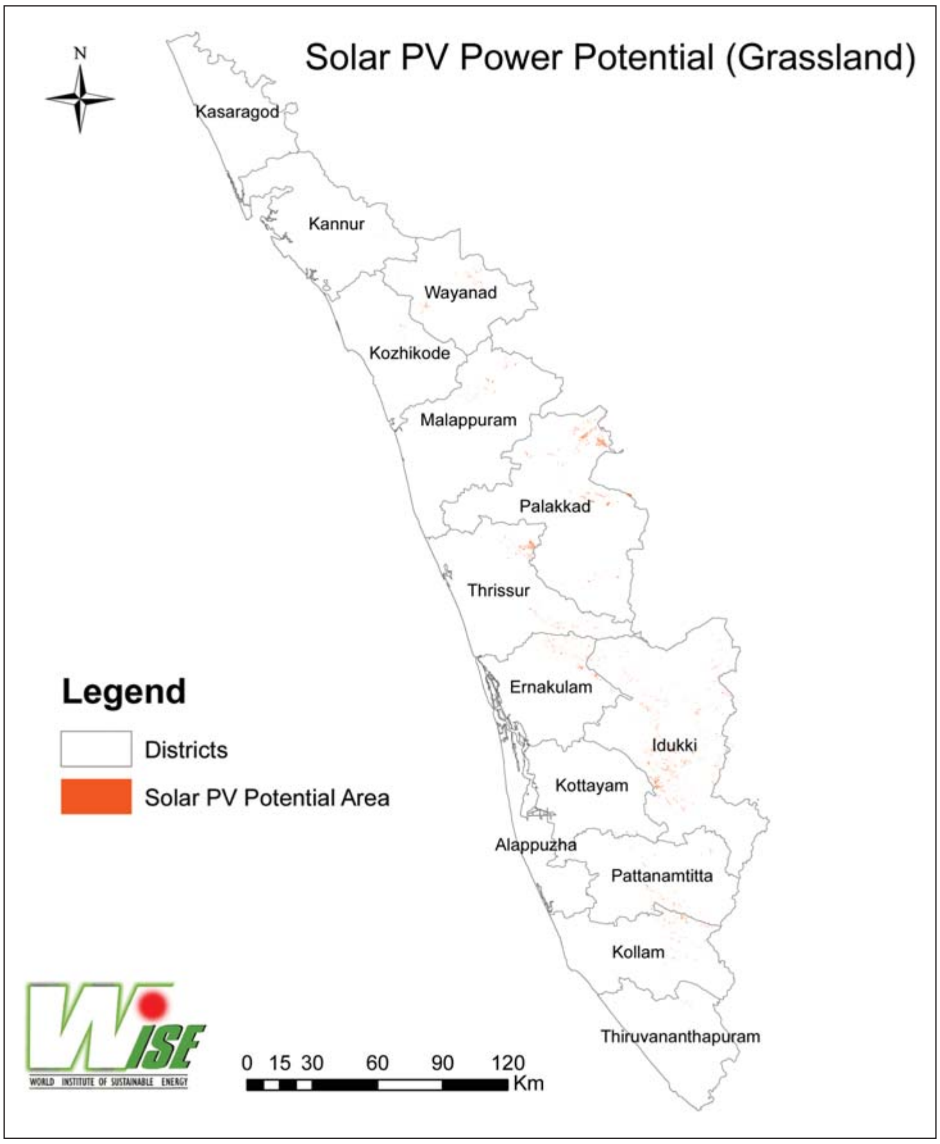


Figure 3.5: Potential of Solar PV – Wasteland

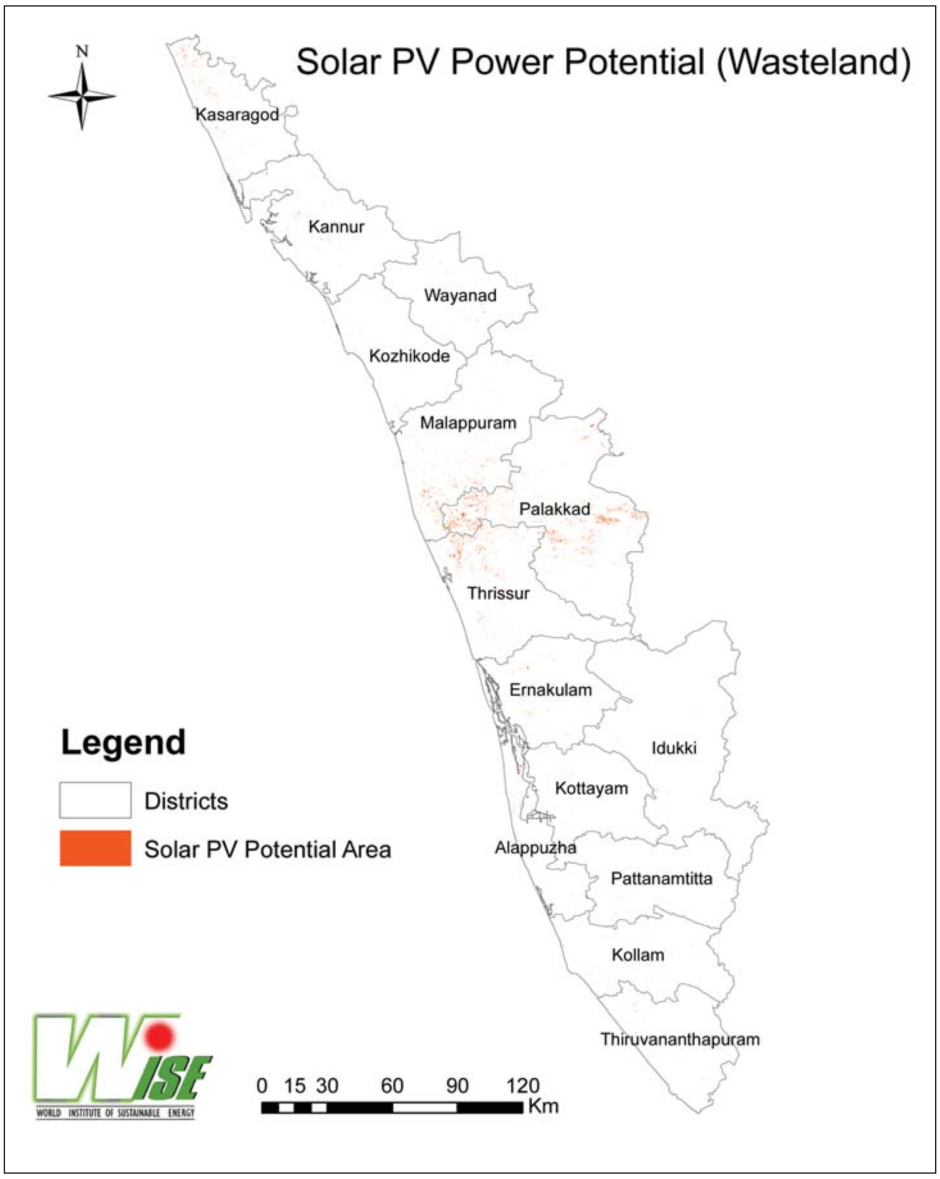


Table 3.3: Solar PV Potential Areas for Different Land Use Categories (in MW)

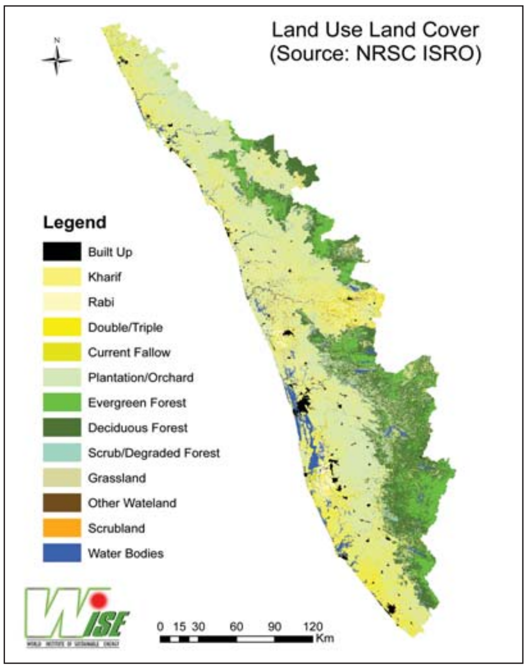
Solar PV Potential	Potential Area (km^2)	Potential (MW)
Wasteland	85.46	4,273.0
Grassland	50.87	2,543.5

The total solar PV potential for the state is estimated at about 6,816 MW. Even assuming development only on wasteland, the total potential is about 4,273 MW. From the results of the GIS analysis, it can be seen that the wasteland based potential areas are available in almost all the districts in small patches but the districts with largest potential seem to be Palakkad, Thrissur, Mallapuram and Kasargod. Grassland based potential, on the other hand is concentrated more around Wayanad, Pallakad, Thrissur, Ernakulam and Idukki.

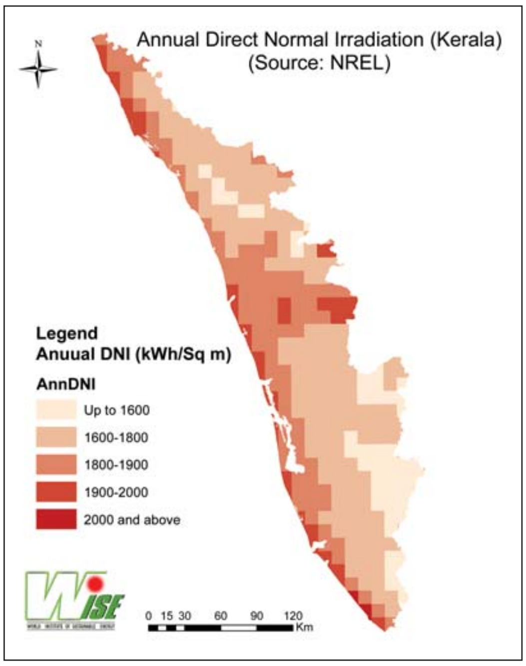
3.4 CSP POTENTIAL IN KERALA

The most critical data layer for CSP assessment was the direct normal irradiance (DNI) resource layer. Figure 3.6 shows the base resource layers: LULC, DNI and Slope.

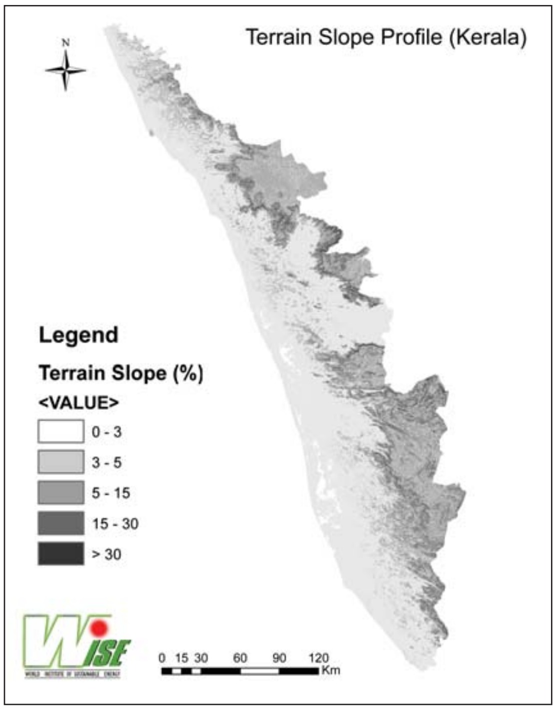
Figure 3.6: GIS Base Resource Layers for Solar CSP Potential Analysis



(A)



(B)



(C)

Based on the methodology, three data layers, namely DNI, terrain slope, and LULC layer, were re-categorized. The re-categorized layers were then overlaid to arrive at the common overlapping area, which was then overlaid with permanent exclusions (land not available for development) and all common areas were removed from the final consideration

The final output layer was derived separately for wasteland and grassland scenario.

Figures 3.7 and 3.8 show the final potential areas for wasteland and grassland. Table 20 gives the stand-alone CSP potential for wasteland and grasslands separately.

Figure 3.7: Wasteland Based Potential of CSP

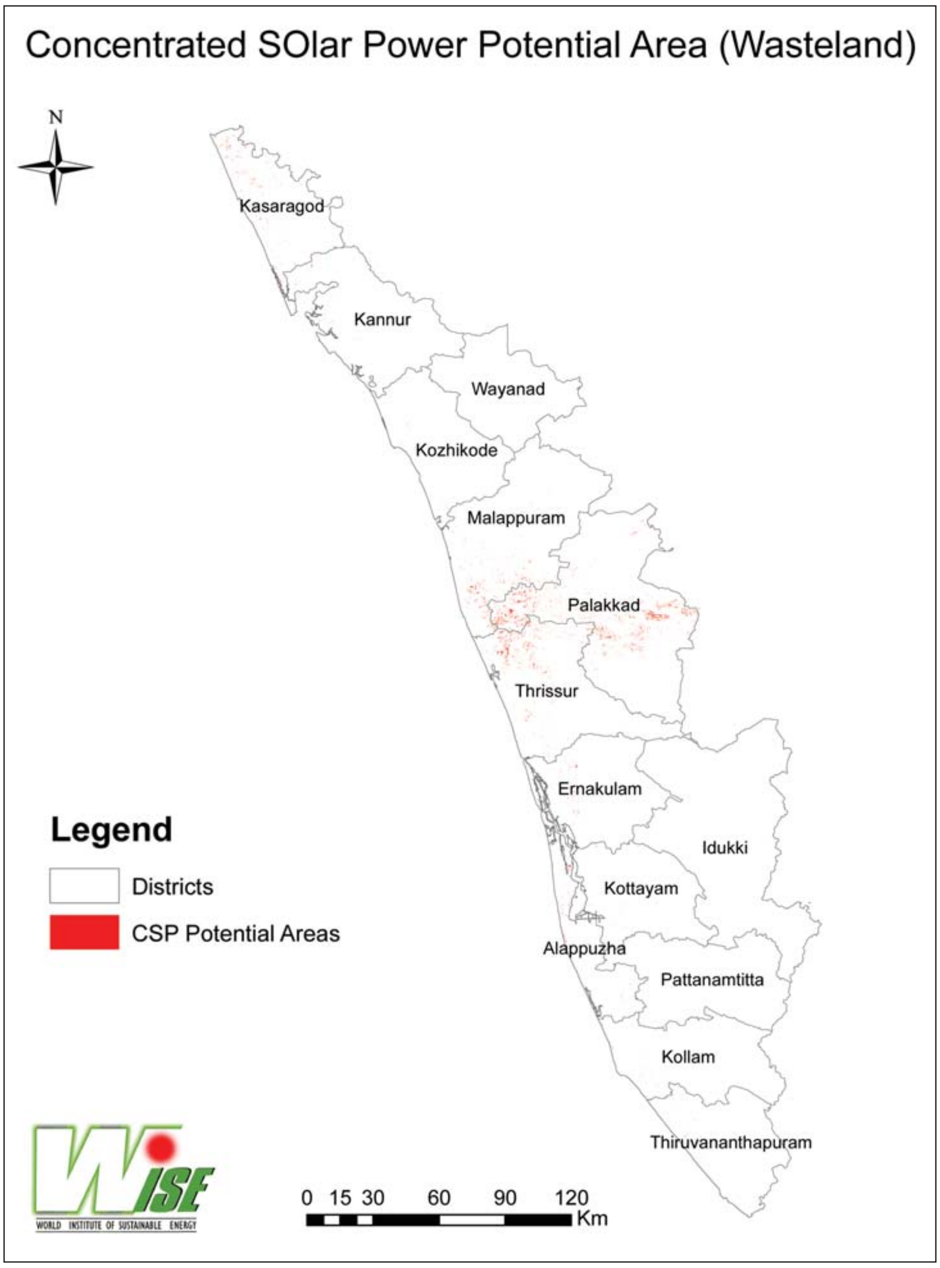


Figure 3.8:
Grassland Based
Potential of CSP

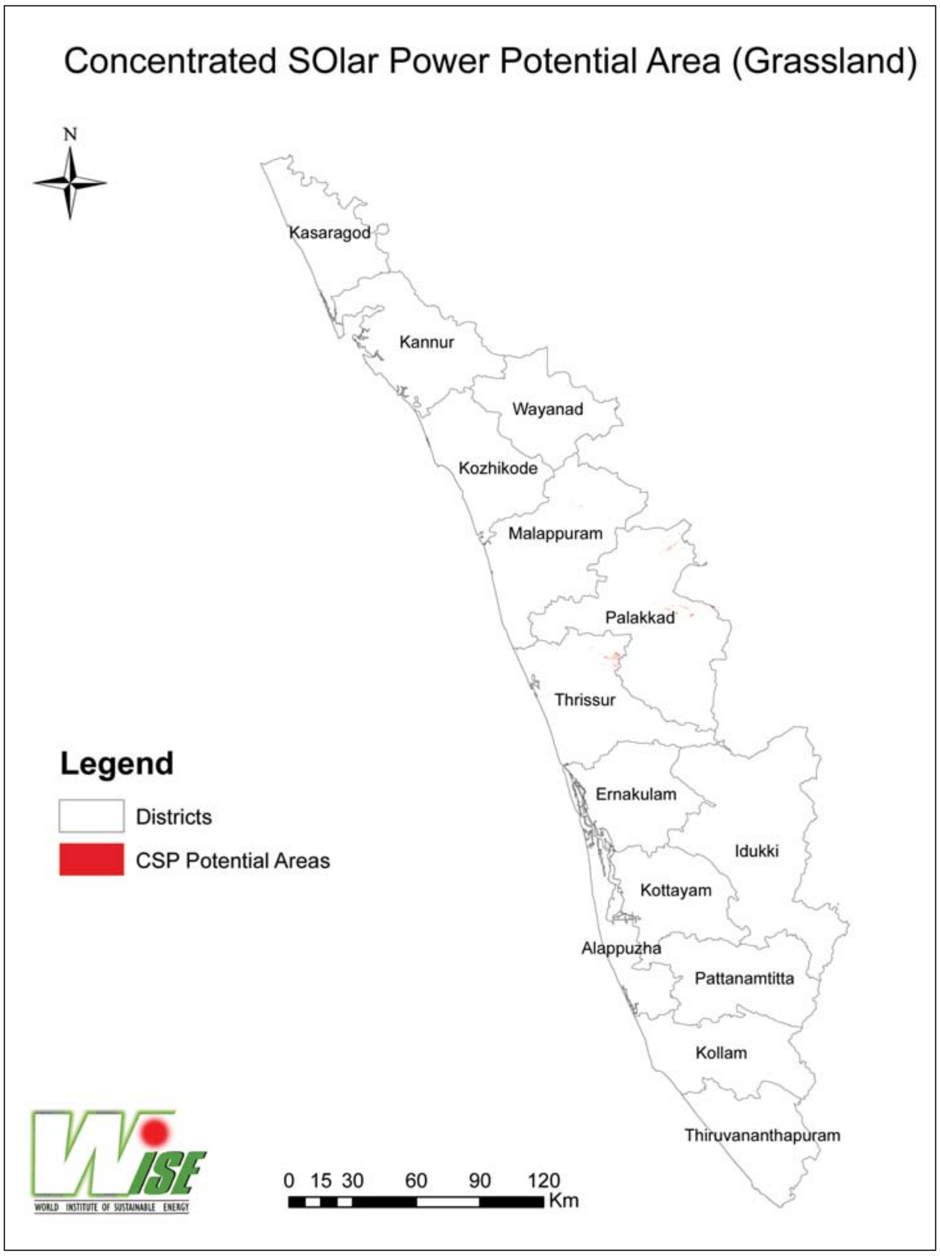


Table 3.4:
CSP Potential Areas
for Different Land Use
Categories (in MW)

Solar CSP Potential	Potential Area (km^2)	Potential (MW)
Wasteland	70.21	2,457.4
Grassland	5.5	192.5

The total grid-tied CSP potential for the state is estimated at about 2,649 MW. Even assuming development only on wasteland, the total potential is about 2,457 MW. From the results of the GIS analysis, it can be seen that the wasteland based potential areas are available mainly in Palakkad, Thrissur and Mallapuram, with small areas in Kasargod, Ernakulam and Alappuzha. Grassland based potential, on the other hand, is concentrated only in Palakkad and Thrissur.

3.5 FLOATING SOLAR PV PANELS

Floating type solar PV power project is a new and emerging concept in India and could prove to be a major option for land- starved state like Kerala. A normal floating PV system can be installed on all types of water bodies like lakes, saltwater lakes, reservoirs, irrigation ponds, small water sources, dams, rivers, etc. In the conventional arrangement, solar installation is constructed to float on a raft membrane. Generated energy is evacuated to a conventional land based transmission / distribution system. Except for the float design, the tracking mechanism and the internal cabling, all other components are same as those used in conventional ground based solar PV installations. The two major advantages of floating PV are use of non-revenue generating area (water surface) and lower temperature over water surface, resulting in higher generation.

A prototype floating solar power project of 10 kW capacity is planned to be installed in a pond in Victoria Memorial, Kolkata. The project involves solar panels and other components that are fitted onto a platform with hollow plastic or tin drums that enable it to float on water. The project area requirement is estimated to be 100m^2 and it is expected to be commissioned in 2014.

In Kerala, the Kerala Irrigation Infrastructure Development Corporation (KIDCO) is also planning to install solar panels in dams to produce 20 MW of power. It is expected that a pilot project by the irrigation department will be implemented at the Meenkara dam in Palakkad district. Floating solar panels will be put up in an area covering six acres at the Malampuzha dam which can produce 1 MW of energy. Later it will be extended to 60 acres which can produce 10 MW of power.

In the past, state-based energy experts have also mooted the idea of using floating PV technology as an alternative to conventional land-based solar PV. In one of the proposals, the experts have indicated that even using a third of the reservoir area of Idukki (60 km^2) can effectively provide an installed capacity of 2,000 MW, which can yield 3,200 MU annually. This can be replicated in other dams and water bodies.

Based on the LULC map of Kerala, the total area of water bodies is estimated to be about 769 km^2 and utilizing even 10 per cent of the total area will translate into an installed base of 3,845 MW. This figure is considered as the maximum harnessable potential for floating PV.

3.6 DECENTRALIZED SOLAR POWER GENERATION POTENTIAL

Considering low availability of land in Kerala for large centralized grid-tied solar power, off- grid solar is increasingly being seen as the best option for power generation. Fortunately, reasonably good annual average GHI is available throughout the state.

3.6.1 Solar Resource Assessment

Considering the prevalence of two monsoon seasons in Kerala spread across 6-7 months, the general notion held by outsiders is that solar PV in Kerala would not be viable. However, consultation of project team with many state-based experts and individual rooftop system owners indicated that except for June and July, the remaining monsoon months have significant number of clear sky days and cloudy sky days with enough diffuse radiation.

Interestingly, radiation analysis utilizing software (METEONORM) also supports the view of local experts. The values of global solar irradiance (GHI) and DNI for each district of Kerala are reproduced below in Table 3.5.

Table 3.5: Solar Resource Analysis for Kerala (District-wise)

Sr. No.	District	Latitude	Longitude	Altitude (m)	DNI (kWh/m²/day)	GHI
1	Alappuzha	9.49	76.33	150	4.29	5.52
2	Kannur	11.87	75.36	225	4.47	5.43
3	Ernakulam	10.00	76.33	279	4.36	5.44
4	Idukki	9.85	76.94	150	4.52	5.44
5	Kasargod	12.50	75.00	400	4.77	5.54
6	Kollam	8.88	76.60	52	4.27	5.50
7	Kottayam	9.60	76.53	150	4.22	5.45
8	Kozhikode	11.25	75.77	225	4.50	5.47
9	Mallapuram	11.03	76.05	471	4.70	5.49
10	Palakkad	10.77	76.65	279	4.55	5.51
11	Pathanamthitta	9.27	76.78	150	4.52	5.62
12	Thrissur	10.52	76.21	279	4.60	5.53
13	Thiruvananthapuram	8.44	76.92	52	4.34	5.52
14	Wayanad	11.61	76.08	471	4.68	5.33
	Average				**4.49**	**5.49**

The GHI daily average value in the state is 5.49 kWh/m²/day, or an annual value of 2,003 kWh/m²/year. Similarly, the DNI daily average value is 4.49 kWh/m²/day, which translates into an annual value of 1,639 kWh/m²/year. As a general principle, any site with GHI more than 1,500 kWh/m²/year is suitable for solar PV technology. A simple resource based assessment indicates that Kerala is highly suitable for developing solar PV systems. However, the resource values do not support suitability of solar thermal power generation because the average DNI is significantly less than the threshold value of 1,800 kWh/m²/year required for developing such projects.

3.6.2 Rooftop PV

The first step in assessing state based potential was to assess the number of rooftops available in the state. Two categories were indentified: individual households and institutional / commercial establishments.

For assessing on-site implementation feasibility, spot surveys of identified households with rooftop systems were carried out for rural and urban households in Thiruvananthapuram, Kochi, Alleppey and Palakkad. Many of the systems having 1 kWp capacity solar photovoltaic rooftops were surveyed and the owners were interviewed. Before conducting the spot survey, the general notion was that there would be a scarcity of shade free rooftops mainly due to proximity of plantation crops and coconut trees in the house compound. However, it was found that most of the houses in cities and practically half of the houses in villages were double-storied pucca houses with flat roofs having clear shadow free areas.

Based on these surveys, it was assessed that on an average 50 per cent of the rural households were partially or fully shaded (20 per cent were fully shaded and 30 per cent partially shaded), while the remaining 50 per cent households had completely shade free rooftop. For urban households, it was assessed that 30 per cent were partially or fully shaded (10 per cent were fully shaded and 20 pre cent partially shaded), while 70 per cent of the households had clear shade free roof areas. This assessment means that practically 80 per cent of households in rural areas and 90 per cent of those in urban areas can use solar PV power packs.

Based on the house roof material categorized in census 2011, households with thatched roofs and polythene covered roofs were not considered suitable for solar PV installation. Out of the remaining categories, roofs with tiles and slates were considered suitable for installation of only 1 kWp solar PV power packs as many of the houses with this kind of roof were found to have 1 kWp systems using additional special kind of structures. Concrete roofs were considered suitable for 3 kWp solar PV power packs, which need around 45 m² of roof area. For partially shaded roofs, inclusion of 20 per cent additional capacity of solar module was proposed to get the desired output of 1 kWp or 3 kWp. Based on these assumptions, the potential for off-grid solar power packs in households are estimated in Table 3.6.

Table 3.6: Decentralized Rooftop PV Power Potential in Kerala Households

Roofs	Rural			Urban			
		Nos	kW		Nos	kW	Total
Thatched / Plastic	100% shaded	163,205	0	100% shaded	95,097	0	
Tile / Asbestos roofs (1kWp/roof)	20% shaded	464,908	0	10% shaded	141,767	0	
	30% partially shaded	697,363	836,835	20% partially shaded	28,353	34,024	
	50% shade free	1,162,271	1,162,271	70% shade free	992,366	992,366	
Concrete roofs (3kWp/roof)	20% shaded	320,043	0	10% shaded	210,114	0	
	30% partially shaded	480,064	1,728,230	20% partially shaded	420,229	1,512,824	
	50% shade free	800,107	2,400,320	70% shade free	1,470,801	4,412,402	
Total MW		6,128			6,952		**13,079**

Table 3.7: Decentralized Rooftop PV Power Potential in Institutional/Commercial Establishments

Decentralized solar PV power potential for institutional / commercial establishments was estimated based on the data available from the Census of India 2011. Table 3.7 shows the assumptions and the final potential figure assuming a requirement of 15 m²/kWp is tabulated below.

Categories of Institutional/ Commercial Establishments in Kerala	Shop/ Office (Nos)	School/ College etc. (Nos)	Hotel, Lodge, Guest Houses, etc. (Nos)	Hospital/ Dispensary etc. (Nos)	Factory/ Workshop/ Work shed etc. (Nos)	Place of worship (Nos)	Total
Total Number of commercial Institutional Buildings with concrete roofs	964,441	75,480	52,509	31,589	165,901	105,562	1,395,482
% shadow free area availability assumed	50	80	50	70	40	80	
Number of household roofs available	482,221	60,384	26,255	22,112	66,360	84,450	741,781
Area available m² assumed	30	1,500	450	750	1,500	450	
Capacity kW	964,441	6,038,400	787,635	1,105,615	6,636,040	2,533,488	18,065,619
Capacity MW	964	6,038	788	1,106	6,636	2,533	18,066

Decentralized solar PV power potential for institutional / commercial establishments was estimated based on the data available from the Census of India 2011. Table 3.7 shows the assumptions and the final potential figure assuming a requirement of 15 m^2/kWp is tabulated below.

The assessment indicates that the total exploitable potential for decentralized solar PV power packs for household sector is about 13,079 MW, while that for institutional / commercial sector is about 18,066 MW. The aggregate potential for decentralized solar PV power packs is assessed at 31,145 MW.

3.6.3 Solar Water Heating

Solar water heating systems are used by both households and commercial buildings. However, considering non-availability of data on occupancy levels in commercial / institutional buildings, only domestic potential for solar water heating has been assessed.

Only households with concrete rooftops with 100 per cent shade free area are considered to be suitable for solar water heating. Based on assessment done for roof top PV, this translates into an availability of 50 per cent rural houses and 70 per cent urban houses. The data on number of houses with concrete roofs is taken from Census 2011.

Assuming an average requirement of 100 litres per day (LPD) solar water heating system (SWHS) for a 5 member household and 200 lpd for a 5-10 member household, the total potential for the state is estimated at 6,812,722 m^2 of the collector area. A simple working of the derivation is shown in Table 3.8 below.

Table 3.8: Assessment of Solar Water Heating Potential for Households

Potential of Solar Water Heater in Kerala			
Description	**Rural**	**Urban**	**Total**
Total households with concrete rooftops	1,600,213	2,101,144	
Feasible houses (%)	50	70	
Feasible houses nos.	800,107	1,470,801	
No. of houses with 100 LPD	400,053	735,400	
No. of houses with 200 LPD	400,053	735,400	
Total collector area (m^2) in 100 LPD houses	800,107	1,470,801	
Total collector area (m^2) in 200 LPD houses	1,600,213	2,941,602	
Total potential (m^2)	**2,400,320**	**4,412,402**	**6,812,722**

3.6.4 Solar Water Pumping

Based on the report *Ground Water Level Scenario in India*[34] majority of the area in the state is blessed with ground water level of less than 10m below ground level (bgl). The report, based on survey of wells spread throughout the geographical area of the state indicates that about 37 per cent of the wells have water level in the range of 5-10m bgl, and only 12 per cent have water level greater than 10 m bgl.

[34] Central Ground Water Board. 2012. *Ground Water Level Scenario in India.* Ministry of Water Resources. Faridabad, India.

Based on the above observations, it is assessed that 87 per cent of the irrigated area may have ground water level of up to 10m bgl. As commercially available solar PV pumps (0.5 -2 hp capacity) easily pump water from a depth of 10 to 12 m, it can be assessed that there is significant potential for use of solar PV pumping in Kerala.

Based on prevailing norms it is presumed that 0.9 kW capacity solar PV pump is sufficient to irrigate 1ha of land. It is further assumed that 100 per cent of irrigated area with a water level of less than 10m bgl (337,560 ha) can be converted into using solar PV for irrigation. This translates into a technical potential of about 304 MW.

3.6.5 Solar Process Heating

Kerala also has significant potential for installation of solar drying systems, especially in areas of fish drying, spices drying and latex drying. The potential opportunity of using this in latex manufacturing process is also huge. However, in the absence of authentic data on process parameters, potential assessment for this sector has not been done.

Solar Fish Drying

In 2011-12, the state produced 693,000 tonnes of fresh fish out of which about 16 per cent was used by the fish drying sector. The main season for fish drying is August-April. At present, a variety of methods are utilized for drying salted fish – sun drying or natural drying, electrical drying and solar drying.

Actual onsite visits to one such facility indicated that local practice of drying fish in open sun can lead to quality issues like high moisture content, uncontrolled drying and contamination. Use of solar drying can be advantageous for units as a controlled process will result in faster drying and a higher quality product. It was also learnt that the payback period for solar drying systems for fish drying applications just 3-4 years, making this option very viable for the industry.

In terms of available technologies, Active Ventilated Cabinet Dryer and Cabinet Dryer with Back up Heating Technologies, which are commercially proven and available, were considered. Based on data available from existing plants, 10 m^2 of solar air-dryer collector area is required for drying 100 kg/batch of fish to the desired moisture content.

Considering the fish drying production figure of 110,880 tonnes in 2011-12 (16 per cent of fresh catch in 2011-12), the area requirement for solar drying system is estimated to be 11,088,000 m^2 of solar air-dryer collector area. In order to figure in site limitations and other constraints, the realizable potential for solar dryers has been assumed to be 75 per cent of this figure, i.e., 8,316,000 m^2 of the collector area.

Solar Spices Drying

Kerala is a leading producer of exotic spices. These spices need careful and tender handling in the drying process to ensure that they retain their proper colour and aroma. Based on actual onsite visit and interaction with official from the Spices Board (Joint Director, Spices Board), Kochi, it was learnt that majority of the spices are harvested between September and October, and require drying in the same months.

The spices need drying at a temperature of 45-50°C (the temperature should never cross 55°C). Presently, the spices are dried in conventional dryers using LPG/firewood/kerosene, which pose the risk of smoke absorption and unregulated heating. Each machine takes a load of 300-500 kg spices per batch and carries out slow drying (24-30 hrs) using flue pipes with spices kept on multi-storeyed (4-5) mesh trays. Initial moisture content of 70-80 per cent is brought down to 10-11 per cent for the spices to retain natural colour and aroma. It was also leant that 33 per cent subsidy is available for conventional spices dryers, and that this could be extended to solar dryers also.

Based on the data provided by the Spices Board of India, the average annual production of spices in tonnes are: Pepper (31,021), Cardamom (7,829), Ginger (31,084), Turmeric (6,520), Cloves (82) and Nutmeg (11,412). A total of 87,947 tonnes of spices are produced annually. Considering 100m^2 of solar air-dryer collector area requirement per tonne of batch, the total potential for spices drying is estimated to be 8,794,700 m^2 of the collector area.

3.7 SUMMARY OF SOLAR POWER POTENTIAL

The summary of the solar potential is shown in Table 3.9.

Table 3.9: Summary of Solar Power Potential

A	Grid-tied Solar PV potential	Potential	Units
1	Wasteland	4,273	MW
2	Grassland	2,543	MW
3	Floating	3,845	MW
B	**Grid-tied Solar CSP potential**	**Potential**	**Units**
1	Wasteland	2,457	MW
2	Grassland	193	MW
C	**Off-grid Solar PV Potential in Kerala**	**Potential**	**Units**
1	Households	13,079	MW
2	Institution/ commercial buildings	18,066	MW
3	Solar Water Pumping	304	MW
D	**Off-grid Solar Thermal Potential in Kerala**	**Potential**	**Units**
1	Solar fish drying system	8,316,000	m^2
2	Solar spices drying system	8,794,700	m^2
3	Solar water heating system	6,812,722	m^2

Even though the estimation indicates a potential of 44,456 MW of solar power (2,650 MW of CSP and 41,806 MW of solar PV), the actual implementable potential would be much less and would depend on technology choices and commercial feasibility.

For instance, even though grid-tied CSP indicates a technical potential of 2,650 MW, none of it may be commercially feasible. Although GIS data source (NREL data) on DNI is showing adequate DNI values (>1800 kWh/m^2), alternative databases usually indicate DNI values, which are about 30-40 per cent less than NREL values, which are used for potential assessment. Field observations also seem to suggest that measured DNI values are significantly below NREL data values. Meteonorm database, which is referred for off-grid solar resource assessment indicates a maximum DNI value 1650 kWh/km^2, which rules out any CSP potential. In view of this, no possibility of CSP capacity addition is foreseen unless technology changes and costs evolution can make the solution workable at some data in the future.

As for decentralized solar potential, it can be seen that decentralized PV and thermal are essentially assumed to share the same rooftops. Considering the low DNI values in Kerala, it would be more resource efficient to go with PV instead of solar water heating applications. However, the potential for solar heating solutions in process industry can be exploited in full.

For decentralized PV, the indicated values suggest a huge potential. Fortunately, as the state has already started tapping it aggressively, it is assumed that the indicated potential can be fully harnessed over time.

For grid-tied PV, the potential figures assume 100 per cent availability of identified potential area of about 135 km^2 (80 km^2 of wasteland and 55 km^2 of grassland). Compared to the state or even the total wasteland area available, the land requirement of wasteland is small but it is assumed that this can be made available fully after considering other social, environmental and land ownership issues. Grassland areas in Kerala are mostly land patches (mostly muddy or swampy areas) that have no alternate use and could therefore be made available.

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4. WIND POWER POTENTIAL IN KERALA

4.1 LAND USE FOR WIND POWER

In line with the land use assumptions stated earlier, 'other wasteland' and 'grassland' are clubbed as 'No Farmland' area for wind development. The categories 'kharif', 'rabi' and 'current fallow' (rain-fed croplands) are clubbed together for separately assessing 'farmland potential'. 'Plantations' are also considered separately. The land use categorization is recaptured again in Table 4.1 below.

Table 4.1: Land-use Categorization for Wind Power Potential Assessment

LULC Code	Description	Area (km^2)	Percentage Inclusion	Scenarios
2	Kharif only	3,749.08	100	
3	Rabi only	601.79	100	Wind Farmland
6	Current fallow	835.31	100	
7	Plantation/Orchard	16,369.47	100	Wind Plantation
12	Grassland	457.54	100	Wind No Farmland
13	Other wasteland	209.09	100	
1	Built-up	538.05	0	
5	Double/Triple	4,244.85	0	
8	Evergreen forest	3,732.68	0	
9	Deciduous forest	6,277.46	0	Exclusion
10	Scrub / Degraded forest	514.91	0	
15	Scrubland	0.04	0	
16	Water bodies	1,265.59	0	
	Total	**38,795.88**	57	

4.2 METHODOLOGY FOR WIND POWER POTENTIAL ASSESSMENT

Wind potential onshore as well as offshore was assessed for 80m hub height. Based on literature review and field-level interactions, standard exclusion and inclusion criteria related to land-use, wind power density values, land slope, site elevation, were finalized with the objective of arriving at total land area available for development. This land area was then multiplied by the turbine density function (7 MW/km^2) to estimate the potential.

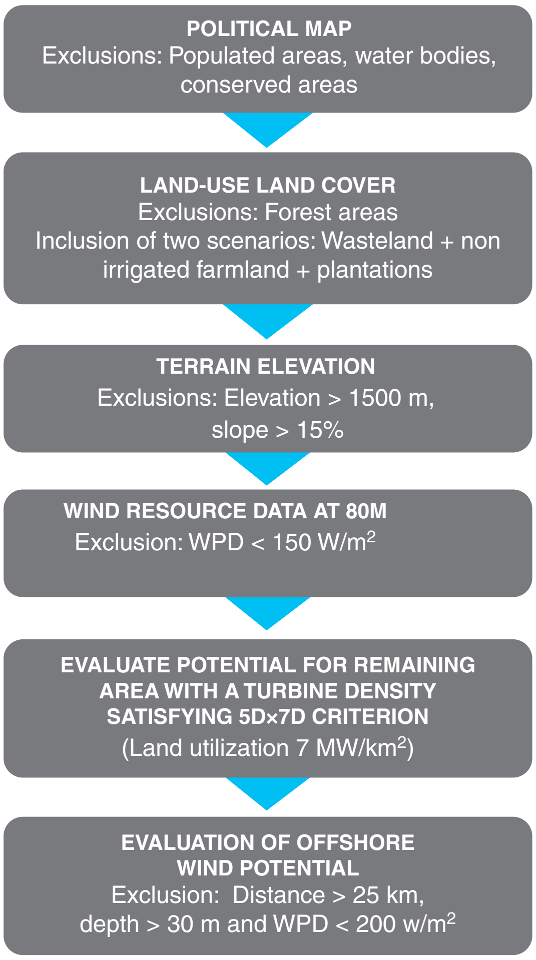
Based on detailed literature review and expert validation done in past study,[35] Table 4.2 and Figure 4.1 show the assumptions used for wind power generation potential assessment for onshore and offshore wind.

[35] WISE. 2012. *Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu.*

Table 4.2: Assumptions for GIS- and MCA-based Wind Potential Assessment for Kerala

Onshore wind		
Assumed parameter	**Exclusion value**	**Source/Remarks**
Wind-power density	<150 W/m^2	To maximize the potential land area at 80 m, 100 m, and 120 m
Land requirement	7 MW/km^2	Conservative, assuming 5D×7D criteria
Land elevation	>1500 m	In line with similar studies
Slope	>15%	in line with similar studies
lLand availability percentage (%) in potential region	100% availability	Non-irrigated farmland (Kharif +Rabi +Current Fallow)+ Non Farmland (wasteland + grassland)
Offshore wind		
Assumed parameter	**Exclusion value**	**Source/Remarks**
Distance from the coast	>25 km	In line with similar studies
Sea floor depth	> 30 m	In line current practices
Cut-off Wind Power Density	< 200 W/m^2	In line with similar studies and techno-commercial consideration

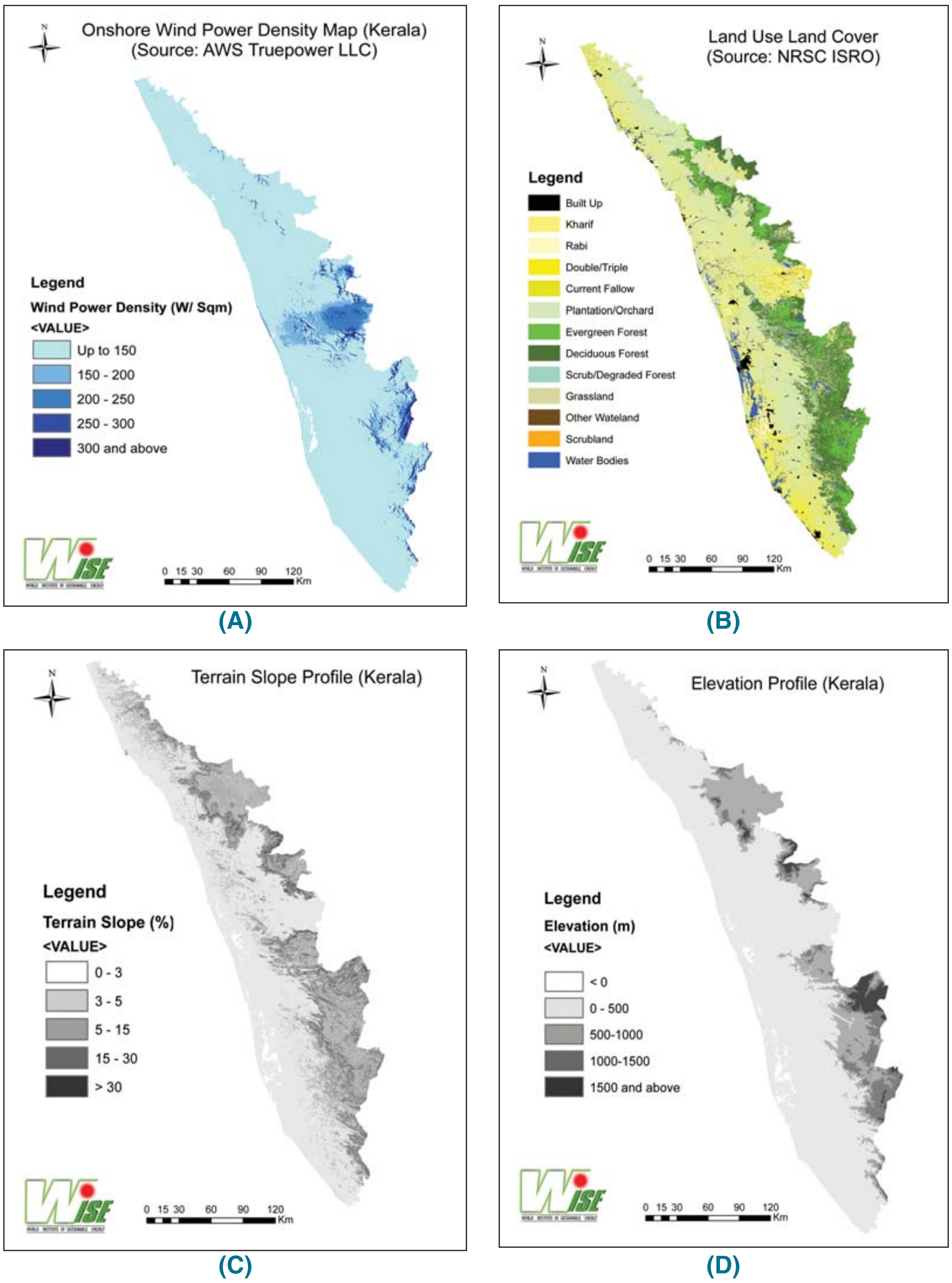
Figure 4.1: Criteria and Methodology for Assessing Wind Power Potential



4.3 ONSHORE WIND ENERGY

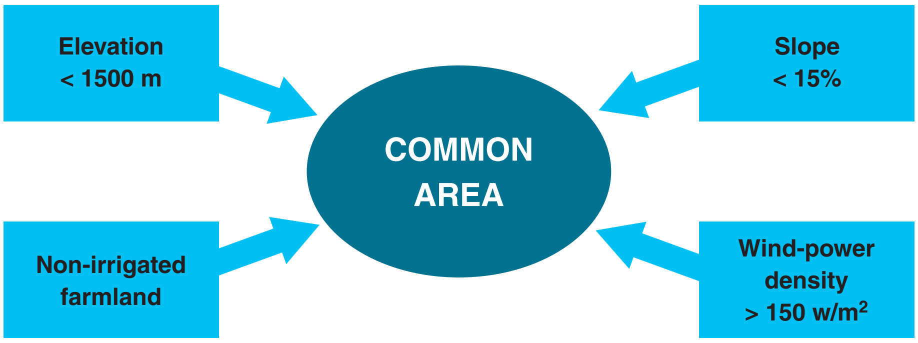
Figure 4.2 shows the four base data layers used in wind power potential assessment: Wind Power Density Map, LULC, Slope and Elevation.

Figure 4.2: Re-categorization Criteria for Onshore Wind



Based on the methodology, four data layers, namely wind-power density, terrain elevation, terrain slope and LULC layers, were re-categorized. Figure 4.3 shows a diagrammatic summary of the operation.

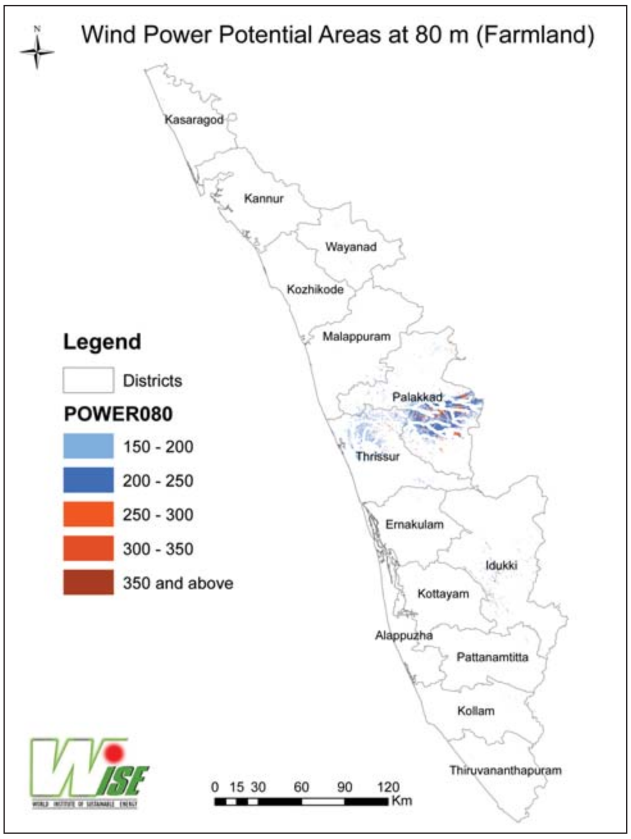
Figure 4.3: Preliminary Methodology for Wind Potential at 80m (Farmland)



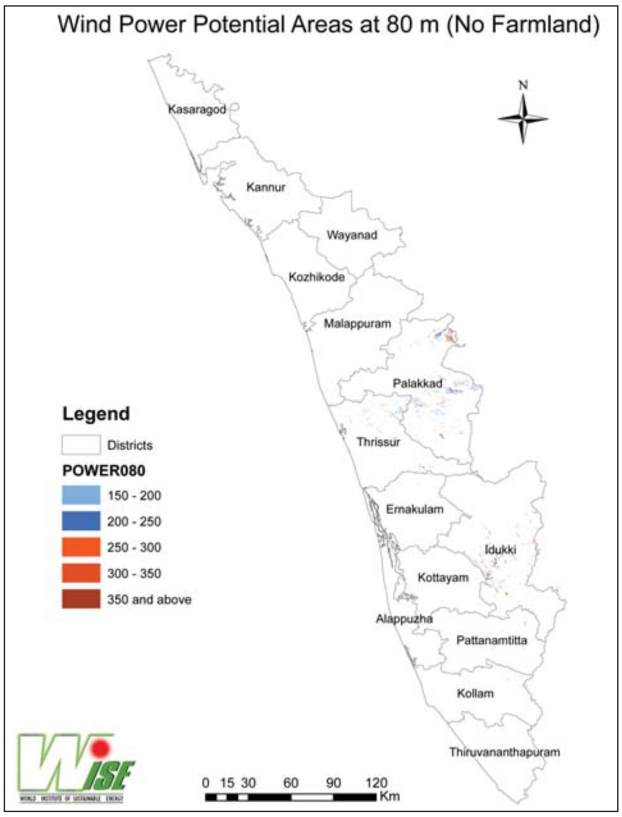
The common area for the categorized layers was then overlaid with permanent exclusions (land not available for development) and all common areas were removed from the final consideration. The remaining area is assumed as area available for wind power development and is multiplied by the turbine density factor of 7 MW/km² to arrive at the farmland potential of Kerala. Resource categorization of potential areas is done on the basis of wind power density to differentiate quality of wind resources.

Similar analysis is done with 'no farmland' and 'plantations' land use availability. Figure 4.4 and Table 4.3 summarize the results.

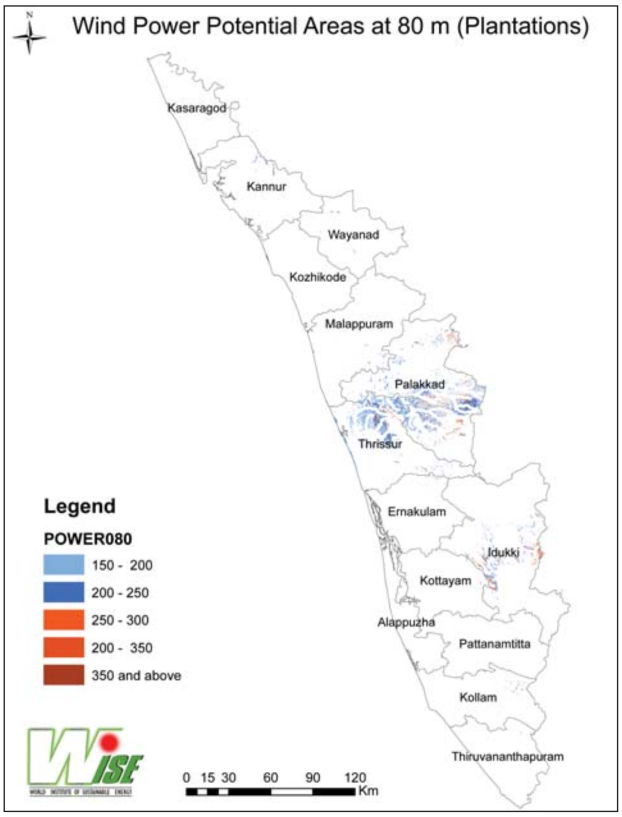
Figure 4.4: Potential of Wind Power at 80m for Farmland, No Farmland and Plantations



(A)



(B)



(C)

Table 4.3: Onshore Wind Potential across Different Land Use Categories (80m)

Onshore Wind Potential	Potential Area (km^2)	Potential (MW)
No Farmland	443.3	3,103.1
Farmland	93.5	654.5
Plantation	513.7	3,595.9
Total	**1,050.5**	**7,353.5**

The total grid-tied wind power potential at 80m for the state is estimated at about 7,353 MW. From the results of the GIS analysis, it can be seen that high resource potential areas are mainly spread across Palakkad (around the Walayar pass and south of Palaghat), Idukki, Thrissur and Wayanad.

4.4 OFFSHORE WIND ENERGY

For offshore wind power assessment, a wind power density map of up to 25 km off the Kerala coastline was provided by AWS Truepower. All areas with wind power density (WPD) of less than 200 W/m² were excluded from consideration. Table 4.4 briefly summarizes the exclusions.

Table 4.4: Basis for Re-categorizing Offshore Wind Potential

GIS data layer	Re-categorization
Distance to coast	Offshore distance< 25 km
Sea Depth	Depth < 30 m
Wind power density	Area >200 w/m^2 (wind power density)

The area with WPD > 200 was identified and a WPD level categorization was done to estimate the potential across different wind zones. 30 m bathymetry contour was derived from mapping the 30 m contour in Google earth at an eye level altitude of 9-10 km. Area inside the 30 m contour having a wind power density value of more than 200 W/sq m was assumed as technically exploitable area for offshore wind power development. Figure 4.5 represents the WPD-based categorization of offshore wind potential areas. Table 4.5 represents a qualitative breakdown of potential areas based on wind power density.

Figure 4.5: Offshore Wind Power Potential Areas

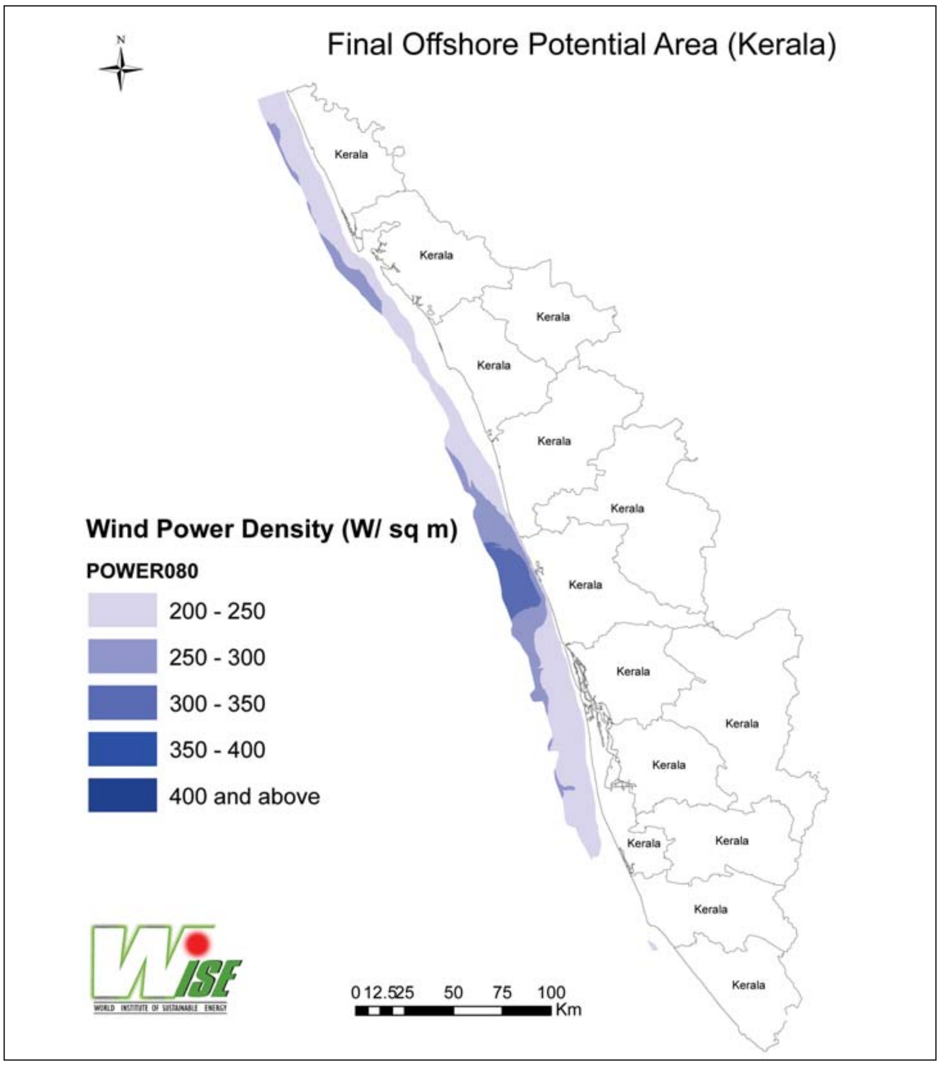


Table 4.5: Offshore Wind Potential at 80 m (Break-up based on WPD)

Offshore wind (80m)		
WPD Range (W/m^2)	**Area (km^2)**	**Potential (MW)**
200-250	4,000	28,000
250-300	1,370	9,590
300-350	551	3,875
350-400	0	0
400 and above	0	0
Total	5,921	41,447

4.5 ANALYSIS OF THE RESULTS

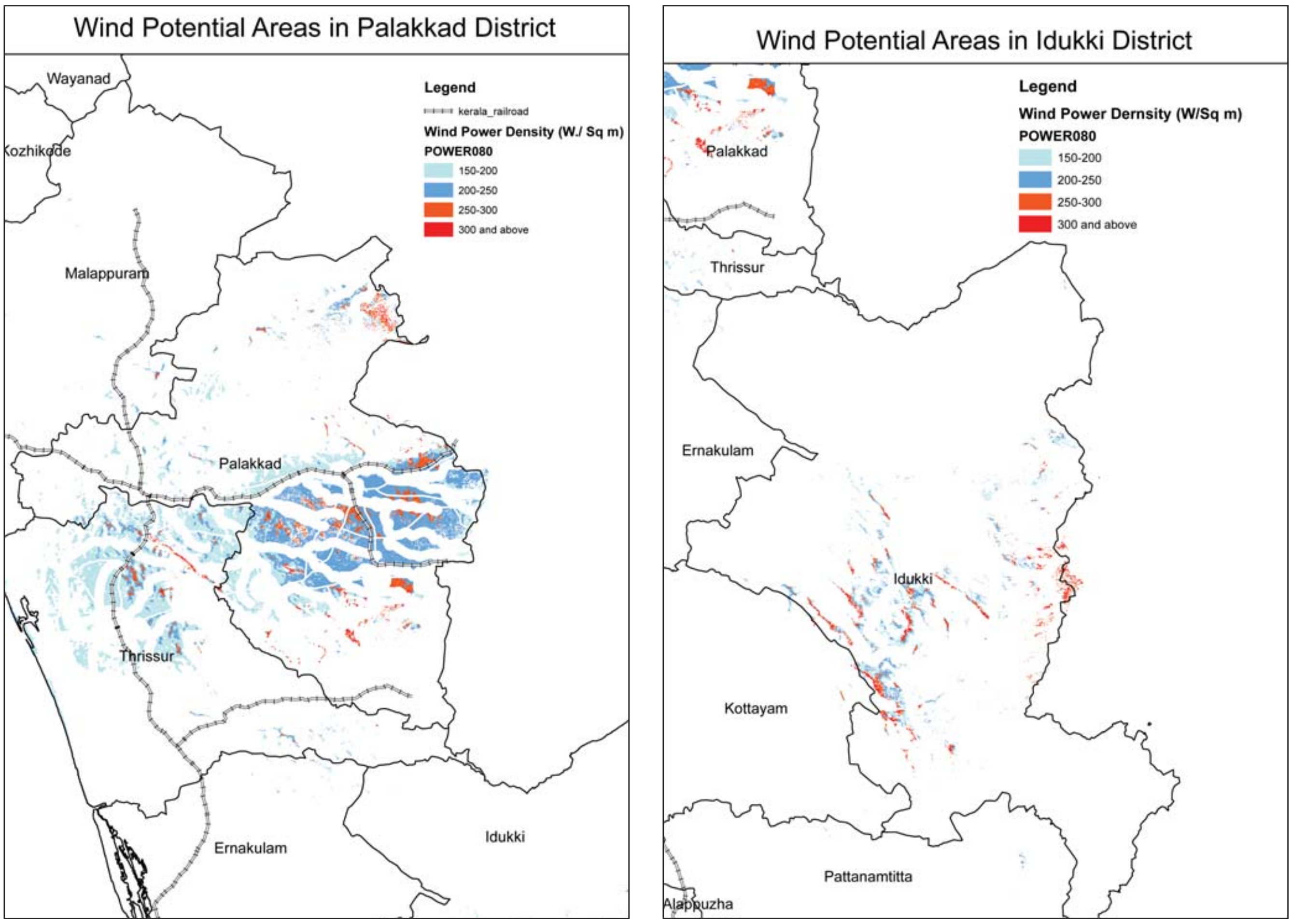
The results of the GIS-based wind potential assessment at 80m hub height for onshore wind and for offshore wind are shown in Table 4.6.

Table 4.6: Results of Wind Potential Assessment at 80m Hub Height

Onshore Wind	WPD > 150		200 < WPD < 250		WPD >250	
Potential	Area (km^2)	MW	Area (km^2)	MW	Area (km^2)	MW
Farmland	443.3	3,103.1	269	1,883	48	336
No Farmland	93.5	654.5	61.3	429	2.6	18.2
Plantation	513.7	3,595.9	202	1414	55	385
Total	**1,050.5**	**7,353.5**	**532.3**	**3,726**	**105.6**	**739**
Offshore Wind	**WPD > 200**		**250 <WPD< 300**		**WPD > 300**	
Potential	**Area (km^2)**	**MW**	**Area (km^2)**	**MW**	**Area (km^2)**	**MW**
Offshore (80 m)	5,921	41,447	1,370	9,590	551	3,875

Table 4.6 indicates a high-grade potential area with generation of about 739 MW onshore and 3,875 MW offshore, and a medium-grade potential area with generation of about 29,829 MW onshore, after considering all considered land use types. Most of the high and medium grade potential areas are in Palakkad and Idukki. Figure 4.6 captures high potential areas from the two districts.

Figure 4.6: Potential Wind Areas in Palakkad and Idukki



(A) (B)

It can be seen that the high-grade and medium-grade potential areas are mostly spread around the Walayar pass in Palakkad, south of Palaghat, west of Pudur (TN) touching the border and in area between Kilakottarra and Muvatagupudur. In Idukki, the prime areas are spread mainly in central east and central west.

However, considering the advantages of a clustered development in easing logistics and designing evacuation networks, the best areas for harnessing wind potential seem to be Walayar pass (North and South of Walayar), south of Palaghat and south west of Kilakottarra. For Idukki, the best potential site seems to be the near the eastern border in central part, which has a predominance of high-grade potential.

Offshore wind resource indicates high-grade potential (>300 WPD) mainly offshore of Thrissur Coast, while medium term potential exists almost all along the coastline except for the coastline south of Alappuzha.

4.5.1 Land impact assessment for developing 100 per cent onshore wind potential

The total land area under high-grade potential is about 105 km^2, while that for medium-grade potential is about 532 km^2 considering all three land use categories.

It has to be understood that the actual utilization of farmland / plantation / wasteland for wind-power development will be substantially less than the indicated land area considering that the actual turbine footprint is only about five acres, with the remaining area being available for alternative uses. In fact, a majority of existing wind turbines in Tamil Nadu are installed on footprint land areas in farmlands and have sustainably co-existed with farming. Table 4.7 calculates the actual land impact of developing 100 per cent of the assessed wind potential.

Table 4.7: Land Impact Assessment for Developing 100 per cent of Assessed Wind Potential at 80m

Parameter	Unit	Equation	Non irrigated Farmland	No Farmland	Plantations	All State
Potential Area	km^2	A	443	94	514	1051
Turbine density	MW/km^2	B	7	7	7	7
Wind Potential	MW	C=A*B	3,101	658	3,598	7,357
Percentage development	%	D	100	100	100	100
Proposed development potential	MW	E=C*D%	3,101	658	3,598	7,357
Turbine rating at 80 m	MW/Turbine	F	1	1	1	1
Number of Turbines	No.	G=E/F	3,101	658	3,598	7,357
Turbine footprint	km^2/Turbine	H	0.02	0.02	0.02	0.02
Actual Land Diversion Required	**km^2**	**I=G*H**	**62**	**13**	**72**	**147**
Total Land use area Kerala	km^2	L	5,186	666	16,370	38,796
Percentage impact on total land mass	**%**	**M**	**1.20**	**1.98**	**0.44**	**0.38**

As can be seen from Table 4.7, development of 100 per cent of wind potential will mean an actual impact of about 1.2 per cent of total farmland, about 2 per cent of total wasteland and grassland, and only 0.44 per cent of total plantation area. On a state level, 100 per cent development would translate into only 0.38 per cent of the land area.

In this context, it is to be noted that the actual decision on the level of deployment is the prerogative of policymakers. However, from the perspective of availability of land, a very high level of wind deployment would not have significant impact on land.

5. POTENTIAL OF SUSTAINABLE BIOENERGY

The term biomass covers a range of organic materials obtained from living or dead vegetation or organisms. It is often used to mean plant based material but could equally apply to both animal or plant derived materials and thus could be concisely defined as the total mass of organisms in a given area or volume. It includes crop residues, forest and wood process residues, animal wastes including human sewage, municipal solid waste (MSW) (excluding plastics and non-organic components), food processing waste, purpose grown energy crops and short rotation forests.

Biomass classification is usually carried out on the basis of its origin which could either be agricultural, forest or animal based. The latter comprises industrial waste as well as that arising from animals, in the form of litter, poultry waste, meat, etc., and the urban and municipal waste originating from human settlements.

Table 5.1: Biomass Classification

Sources	Type
Agriculture	Dry lignocellulosic energy crops Agricultural residues
Forestry	Plantation forestry Forestry by-products
Industry	Industrial residues
Waste	Anthropogenic waste Livestock waste

According to Biomass Resource Atlas of India, biomass based power generation potential in Kerala is 501 MW. No separate state level assessment has been done for assessing the heat and biofuel potential for the state. The *Energy Report 2011* indicates that the long term bio-resources shall be mainly used as fuels for heat or transportation. In this study, the main focus is on present potential and future possibilities of biofuels.

For the purpose of analysis, the bioenergy potential assessment is divided into two sections. The first sections makes projections related to resource availability, while the second section estimates the technological potential.

5.1 PROJECTIONS OF BIOMASS RESOURCES

The most critical factor in assessment of biomass power potential is the actual availability of biomass residue that can be used for power generation or fuel synthesis, unlike in the case of other technologies, where assumptions related to technical parameters are crucial. Consequently, biomass potential assessment is very location-specific and depends largely on the pattern of biomass residue generation and consumption at a local level. Long term predictions for biomass resources have inherent limitations because of these externalities, but the current assessment aspires to cover a variety of aspects not limited purely to power generation potential but also to existing, near-commercialization and untested biomass based technologies that can play a role in the future energy scenario.

The major challenge in assessing and projecting resource availability of biomass is the rapidly changing land use pattern in Kerala, which has seen increasing diversion of cultivable area to non-agriculture use, increasing diversion of land under food crops to cash crops, etc. The resource assessment covered here tries to integrate all these aspects holistically.

5.1.1 Resource Availability projections for Agricultural residues

The main crop residues covered under this section include paddy, tapioca, coconut, areca nut, rubber and cashew. All of these crops produce residues which are either directly collected from the farms (in-situ) or from their respective processing industries. Table 5.2 below describes the residues generated from each of these crops along with the crop life cycles.

Table 5.2: Life Cycle and Residue Generation for Major Crops in Kerala

Crop	Crop Life Cycle (Years)	Component	Residue Generation per kg of Crop* (kg)
Paddy	0.5	Husk Straw	0.2 1.5
Tapioca	1	Stalks	0.75
Coconut	30	Husk & Pith Shells Fronds	0.53 0.22 4 Tonnes/ha
Areca-nut	30	Husk Fronds	0.8 3 Tonnes/ha
Rubber	30	Primary Wood Secondary Wood	3 Tonnes/ha 2 Tonnes/ha
Cashew		Nut Shell Apple	0.65 10

* Biomass Resource Atlas of India. Residue Generation per kg of Crop. http://lab.cgpl.iisc.ernet.in/Atlas/Downloads/CropImages_with_residuedetails.pdf.

These residues are primarily collected in-situ, i.e., directly from the farms once the crop has been harvested. In many cases such residues are either burnt to prepare the soil for the next cropping season or it is left on the farm to mulch and improve soil's nutrition level. In Kerala, it is mostly paddy, tapioca, coconut, rubber and areca-nut which have some potential in terms of residue collection directly from the farms.

Considering the variety of alternative uses for many crop residues, a standard availability of 10 per cent has been assumed. However, changing consumption trends and improved collection efficiency in the future could make a larger resource base available for generation of energy from the sources mentioned above. Thus, starting from a base level of 10 per cent today, the net available residue projections until the year 2050 have been made considering the collection efficiency percentages of 15, 25, 35 and 50 in the years 2020, 2030, 2040 and 2050 respectively.

Paddy

Paddy is sown across all the three seasons. Even though the state grows nearly 600 different varieties of paddy across 14 districts, the actual acreage under paddy is steadily coming down. The total paddy area recorded in the year 1961-62 was 753,000 ha, which increased to 876,000 ha in 1975-76. Thereafter the crop saw a rapid decline in total sown area as the figures reached 276,000 ha by the year 2005-2006, a decline of nearly 70 per cent in the last three decades. The trend has continued so far with the area reaching a low of 213,000 ha in the year 2010-2011, constituting just 8.05 per cent of the total sown area in the state.

The agricultural biomass available from paddy crop is rice straw. Approximately 1.5 kg of rice *straw* is generated per kilogram of crop.[36] Rice straw in Kerala is usually either left over farms to be mulched or is burnt so that the soil can be prepared for the next crop cycle. The predominance of small and fragmented land parcels, lack of mechanization and high labour costs make collection of rice straws difficult and as a result, the collection of straw is negligible. However, this availability can increase in case of better prices and increased farm mechanization.

Although there has been a significant decline in the area under cultivation of paddy in Kerala over the last few years, it is not anticipated that this trend will continue as the Kerala Conservation of Paddy Land and Wetland Act of 2008.[37] At the same time, no increase in land under paddy is assumed owing to the established remunerative benefits from cash crops like coconut and rubber.

Table 5.3 illustrates the total rice straw generation and its net availability for power generation from paddy farming in Kerala. The projected values have been calculated assuming no change in area under paddy cultivation in Kerala over the next four decades. The collection efficiencies have been considered to be 10 per cent for the year 2011, 15 per cent for 2020, 25 per cent for year 2030, 35 per cent for 2040 and 50 per cent for 2050.

Table 5.3: Estimation of Rice Straw and Rice Husk Availability

Rice Straw	2011	2020	2030	2040	2050
Rice Production (MT)	522,000	522,000	522,000	522,000	522,000
Total Straw Generation (MT/Y)	783,000	783,000	783,000	783,000	783,000
Collection Efficiencies (%)	10	15	25	35	50
Net Straw Availability (MT/Y)	78,300	117,450	195,750	274,050	391,500
Rice Husk	**2011**	**2020**	**2030**	**2040**	**2050**
Rice Production (MT)	522,000	522,000	522,000	522,000	522,000
Total Husk Generation (MT/Y)	104,000	104,000	104,000	104,000	104,000
Collection Efficiencies (%)	0.1	0.15	0.25	0.35	0.5
Net Husk Availability (MT/Y)	10,400	15,600	26,000	36,400	52,000

[36] Biomass Resource Atlas of India. Rice straw http://lab.cgpl.iisc.ernet.in/Atlas/Downloads/CropImages_with_residuedetails.pdf.
[37] The Kerala Conservation of Paddy Land and Wetland Act of 2008. http://keralalawsect.org/acts/Act2008/act28_2008/index.html.

Coconut

Coconut based farming is the mainstay of farmers in Kerala with nearly 40 per cent[38] of the state's net cropped area dedicated to the cause. A cash crop, coconut also helps generate significant direct and indirect unemployment across the state through a wide array of coconut product related industries ranging from cottage to large scale.

The total area under coconut cultivation recorded in the year 1965-66 was 461,475 ha,[39] which nearly doubled to 906,984 ha by 2003-04. Thereafter the crop has seen an average year on year decline of 2.5 per cent for the last six years with the area under coconut cultivation reaching to 770,000 ha by 2010-11.

Several reasons have been cited to account for this recent decline in area under coconut plantation, few of them being unavailability of skilled coconut climbers for nut harvesting,[40] mite infestation, intermittent draughts, inability of coconut farmers to develop necessary irrigation infrastructure due to small and fragmented land holdings, soil nutrient depletion and market fluctuations.[41]

Coconut plantations generate husk and pith, shells and fronds. The average crop to residue ratio is 0.53 kg per kilogram of nuts for husk, 0.22 kg per kiligram of product for shells and about 4 MT of fronds per hectare of coconut plantation.[42] The *husk* is procured directly by the coir industries. Shells also have alternative non-energy uses. Incidentally, *shells* are used as charcoal or activated carbon in some international markets but are not used for the same application here.

The only residue that is available from the coconut plantation farms are the *fronds* which can be utilized for energy generation. A part of the coconut fronds is utilized for manufacturing temporary thatching materials and roofing arrangements.[43] Rest may be available for the purpose of energy generation.

It is anticipated that the area under coconut farming will continue to decline with the neighbouring states like Tamil Nadu and Andhra Pradesh becoming highly competitive over the years in terms of increasing their area under coconut cultivation, nut yield as well as by developing markets for products from processing industries. However, the collection efficiency is bound to increase over the years owing to increased mechanization of the collection process. At the same time,

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[38] ENVIS Centre. Coconut Farming. http://www.kerenvis.nic.in/Database/Agriculture_828.aspx.
[39] Coconut cultivation in hectares. http://www.ras.org.in/paddy_cultivation_in_kerala#tbl1.
[40] Philip, Shaju. 2012. "Kerala's Coconut Forms Get Some New ;Friends'". *The Financial Express* (11 May). http://www.financialexpress.com/news/kerala-s-coconut-farms-get-some-new-friends-/947864/1.
[41] Soil Nutrient Depletion and Market Fluctuations. http://www.teriin.org/index.php?option=com_ongoing&task=about_project&pcode=2009WR03.
[42] Plantation of Coconut. http://lab.cgpl.iisc.ernet.in/Atlas/Downloads/CropImages_with_residuedetails.pdf
[43] Krishna, Aswathi. 2013. "These Women Weave Coconut to Eke Out a Living". *The New Indian Express* (29 April). http://newindianexpress.com/states/kerala/These-women-weave-coconut-fronds-to-eke-out-a-living/2013/04/29/article1566236.ece1.

reduction alternative uses (uses in thatched roofing material) will also facilitate better collection efficiencies.

Table 5.4 describes the total available and projected frond generation till year 2050. The projected values have been calculated based on the trend observed in area under coconut cultivation in the past 25 years. Net availability too has been calculated based on the standard 10 per cent residue availability for year 2011, 15 per cent for 2020, 25 per cent for year 2030, 35 per cent for 2040 and 50 per cent for 2050, considering about 50 per cent improvement in collection efficiencies every decade.

Table 5.4: Estimation of Coconut Frond Availability

Coconut Fronds	2011	2020	2030	2040	2050
Area under coconut cultivation ('000 ha)	770	793	751	694	649
Total frond generation (MT/Y)	3,080,000	3,172,000	3,004,000	2,776,000	2,596,000
Collection efficiencies	10	15	25	35	50
Net frond availability (MT/Y)	308,000	475,800	751000	971600	1,298,000

Rubber

Kerala accounts for more than 90 per cent of the natural rubber produced in the country.[44] More than 9 lakh growers are engaged in the production of rubber in Kerala,[45] with an average landholding size being less than 0.5 ha. A major cash-crop, the area recorded under rubber cultivation in the year 1965-66 was 121,009 ha, which increased by more than 3 times in the year 2005-06 to 494,400 ha.

The major reason for this trend has been the increasing prices of rubber. The year on year average growth in prices of rubber in the last one decade has been more than 20 per cent.[46] The trend is expected to continue as the rubber processing industries in Kerala mature, state government incentivizes domestic rubber production,[47] and as more mechanization comes into the picture to compensate for the shortage in labour.

Considering an average year on year growth of 1.16 per cent in the area under rubber cultivation, Kerala would have nearly 850,000 ha under rubber plantation by the year 2050.

Table 5.5 describes the projected total generation and availability trend for rubber wood generation by the year 2050. The projected values have been calculated based

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[44] Natural rubber production. http://www.dsir.gov.in/reports/ExpTechTNKL/Abs%20new/Rubber.htm.
[45] Rubber Plantation in Kerala. http://shodhganga.inflibnet.ac.in/bitstream/10603/6550/10/10_chapter%202.pdf.
[46] Krishnakumar, P. K. 2013. "Kerala Turns to Rubber for Better Farm Returns, Switches from Arecanut, Cononut". *The Economic Times* (19 June). http://m.economictimes.com/markets/commodities/kerala-turns-to-rubber-for-better-farm-returns-switches-from-arecanut-coconut/articleshow/20656231.cms.
[47] Business Line. 2013. "Kerala CM Asks for Raise in Import Duty on Rubber". *Business Line* (5 March). http://www.thehindubusinessline.com/industry-and-economy/agri-biz/kerala-cm-asks-for-raise-in-import-duty-on-rubber/article4478800.ece.

on the changing pattern of area under rubber cultivation over the last 25 years. Net wood availability has been calculated based on the assumption of 10 per cent residue availability for year 2011, 15 per cent for 2020, 25 per cent for year 2030, 35 per cent for 2040 and 50 per cent for 2050.

Table 5.5: Estimation of Primary Rubber Wood Availability

Coconut Fronds	2011	2020	2030	2040	2050
Area under rubber cultivation (ha)	534,230	599,870	673,576	756,337	849,267
Total primary wood generation (MT/Y)	1,602,690	1,799,611	2,020,727	2,269,011	2,547,802
Collection efficiencies (%)	10	15	25	35	50
Net primary wood availability (MT/Y)	160,269	269,942	505,182	794,154	1,273,901

Areca-nut

Areca-nut, the seed taken out from Areca palm, is a major ingredient in the tobacco industry in the country. It is also used widely in religious and cultural ceremonies. Veterinary medicine is another area where areca-nut finds wide applications. The major residues obtained from areca-nut plantations are the fronds, obtained at the rate of 3 tonnes per hectare per annum, and the husk obtained at the rate of 0.8 kg per kilogram of areca-nut crop. In terms of availability, fronds are mainly consumed by elephants as their staple diet, and as such are not available in excess for the energy generation. Areca-nut husk on the other hand doesn't find a significant alternate use and could be utilized for the generation of power. Research has been carried out with areca-nut husk as a potential substrate for generating energy through gasification based technologies.[48]

India is the leading producer of areca-nut in the world with 53 per cent share of global output. Indonesia, Bangladesh, China, Myanmar and Thailand are the other producers of areca-nut. China is credited with the highest productivity of over 3 tonnes per hectare while India is the fourth with 1.18 tonnes per hectare. In India areca-nut is mainly grown in Kerala and Karnataka which together account for more than 80 per cent of the total domestic production.[49]

The area under cultivation of areca-nut in Kerala saw an increase of 83 per cent between the years 1985-86 and 2004-05[50] (49,224 ha in 1965-66 and 108,590 ha by the year 2005-06). However, since 2005-06, the area under areca-nut production has been steadily declining at an average year on year rate of 1.6 per cent. The primary issues being faced by areca-nut farmers in Kerala are cheaper imports from neighbouring countries, declining production due to weather vagaries and crop diseases, declining prices in the domestic markets owing to central government's move on implementing ban on tobacco based products (a major market for areca-

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[48] Areca-nut husk as a potential substrate for generating energy through gasification based technologies. http://webpages.mcgill.ca/staff/deptshare/FAES/066-Bioresource/Theses/theses/353GuillaumePilon2007/353GuillaumePilon2007.pdf.

[49] Changing Price Trends of Areca-nut. http://www.indiaagronet.com/indiaagronet/News/changing_price.htm.

[50] Department of Economics and Statistics. *Area, Production and Productivity Trend of Important Crops in Kerala (From 1985-86 to 2004-05).* Government of Kerala. Thiruvananthapuram, Kerala. http://www.ecostat.kerala.gov.in/pdf/areappt.pdf.

nut) and shortage of labour.[51] The central government has already directed all the state governments not to further increase the area under areca-nut cultivation,[52] mainly because of market factors and the deleterious health effects arising out of tobacco based products which have areca-nut as one of their constituents. Considering this situation, it is not anticipated that the area under areca-nut cultivation will be expanded in future.

Table 5.6 below describes the availability of areca-nut husk where the area under areca-nut plantation is considered to decline at a rate of 1.66 per cent per year (rate of decline for past five years). Considering the alternative uses of areca-nut husk for manufacturing of thick boards, fluffy cushions, non-woven fabrics, thermal insulation and wrapping paper, and as a substrate for mushroom cultivation,[53] the net availability has been calculated assuming 10 per cent residue availability for year 2011, 15 per cent for 2020, 25 per cent for 2030, 35 per cent for 2040 and 50 per cent for 2050.

Table 5.6: Estimation of Acrea Nut Husk Availability

Acrea Nut	2011	2020	2030	2040	2050
Annual Production (MT/Y)	99,834	82,976	71,324	60,285	50,955
Total Residue Generation (MT/Y)	79,927	73,019	62,765	53,051	44,840
Availability (%)	10	15	25	35	50
Net Availability (MT/Y)	7,993	10,953	15,691	18,568	22,420

Tapioca

Tapioca or cassava as it is popularly known is a major crop grown in Kerala. But the cropping pattern of the last 15 years indicates that major portion of land under tapioca cultivation has shifted to rubber plantation. During 1995-96, the area crop area under tapioca cultivation was 113,601 ha, which declined to just 72,284 ha by 2010-11. However, an increase in yield of 48 per cent helped cap the decline in total production to 5.6 per cent during this period.

Some of the reasons cited regularly for the decline in area under tapioca cultivation are price volatility in the domestic markets, import of cassava starch from Vietnam and Thailand,[54] unpredictable monsoons, high labour and manure costs, and a shift to rubber plantation, which is much more remunerative.[55]

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[51] Narayan Kutty, C. S. 2011. "Hike in Areca-nut Prices Offset by Low Yield". *The Hindu* (1 May). http://www.hindu.com/2011/05/01/stories/2011050160970900.htm.
[52] Kebbehundi, Ramesh S. 2013. "Future Tense for Arecanut Growers in Davangere". *Deccan Herald* (20 November). http://www.deccanherald.com/content/206254/future-tense-arecanut-growers-davangere.html.
[53] Anon. 2010. "Arecanut Husk - Biomass". http://renfuels.blogspot.in/2010/08/arecanut-husk-biomass.html.
[54] Sajeev Kumar, K. 2012. "Tapioca Starch Imports Hit Kerala Cassava Cultivation". *Business Line* (2 October). http://www.thehindubusinessline.com/industry-and-economy/agri-biz/tapioca-starch-imports-hit-kerala-cassava-cultivation/article3957841.ece.
[55] Ramabhadram Pillai, R. 2012. "Prospects Grim for Coconut, Tapioca Growers". *The Hindu* (18 October). http://www.thehindu.com/todays-paper/tp-national/tp-kerala/prospects-grim-for-coconut-tapioca-growers/article4008093.ece.

However, just like any other commodity's price that is driven by market forces, the prices of tapioca did see a hike in the retail market this year as a result of the shrinking acreage of tapioca.[56] This would again help farmers gain more confidence in this crop and could result in an increased sowing of tapioca once again for the next few years. However, the rate by which it will grow will depend upon a lot of factors like market prices of rubber, state government's stance on increasing import duties on tapioca starch and many others apart from change in climatic condition. At the same time, the demand of cassava could well increase in the near future as the demand for ethanol increases to substitute petroleum based products.[57]

The major residue obtained from cassava is the stalk which is left on the farm post the crop harvest. Nearly 0.75 kg of stalks is obtained per kilogram of crop harvest. As of now this doesn't find any use and can be utilized for the purpose of energy generation. Table 5.7 describes the total generation and net availability of cassava stalks from the year 2010-50. Since it is difficult to estimate the rate of change in the crop area under tapioca cultivation for the next four decades, a constant area is assumed for the crop. The residue collection is however assumed to increase over the years because of increasing farm mechanization.

Table 5.7: Estimation of Tapioca Stalks Availability

Tapioca Stalks	2011	2020	2030	2040	2050
Area under tapioca cultivation (ha)	2,360,081	2,360,081	2,360,081	2,360,081	2,360,081
Total stalks generation (MT/Y)	1,770,061	1,770,061	1,770,061	1,770,061	1,770,061
Collection efficiencies (%)	10	15	25	35	50
Net stalks availability (MT/Y)	177,006	265509	442,515	619,521	885,030

5.1.2 Resource Availability projections for Agro-industrial residues

These residues are obtained from primary and secondary agro-based processing units as well as from cottage, small and medium scale industries which utilize either agro-residues or wastes from their processing to manufacture value added products. In Kerala, the major sources for availing such resources are the rice mills, coir industries, cashew and tapioca processing industries.

Rice mills

Rice husk is generated as a by-product of paddy shelling at rice mills. At present the paddy milling capacity of state is about 3,000-3,500 MT per day, from the 125 operational paddy mills.[58] These rice mills in Kerala are meeting only 20 per cent of the state's requirements. The rest is either compensated through the public distribution system or through imports from neighbouring states.

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[56] Anon. 2013. "Call it Yummy But Not Cheap, Anymore". *The Hindu* (25 June). http://www.thehindu.com/news/cities/Kochi/call-it-yummy-but-not-cheap-anymore/article 4847372.ece.
[57] Anon. 2010. "Tapioca for Food and Fuel". *The Hindu* (4 December). http://www.hindu.com/2010/12/04/stories/2010120450981900.html.
[58] Kerala State Industrial Develpopment Corporation. "Project Profile on Modern Rice Mill". http://www.emergingkerala2012.org/pdf/Food%20Processing/Modern%20Rice%20Mill%20-KSIDC.pdf.

Rice mills result in generation of rice husk and bran. While rice bran is directly sold to fodder manufacturing companies, husk can be utilized as fuel. Approximately 0.2 kg of husk is generated per kilogram of rice crop processed at mills. Nearly 100,000 MT[59] of husk was generated in Kerala in 2010-11. Most of this is either utilized as energy source for running shelling operations or for preparation of parboiled rice.[60]

Table 5.8 describes the total husk generation trend and its possible availability by 2050. The projected values have been calculated assuming no change in area under paddy cultivation in Kerala over the next 4 decades owing to state government policies. Net rice husk availability has been calculated based on the assumption of 10 per cent residue availability for 2011, 15 per cent for 2020, 25 per cent for 2030, 35 per cent for 2040 and 50 per cent for 2050, considering that a usage shift in rice-husk consumption may take place in the future which will ensure increased availability of husk for energy applications.

Table 5.8: Estimation of Rice Husk Availability

Rice Husk from Rice Mills	2011	2020	2030	2040	2050
Total husk generation (MT/Y)	800,000	800,000	800,000	800,000	800,000
Net husk availability (MT/Y)	78,300	117,450	195,750	274,050	391,500

Coir Industries

Coconut and areca-nut husk are used as major raw materials by the coir industries in Kerala. Almost all the husk generated is utilized by the coir industry. Husk is composed of 70 per cent pith and 30 per cent fibre on dry basis.[61] Coir industries have traditionally been manufacturing items like yarns for the production of floor coverings, mats and matting, cordage and nets, bristle fibres for brooms and brushes. Lately the demand for coir has also seen a significant rise in other novel commercial applications like use as insulating materials, fibre re-enforced composite materials, geo-textile products, stemming from the need to use environmentally benign raw-materials and utilization of waste resources. There doesn't seem to be any possibility of availability of husk in the future too as Kerala is experiencing a short-fall in husk availability even today and coir is being imported from neighbouring states to meet the demands of local industries in Kerala.[62] The fact that the Kerala government has also been providing capital subsidy schemes[63] for de-fibring and coir pith processing units would only improve the utilization / consumption of husk within this sector, thus further diminishing the possibility of its use as a potential energy resource.

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59 Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. http://eands.dacnet.nic.in.
60 Anon. "Rice Husk Ash Pozzolana". http://shodhganga.inflibnet.ac.in/bitstream/10603/5756/8/08_chapter%206.pdf
61 Coconut Tree of Life. http://www.fao.org/docrep/005/y3612e/y3612e03.htm#TopOfPage.
62 Madanan, K. 2009. "Strengthen Strategy against Stagnation". *Kerala Calling.* (October) http://www.old.kerala.gov.in/keralacal_oct09/pg28-30.pdf.
63 KITCO. Integrated Coir Processing Units. http://www.emergingkerala2012.org/pdf/Manufacturing,%20Engg%20&%20Automotive/intergrated-coir-processing-unit.pdf.

Another by-product obtained from the coir industries is the *pith*. Approximately 2 kg of pith is generated per kilogram of fibre extracted. However its physical properties in having long shelf-life (low rate of biodegradability) and highly porous structure makes it a good substitute for peat moss in the horticulture market.

It is thus assumed that residues from this sector are not available for energy generation.

Cashew Processing Industry

The share of cropped area under cashew in the state has been declining at an annual average rate of 6.8 per cent since the last 15 years.[64] The major reasons cited for the decline are unavailability of facilities within the state for processing of raw cashew nut and manufacturing of value-added products[65], no incentives by state government to re-plant the aging cashew plantations, unpredictability in the market and heavy reliance on middlemen for sale of crop[66]. Although the government is trying to promote cashew plantations on a large scale, the commercial benefits of growing rubber far outweigh those of growing cashew.

The two major residues obtained from cashew are cashew nut shell and cashew apple. While cashew apples are collected from the ground post-harvesting, cashew nut shells are obtained during the cutting and shelling operation performed at the mill. The quantity of cashew nut shells obtained during the processing of the crop is about 67 per cent of the total weight of raw cashew nut seeds.[67] On the other hand, the quantity of cashew apple generated is about 10kg per kilogram of raw cashew.[68] Most of the cashew apples are at present wasted and practically not utilized by the industry in any of the cashew growing tracts in India except Goa.[69] However, these could potentially be utilized for the generation of bio-ethanol. This aspect is discussed further in subsequent section.

Table 5.9 describes the availability of cashew nut shell and cashew apples over time, assuming a year on year decline of 2.5 per cent in area under cashew nut cultivation.

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[64] Department of Economics and Statistics. 2010. *Agricultural Statistics 2008-09*. Government of Kerala. Thiruvananthapuram, Kerala. 23-55pp. http://www.ecostat.kerala.gov.in/docs/pdf/reports/agristat/agc0809table1.pdf.
[65] Harikumar, A. 2008. "Rubber Erasing Cashew Plantations in Kannur, Kasaragod State Trends". *The Hindu* (15 September). http://www.hindu.com/2008/09/15/stories/2008091553590400.htm.
[66] Nair, G. K. 2009. "Kerala Sets Up Agency to Hike Cashew Output". *Business Line* (24 May). http://www.thehindubusinessline.com/todays-paper/tp-agri-biz-and-commodity/kerala-sets-up-agency-to-hike-cashew-output/article1052398.ece.
[67] Mohod, Atul, Jain, Sudhir and Ashok Powar. 2001. "Cashew Nut Shell Waste: Availability in Small-Scale Cashew Processing Industries and Its Fuel Properties for Gasification". http://www.hindawi.com/isrn/re/2011/346191.
[68] Potty, V. P. "From Cashew Apple to Bioethanol". http://www.emergingkerala2012.org/pdf/Food%20Processing/BIOETHANOL%20Procudtion%20from%20Cashew%20Apple.pdf.
[69] CEPC Laboratory and Technical Division. 2010. *Production of Industrial Bio ethanol from Cashew Apple*. The Export Promotion Council of India. Kollam, Kerala. http://cepclab.org.in/?p=25.

Table 5.9: Estimation of Cashew Apple Availability

Cashew Residues	2011	2020	2030	2040	2050
Area Under Cashew (ha)	35,818	27,807	21,587	16,759	13,010
Total Cashew Production (MT/Y)	27,795	21,578	16,752	13,005	10,096
Total Nut Shell Generation (MT/Y)	18,622	14,457	11,224	8,713	6,764
Total Cashew Apple Generation (MT/Y)	277,948	215,779	167,516	130,047	100,960
Collection Efficiencies (%)	0.1	0.15	0.25	0.35	0.5
Net Nut Shell Availability (MT/Y)	1,862	2,169	2,806	3,050	3,382
Net Cashew Apple Availability (MT/Y)	27,795	32,367	41,879	45,517	50,480

Agro-Based Wood-Processing Industries

The plantation based wood-processing industries generate a significant amount of saw-dust and bark[70] as by-products. The major plantations in Kerala are that of rubber, coconut and areca-nut. All these three varieties have a useful life-cycle of 25-30 years[71] after which they need to be cut and re-planted. The process of re-planting is a continuous process as trees age and newer and better varieties are sown. Thus, the availability of such tree logs is maintained through-out the year on a consistent basis for the purpose of timber as well as fuel.

Although the area under cultivation of coconut and areca-nut may decrease in the coming years, as seen in the previous section, it will be safe to assume that the availability of rubber wood will increase in the coming years and this in turn would result in generation of higher amounts of processing wastes like bark and saw-dust that could be used for energy related applications.

During replanting most of the softwood plantations yield about 180 cubic meters of green wood per hectare.[72] This is equivalent to about 81 MT of dry wood per hectare assuming 0.72 tonne per cubic metre of green wood yield with a moisture content of 60 per cent. Considering a useful life cycle of 30 years for coconut, areca-nut as well as rubber plantations, nearly 2.59 tonnes of wood would be generated per hectare annually from each of the crops.[73]

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[70] Mathew, Jacob. 1994. *Characterization of Wastes from Natural Rubber and Rubber Wood Processing Industries and Their Utilization for Biomethanation.* Thesis submitted to the Cochin University of Science and Technology. Cochin, Kerala. http://dyuthi.cusat.ac.in/xmlui/bitstream/handle/purl/3059/Dyuthi-T1033.pdf?sequence=1.

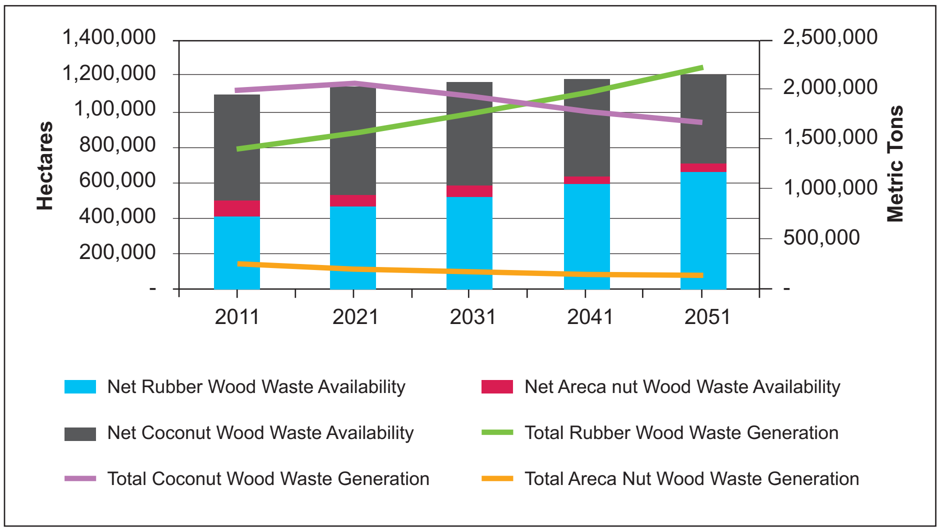
[71] Koopmans, Auke and Koppejan, Jaap. 1997. "Agriculture and Forest Residue: Generation, Utilization and Availability". Paper presented at the Regional Consultation on Modern Applications of Biomass Energy, Kuala Lumpur, Malaysia (6-10 January). http://ces.iisc.ernet.in/energy/HC270799/RWEDP/acrobat/p_residues.pdf.

[72] Lim, K.O. 1986. "The Energy Potential and Current Utilization of Agriculture and Logging Wastes in Malaysia". *Renewable Energy Review Journal.* 8 (2) (December), RERIC-AIT, Bangkok.

[73] DNR. *Woody Biomass Feedstock for the Bioenergy and Bioproducts Industries.* Indiana Department of Natural Resources. Indiana. http://www.in.gov/dnr/forestry/files/fo-WoodyBiomass_final.pdf.

Figure 5.1 describes the net availability of wood wastes from coconut, rubber and areca-nut plantations. A standard residue figure of 2.59 tonnes per annum per hectare has been considered from all these three plantations, and it is further assumed that this amount can be generated on an annual basis as re-planting is a continuous process. Also, the wood collection efficiency has been taken to be 60 per cent and the residue generation has been given another factor of 50 per cent as the rest is utilized for other purposes.

Figure 5.1: Net Wood Waste Availability from Rubber, Coconut and Areca-Nut Plantations in Kerala



5.1.3 Resource Availability Projections for Forest Residues

Forest cover, as defined by Forest Survey of India, includes all areas, more than one hectare in extent, with tree canopy density of more than 10 per cent. Even though the land area of Kerala is only 1.2 per cent of India, the forest cover is 2.30 per cent of the national average.

The area under forest cover in Kerala has not seen any changes since 1980-81. It has remained constant at the figure of 1,081,509 ha till date, and accounts for about 27.8 per cent of Kerala's total geographical area.[74]

Table 5.10 below has been sourced from the FSI and describes the share of forest types within Kerala in the year 2009.

Major forest produce include timber, reeds, bamboo, sandal wood and fire wood. The quantity of timber production in 2009-10 was 51,665.6 cum (round log).[75] The number of bamboos and reeds produced were 6.96 lakh and 148.55 lakh respectively. Sandal wood production was 51,120.7 kg.

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[74] Department of Economics and Statistics. 2010. Agricultural Statistics 2009–10. Thiruvananthapuram. Chapter 2 http://www.ecostat.kerala.gov.in/docs/pdf/reports/agristat/agst0910_2.pdf.

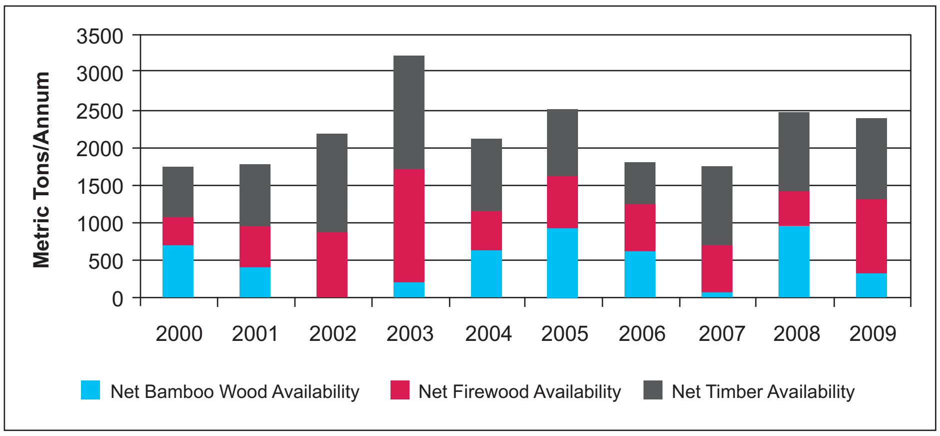
[75] ENVIS Centre. Forest. http://www.kerenvis.nic.in/Database/FOREST_819.aspx.

Table 5.10: Area Covered by Different Forest Types in Kerala

Type of Forest	Area Covered (Km^2)	Share (%)
Tropical Wet Evergreen	2,463.74	26.21
Semi-Evergreen	2,148.84	22.86
Tropical Moist Deciduous	1,705.16	18.14
Tropical Dry Deciduous	215.26	2.29
Mountain Sub-Tropical Temperate Shoals	48.88	0.52
Plantation	2,817.18	29.97
Grassland	1.00	0.01
Total	**9,400.06**	**100.00**

Different activities pertaining to wood-processing generate different rates and types of waste as described below:

Figure 5.2: Net Availability of Major Forestry Residues between 2000 and 2009 in Kerala[76]



Logging residues

Recovery rates vary considerably depending on local conditions. A 60/40 ratio is often found in the literature, e.g., for every cubic meter of log removed, 0.4 cubic meter of waste remains in the forest.

In order to calculate the amount of logging residues an average recovery factor of 60 per cent has been used.[77]

Saw-milling

Recovery rates vary with local practices as well as species. After receiving the logs, about 12 per cent is waste in the form of bark. Slabs, edgings and trimmings amount to about 34 per cent, while sawdust constitutes another 12 per cent of the log input. After kiln-drying the wood, further processing may take place resulting in another 8 per cent wastage (of log input) in the form of sawdust and trim end (2 per cent) and

[76] Net Availability of Major Forestry Residues between 2000-01 and 2009-10 http://spb.kerala.gov.in/images/ec2010/chapter6/6.pdf.
[77] FRIM. 1992. "Utilization of Industrial Wood Residues". Paper presented at the workshop on "Logging and Industrial Wood Residues Utilization" in Jakarta, Indonesia (24 August).

planer shavings (6 per cent). For calculation purposes a yield factor of 50 per cent has been used (38 per cent solid wood waste and 12 per cent sawdust).[78]

Plywood production

Plywood making is a large-scale operation and involves the cutting of the logs to the length required and de-barking the logs. After the preparatory operations, sizing, debarking and cleaning, the logs are sliced, i.e., the logs are rotated in a machine. Recovery rates vary from 45 to 50 per cent with the main variable being the diameter and quality of the log. Of the log input, the main forms of waste are log ends and trims (7 per cent), bark (5 per cent), log cores (10 per cent), green veneer waste (12 per cent), dry veneer waste (8 per cent), trimmings (4 per cent) and rejected plywood (1 per cent). These form the largest amount of waste while sanding the plywood sheets results in another loss of 5 per cent in the form of sander dust.[79] For calculation purposes a yield factor of 50 per cent has been used, with 45 per cent solid wood residues and 5 per cent in the form of dust.

Figure 5.2 describes the availability from major forestry residues between the period 2000 and 2009 in Kerala. The major sources of such residues in Kerala are the timber mills, fire-wood and bamboo. The net availability of waste residues from timber mills is considered as 30 per cent (considering the wastes from three types of processing steps as described above) while the availability of fire-wood and bamboo is assumed at 50 per cent considering their alternative uses and collection efficiencies. Assuming the area under forest cover to be constant, the average residue generation in this time period has been approximately 22,000 MT. Table 5.11 shows the estimated availability of wood residues in Kerala.

Table 5.11: Estimation of Forest Wood Availability

Wood	2011	2020	2030	2040	2050
Area under Rubber (ha)	534,230	599,870	673,576	756,337	849,267
Total Rubber Wood (MT/Y)	1,383,656	1,553,664	1,744,561	1,958,913	2,199,602
Rubber Wood Availability (MT/Y)	415,097	466,099	523,368	587,674	659,881
Area under Acrea Nut (ha)	99,834	82,976	71,324	60,285	50,955
Total Acrea nut wood (MT/Y)	258,570	214,908	184,728	156,139	131,974
Acrea nut wood availability (MT/Y)	77,571	64,472	55,418	46,842	39,592
Area under coconut (ha)	770,000	793,000	751,000	694,000	649,000
Total Coconut wood (MT/Y)	1,994,300	2,053,870	1,945,090	1,797,460	1,680,910
Coconut wood availability (MT/Y)	598,290	616,161	583,527	539,238	504,273

[78] Koopmans, Auke and Koppejan, Jaap. 1997. "Agriculture and Forest Residue: Generation, Utilization and Availability". Paper presented at the Regional Consultation on Modern Applications of Biomass Energy, Kuala Lumpur, Malaysia (6–10 January). http://ces.iisc.ernet.in/energy/HC270799/RWEDP/acrobat/p_residues.pdf

[79] FAO. 1990, *Energy Conservation in the Mechanical Forest Industries.* FAO Forestry Paper No. 93, Food and Agriculture Organization (FAO). Rome.

5.1.4 Potential availability of Municipal Solid waste

In Kerala the MSW generated in 2012 was reported to be 8,338 tonnes per day while only 1,739 tonnes of it was collected and treated,[80] which indicates a collection efficiency of just 21 per cent, way lower than the national average of 70 per cent. In terms of the MSW composition, nearly 70 per cent of the waste generated in Kerala is compostable organics and the rest comprises paper, plastics, metals and glass which can also be incinerated to generate power.

Independent studies carried out by the National Environmental Engineering Research Institute (NEERI) in 1996 in Indian cities suggests that the quantum of MSW generation varies between 0.21-0.35 g/capita/day in the urban centres and up to 0.5 kg/capita/day in large cities.[81] Studies by the Urban Development Section (East Asia and Pacific Region) of the World Bank indicate that the rate of waste generation is estimated to grow at an exponential ratio of 1.41 per cent per annum. Based on these inputs, the present minimum generation of MSW is considered at about 0.242 kg/head/day.

The MSW potential is dependent on three variables: population, MSW generation per capita and collection efficiencies. The population projections[82] suggest that Kerala would see a declining rate of population in the years to come. At the same time, with an increase in standard of living, the per capita MSW generation is also bound to increase. Also, the collection efficiencies would increase as governments realize the power generation potential involved and as people demand higher standards of living. The rate of increase in per capita MSW generation has been considered as 1.41 per cent and the collection efficiency has been given a year on year incremental value of 0.5 per cent so that it at least becomes comparable to the national MSW collection average of 60 per cent.

Based on above assumptions, Table 5.12 indicates the net MSW availability in Kerala until the year 2050.

Table 5.12: Estimation of MSW Availability

MSW generation	2011	2020	2030	2040	2050
Per Capita MSW	0.26	0.30	0.34	0.39	0.45
Collection Efficiency (%)	21.0	22.1	29.4	43.3	63.8
Total MSW (MT/Y)	631,452	872,764	1,034,923	1,189,830	1,326,090

80 Central Pollution Control Board. *Status Report on Municipal Solid Waste Management.* Ministry of Envirenment and Forest. Delhi, India. http://www.cpcb.nic.in/divisionsofheadoffice/pcp/MSW_Report.pdf.

81 NEERI. 1996. *Municipal Solid Waste Management in Indian Urban Centres.* National Environmental Engineering Research Institute. Nagpur, India.

82 Mehmood, Aslam and Kundu, Amitabh. "Demographic Projections for India 2006–2051: Regional Variations". Draft. Jawaharlal Nehru University. New Delhi. http://nrlp.iwmi.org/PDocs/DReports/Phase_01/01.a.Demographic%20Projections%20–%20Aslam%20Mahmood.pdf.

Table 5.13: Bioenergy Resources in Kerala: A Summary

5.1.5 Summary of Biomass Resource availability

The following table provides summary of biomass resources from various sources.

Source	Crop	Residue Type	Projections	Comments
Agriculture and Agro - Processing	Paddy	Straw Husk	Area under paddy production has been assumed to be constant for the next 4 decades	Strict enactment of paddy and wetland conservation act in Kerala would curb the changeover of paddy cultivated areas to other uses.
	Tapioca	Stalks	Projections are made based on the past trends of 20 years.	Collection efficiency of stalks is assumed to increase in the future
		Processing Residues		Good potential exists for biogas as well as bio-ethanol production
		Roots		There are no specific projections for the use of the main crop for the purpose of energy generation. However, some part of it may be utilized for generation of bio-ethanol as gasoline becomes scarce and expensive.
	Coconut	Fronds	The projected values have been calculated based on the trend observed in area under coconut cultivation in the past 25 years.	The area under coconut cultivation is expected to show a downward trend in the coming years as the neighbouring states become more price competitive as well as get better in terms of productivity. Also, the increasing rubber prices would make coconut relatively unattractive.
	Rubber	Primary Wood	The projected values have been calculated based on the changing pattern of area under rubber cultivation over the last 15 years. An average year on year growth of 1.16 per cent is assumed based on past trend	The life cycle of these crops is around 30 years. Therefore, no major changes are envisaged in the next 3-4 decades. However, collection efficiency of the residues is expected to increase over time as alternative usages (thatching, roof materials) become obsolete.
	Areca-Nut	Husk	Area under areca-nut cultivation has considered to be declining at a rate of 1.66 per cent as has been the trend since the past 5 years.	Uncertainty on use of the nut in tobacco based products which is its biggest application has resulted in a decline over the last few years. The area under areca-nut cultivation may also remain a constant if the demand in international markets increase.

Continued...

Continued...

Source	Crop	Residue Type	Projections	Comments
	Cashew-Nut	Shell Cashew Apple	Based on past trend, the area under cashew cultivation has been assumed to decline at 2.5 per cent per annum over the projection period.	The area under cashew cultivation has been declining at a rate of 6.8% since last 15 years. However, it is expected that this rate of decline will become slower as the number of cashew processing industries increase and as the use of its waste residues makes the entire value chain more remunerative.
Forest	Forest Residues	Saw-dust/ Bark/ Trimmings	Given the selective cutting and efforts to retain the forest cover, no change in area is envisaged.	Expected to remain at the present level.
Urban waste	MSW	Solid Waste	Has been calculated as a function of increasing population, increasing per capita waste generation and increasing waste collection efficiencies.	This source could come up as a significant source of power generation in the near future in Kerala with increasing trends of consumerism and urbanization as well as improvements in waste collection systems.

5.2 ENERGY POTENTIAL OF VARIOUS TECHNOLOGIES

Numerous technologies are available to make use of the solid, liquid and gaseous fossil-fuels like coal, oil and natural gas. Most of these technologies could be utilized to make use of bio-resources as well.

There are a number of technological options available by which energy extraction could be possible from biomass. Conversion technologies may release the energy directly, in the form of heat or electricity, or may convert it to another physical form, such as liquid, solid or gaseous forms which could be easily transported and burnt at locations other than the source of generation. Most common biomass utilization technologies are thermal and biochemical conversion technologies.

The conversion efficiencies for feedstock to power vary with different technologies as well as with the kind of feedstocks. While combustion technology offers much better conversion efficiency over gasification technology, it finds limitations in terms of smaller and decentralized power generation applications, which is more suited to gasification based systems. Thus, Kerala could realize a higher power generation capacity if only combustion technology were to be implemented, but there is a better chance of reaching out to a higher number of families and individuals by implementing gasification based systems especially in rural areas. Hence, going forward, the state government would need to look at promoting both these technologies depending upon need, availability of resources and scale of operations.

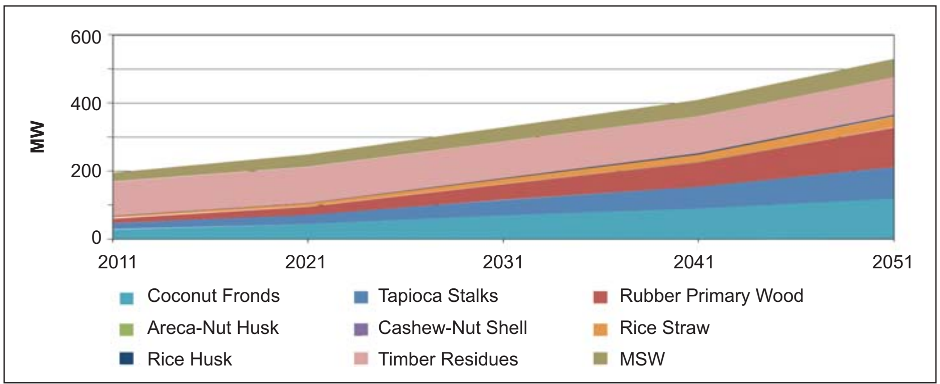
Table 5.14: Technology Variant and Feedstock Options in Kerala

Technology	Feedstock
Gasification and Combustion	
Known and proven technologies. Their efficiencies will improve over period of time. Gasification technology and even the MW scale combustion technologies can provide decentralized power solution Paddy Straw	Paddy Husk Coconut Fronds Rubber Wood Areca-Nut husk Tapioca Stalks Cashew-Nut Shell Timber Residues MSW
Anaerobic Digestion	
Proven technologies with high degree of decentralized production option. Needs adaptation for the new organic materials	Organic Fraction of MSW Animal Wastes Water Hyacinth Tapioca Industry Wastes
Biomass to Liquid	
There are number of technologies in the various stages of development. This technology option has great relevance for the transport fuel and industrial liquid fuel application and the developments in future can practically covert all cellulosic biomass into liquid.	Rice Straw Tapioca roots and stalks Cashew Apple Plastic and Rubber Fraction of MSW Algae All cellulosic biomass (till the technology is matured)

5.2.1 Gasification and Combustion

Gasification is a partial combustion process whereby a carbon source such as biomass, is broken down into carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2) and possibly hydrocarbon molecules such as methane (CH_4). Gasification is a technology of great relevance especially in the de-centralized or rural scale power generation scenario. The overall conversion efficiency is generally considered to be about 16 per cent in case of gasifiers.[83] Both raw as well as processed forms of biomass material could be utilized as feedstock for this technology. Figure 5.3 and Table 5.15 describe the power generation potential through employment of gasification technology in Kerala to take care of the waste residues from agriculture, agro-processing industries, and timber processing units, as well as MSW.

Figure 5.3: Power Generation Potential through Gasification



[83] Ankur Scientific Energy Technologies Pvt. Ltd. http://www.ankurscientific.com/powergeneration.htm

Table 5.15: Power Generation Potential through Gasification

Gasification Based Potential	2011	2020	2030	2040	2050
Coconut Fronds	28	44	69	90	120
Tapioca Stalks	19	28	46	65	93
Rubber Primary Wood	15	24	46	72	115
Areca-Nut Husk	0.19	0.25	0.36	0.43	0.52
Cashew Nut Shell	0.21	0.25	0.32	0.35	0.38
Rice Straw	6	9	16	22	32
Rice Husk	1	1	2	3	5
Timber Residues	100	105	107	108	111
MSW	26	35	42	48	54
Total	**195**	**248**	**329**	**409**	**529**

Hence, the overall power generation potential through employment of gasification based technologies in Kerala by the year could rise above 500 MW, up from the present 200 MW potential. In terms of agricultural waste residues, paddy straw, rubber wood, tapioca stalks and coconut fronds hold a major power generation potential. Cumulatively these four resources could be utilized to generate power up to 350 MW using gasification technology and considering the net available residues by the year 2050. Other resources like husk of paddy and areca-nut, rice husk and cashew-nut shell could also be utilized to set up small scale decentralized gasification based power solutions especially for rural areas in Kerala.

Timber residues that include not only the forest residues but also the residues from the processing of plantation woods like areca-nut, coconut and rubber, have a potential to power of nearly 80 MW projects spread across the state.

A majority of MSW is generated within the cities where small scale gasification systems may not hold much relevance. Hence incineration or combustion of non organic MSW component would be better. On the other hand, the organic component can be utilized for generation of biogas or for heat supply and for manufacturing organic manure.

Combustion is the most direct process of biomass conversion into energy. The process results in generation of heat which could be utilized for either thermal applications or for meeting electrical requirements by the generation of steam. With increasing prices of liquid fuels like high speed diesel and furnace oil, which are predominantly used for industrial applications as well as for power generation, demand for solid fuel fired combustion based systems has increased significantly. Based on the feedstock type, customized solutions can be provided to burn either chopped biomass wastes or densified biomass based products like pellets and briquettes. The technology could also be used to burn flammable components of MSW by compacting them into pellets and by converting them into refused derived fuel (RDF). In general the conversion efficiency using combustion based systems for power generation is considered to be 40 per cent for most of the feedstocks and 30 per cent for MSW.[84] These values have been considered while calculating the power generation potential using bio-resources in Kerala.

[84] Conversion of MSW into RDF.
http://wwf.panda.org/what_we_do/footprint/climate_carbon_energy/energy_solutions22/renewable_energy/sustainable_energy_report

Figure 5.4 and Table 5.16 describe the energy generation potential through waste residues available in Kerala using combustion-based technologies.

Figure 5.4: Power Generation Potential through Combustion-based Technologies

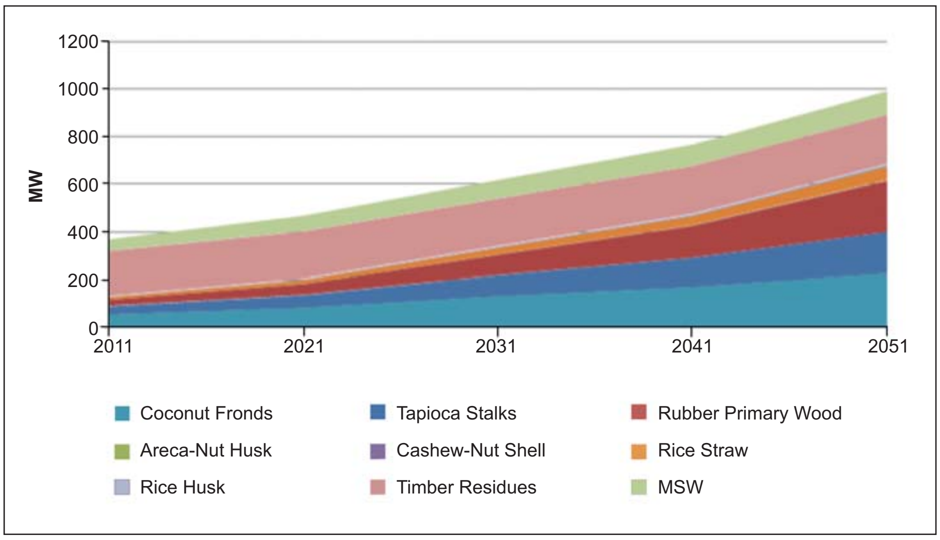


Table 5.16: Power Generation Potential through Combustion-based Technologies

Combustion Based Potential (MW)	2011	2020	2030	2040	2050
Coconut Fronds	53	82	130	168	225
Tapioca Stalks	35	52	87	122	174
Rubber Primary Wood	27	46	86	135	216
Areca-Nut Husk	0.35	0.48	0.68	0.81	0.98
Cashew Nut Shell	0.40	0.46	0.60	0.65	0.72
Rice Straw	12	18	30	41	59
Rice Husk	2	3	4	6	9
Timber Residues	188	198	200	202	207
MSW	48	66	79	90	101
Total	**366**	**466**	**617**	**766**	**993**

Cumulatively there is a potential to generate nearly 1,000 MW of power using resources available by the year 2050, up from the current potential of approximately 350 MW. In terms of agricultural waste residues, paddy straw, rubber wood, tapioca stalks and coconut fronds hold a major power generation potential. Cumulatively these four resources could be utilized to generate power up to 650 MW using combustion technology and considering the net available residues by the year 2050. Paddy husk has the potential to add another 10MW approximately while other resources like areca-nut husk and cashew-nut shell would be difficult to be utilized through combustion technologies owing to insignificant unavailability and low efficiencies associated with combustion technology at smaller scales. In terms of timber residues, Kerala has a potential to set up nearly 200 MW of power projects spread across the state.

Interestingly, if all these residues are used for heating applications in industries instead of power generation, the total heat value of these biomass resources is as shown in Table 5.17 below.

Table 5.17: Combustion Based Heat Potential of Biomass Residues

Combustion Based Potential (TJ)	2011	2020	2030	2040	2050
Coconut Fronds	1,536	2,372	3,744	4,844	6,471
Tapioca Stalks	1,000	1,500	2,500	3,499	4,999
Rubber Primary Wood	784	1,321	2,472	3,886	6,233
Areca-Nut Husk	10	14	20	23	28
Cashew Nut Shell	11	13	17	19	21
Rice Straw	341	511	852	1,193	1,705
Rice Husk	51	76	127	177	253
Timber Residues	5,421	5,694	5,770	5,826	5,973
MSW	1,382	1,911	2,266	2,605	2,903
Total	**10,536**	**13,411**	**17,767**	**22,072**	**28,586**

With respect to MSW, combustion or incineration systems prove to be the best fit in term of efficiency and raw-material adaptability. Also, an important application could be in terms of using this for industrial heating and cooling applications as a replacement to the more expensive oil and coal, post their conversion to RDF's. Nearly 100 MW of power could be generated by the year 2050 utilizing this resource.

5.2.2 Biogas

Highly efficient biochemical processes have developed in nature to break down the molecules of which biomass is composed. As biomass is a natural material, many of these biochemical conversion processes can be used to harness energy for a variety of applications. Anaerobic digestion (AD) is a treatment that decomposes the organic waste in the absence of oxygen, producing biogas that can be used to generate electricity and / or heat. It is a natural process but requires continuous monitoring of the physic-chemical environment within the digester to maintain the rate and activity of the entire process.

Although any organic biomass could be used to generate biogas which could in turn be utilized for generation of heat or power, the agricultural residues are usually not preferred as a feedstock material for AD technology. The reason for this is the high retention times required in the digester which makes them highly voluminous and capital intensive in terms of design.

Organic Component in MSW

A viable feedstock could be the organic fraction in MSW, which could account for nearly 70 per cent of the waste in Kerala. If the organic waste is buried in pits under partially anaerobic conditions, it will be acted upon by anaerobic micro-organisms with the release of methane and carbon dioxide; the organic residue left is good manure. The biogas, which has 55-60 per cent methane, can be used directly as a fuel or for power generation. The conversion efficiency for such systems using MSW has been considered to be 23 per cent.[85]

[85] Organic component in MSW. http://wwf.panda.org/what_we_do/footprint/climate_carbon_energy/energy_solutions22/renewable_energy/sustainable_energy_report.

An additional benefit in this process is the generation of high quality manure which could be utilized as a resource for soil nourishment. Almost any organic material can be processed with AD, including waste paper and cardboard, grass clippings, leftover food, industrial effluents, sewage and animal waste.

Solid and Liquid Wastes from Tapioca Processing Industries

The liquid and solid wastes emanating from tapioca processing industries could also be utilized for generation of biogas. It has been observed that nearly 350 kg of solid wastes in the form of peels and fibre are generated from these industries per tonne of tapioca roots processed. At the same time, each tonne of tapioca requires nearly 3.3 m^3 of water[86] during the peeling process, which is then discharged down the drain. Both these sources have significant biogas generation potential which has been proven through research. It has been estimated that each tonne of the solid waste coming from tapioca industries has the potential of generating 335 m^3 of biogas equivalent to nearly 500 units of power. Also, each m^3 of liquid waste from this industry is capable of generating approximately 3.6 m^3 of biogas or 5.4 units of power.[87]

Animal Wastes

As per the department of Animal Husbandry Dairying & Fisheries of India, Kerala had a total bovine population of 1,798,262, which includes both cattle and buffaloes of exotic as well as indigenous varieties.[88] Considering the fact that each cattle head generates nearly 10-12 kg of dung per day[89], there is a potential to utilize about 18,000 MT of cattle dung every day in Kerala. This resource can in turn generate nearly 700,000 m^3 of biogas.

However, due to the distributed nature of availability of this resource, it is usually recommended to set up small-scale family sized biogas plants of 2-4 m^3 in size to cater to domestic cooking requirements. As per the Ministry of New and Renewable Energy, government of India, there is a potential of setting up nearly 150,000 such family size biogas plants across the state.[90]

Figure 5.5 and Table 5.18 illustrate the biogas generation potential from various organic as well as high carbon sources in Kerala. Nearly 19 PJ can be generated using these four sources in Kerala by the year 2050.

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86 FAO. Impact of Cassava Processing on the Environment. http://www.fao.org/docrep/007/y2413e/y2413e0d.htm.

87 Salafudin, R. Marwan. 2010. "Preliminary Investigation to Modify Tapioca Based Plant Become Energy Self Sufficient Plant". 7th Biomass Asia Workshop (29 November–1 December). Jakarta, Indonesia. http://www.biomass-asia-workshop.jp/biomassws/07workshop/poster/16.%20Salafudin_Full%20Paper.pdf.

88 Department of Animal Husbandry Dairying & Fisheries. 2007. 18th Live Stock Census 2010. Ministry of Agriculture. New Delhi, India. http://dahd.nic.in/LS_hindi.pdf.

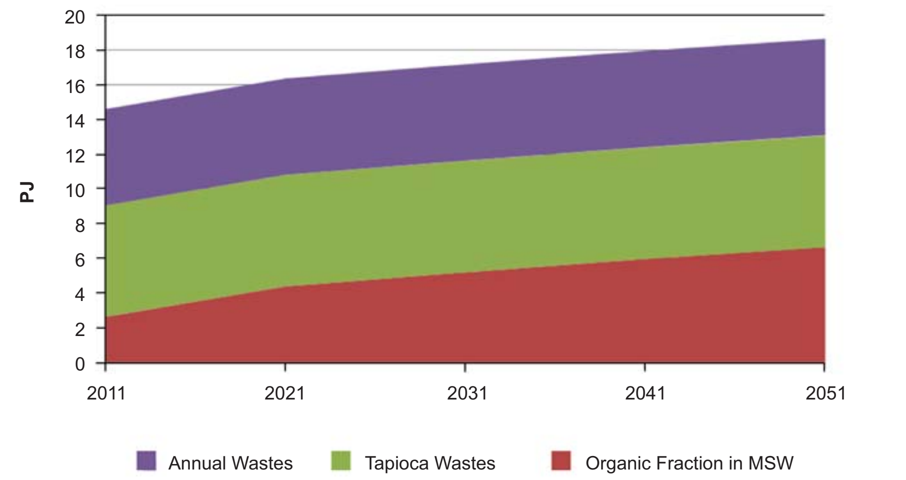
89 Agriculture Information.com. Generation of cattle dung per day. http://www.agricultureinformation.com/forums/blogs/akshay7/8686-bio-gas-electricity-project. html

90 Ministry of New and Renewable Energy. Family Type Biogas Plants Programme. http://www.mnre.gov.in/schemes/decentralized-systems/schems-2.

Table 5.18: Biogas Potential in Kerala

Biogas Heat Value (PJ)	2011	2020	2030	2040	2050
Organic Fraction in MSW	2.62	4.37	5.18	5.95	6.63
Tapioca Wastes	6.45	6.45	6.45	6.45	6.45
Animal Wastes	5.52	5.52	5.52	5.52	5.52
Total	**14.59**	**16.34**	**17.15**	**17.92**	**18.6**

Figure 5.5: Heat Generation Potential using Biogas in Kerala



Note

Water hyacinth too holds a significant potential for biogas generation in Kerala. It is considered to be one of the most destructive and unbeatable weeds not only in Kerala but globally.[91] It clogs up rivers, waterways and entire lakes, killing aquatic life, hampering river transport and fisheries. However, research indicates that it could be used as a reliable source of power considering its high growth rate of nearly 17.5 MT/ha/day.[92] About 0.014m^3 of biogas[93] could be generated from one kilogram of this plant which is nearly 85 per cent of water.[94]

However, based on extensive stakeholder consultation with state based energy experts and biologists, water hyacinth is considered ecologically destructive and is hence not considered as a source of biogas.

[91] Water hyacinth. http://www.thehindu.com/features/friday-review/history-and-culture/weed-woes/article 4680332.ece

[92] Venu, Mukesh. 2012. "Water Hyacinth: The Alternative to Fossil Fuel". Yentha.com (29 May). http://www.yentha.com/news/view/4/water-hyacinth-the-alternative-to-fossil-fuel.

[93] Ibne Al Imam, Md. Forhad, Khan, M. Z. H., Sarkar, M. A. R. and S. M. Ali. 2013. "Development of Biogas Processing from Cow dung, Poultry Waste, and Water Hyacinth". *International Journal of Natural and Applied Science.* Vol. 2, No. 1. http://urpjournals.com/tocjnls/38_13v3i1_3.pdf.

[94] Pillai, R. Ramabhadran. 2006. "KIDS Develop Biogas from Water Hyacinth". The Hindu (24 November). http://www.hindu.com/2006/11/24/stories/2006112421440400.htm.

5.2.3 Bio-fuels (Biomass to Liquid technologies)

This section discusses the conversion of bio-residues into liquid fuels which could be utilized as *transportation fuels,* a replacement of the currently used fossil fuels – gasoline, diesel and jet fuels. The feedstock chosen are typically the ones which have low moisture content in order to meet the raw material requirements for most of these conversion technologies.

Two prominent technologies, on which research is being carried out globally with regards to biomass to liquid oil conversion, are pyrolysis and bio-ethanol formation. While there has been a considerable debate with regards to use of food crops like sugarcane, tapioca and corn for manufacturing bio-ethanol, recent shift towards use of waste biomass feedstocks has brought this technology in focus once again. Pyrolysis on the other hand is an established process for the conversion of oil based products like plastic as well as agricultural processing wastes like rice husk to oil that could be utilized to offset diesel for power generation as well as transport purposes. Another technology to be discussed in this chapter is that of rapid thermal processing, being developed by Envergent technologies. The resultant product from this technology is an intermediate low quality liquid fuel that could be used for the purpose of heat and power generation, and could be further processed and utilized as transportation fuels of different order of purity and purpose.

Recent research is also being aimed at the third generation of biofuels namely algal oil which is a completely new oil generation opportunity that has a potential to make a significant dent in the energy markets by the year 2050.

Even though this section has worked out three scenarios of energy availability for biofuels (BAU, moderate and aggressive), only aggressive scenario is considered for analysis. This is done because it is assumed that once any of the existing or new technologies reach commercialization, the uptake of these technologies would be very high. Considering the existing dependence on fossil fuel imports and high level of budget expenditure, it is expected that alternative technologies would be upscaled by both private and public sectors.

Rapid Thermal Processing Technology

One technology in use for biomass to liquid conversion is the rapid thermal processing (RTP) technology. The technology is a fast thermal process in which biomass, usually forest residues or agricultural by-products are rapidly heated to approximately 500°C in the absence of oxygen. A tornado of hot sand vaporizes the biomass, which is then rapidly quenched, typically yielding 65 wt per cent to 75 wt per cent RTP green fuel. This pourable liquid can then be used as fuel for industrial heat or electrical generation, or it eventually can be further upgraded to produce transportation fuels. The technology is being currently developed by Envergent Technologies, a Honeywell company.[95] A majority of the feedstock like coconut fronds, rubber primary wood and other timber residues could be processed using this technology to generate RTP green fuel and then further processed to produce substitutes to transportation fuels like gasoline, diesel and jet fuel.[96]

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[95] Rapid Thermal Processing Technology. http://www.envergenttech.com/rtp.php.
[96] Envergent Technologies. RTP and the Future: Green Transportation Fuels. http://www.envergenttech.com/transportation-fuels.php.

However, considering this technology is still under development stages, commercial availability of this technology is assumed only by 2030.

The three main residues considered suitable for RTP are primary rubber wood, coconut fronds and timber residues. The timber residue generation from softwoods like that from areca-nut, coconut and rubber plantations has been taken to be 2.59 tonnes per annum per hectare. Also in this case the aggressive scenario has been considered to be having 50 per cent of such residues available for the purpose of conversion to oil. Based on the biomass resource assessment done in section 5.1, the total generation potential of bio-crude from this method for selected residues is as shown in Table 5.19.

Table 5.19: Bio-crude Potential from Agro-residues

Bio-Crude through RTP (toe)	2011	2020	2030	2040	2050
Rubber Primary Wood			325,919	365,964	410,930
Timber Residues			619,657	625,502	641,318
Coconut Fronds			345,016	317,973	296,539
Total			**1,290,592**	**1,309,440**	**1,348,786**

Pyrolysis

Pyrolysis is the thermal degradation of waste in an oxygen-starved environment in which the oxygen content is low for gasification to take place. The process is a non-combustion heat treatment that catalytically (chemically) decomposes waste materials by applying heat, directly or indirectly to the waste material in an oxygen free environment. It involves an endothermic reaction which requires an input of energy that is typically applied indirectly through the walls of the reactor in which the waste material is fed into. Pyrolysis liquefaction occurs under pressure and at operating temperatures above 430°C.[97]

The aggressive scenario considers an efficiency of 65 per cent. The oil generated from the pyrolysis of the plastic and rubber wastes in Kerala is considered to have 80 per cent purity of that of fossil diesel which has a colorific value of about 44,800 KJ/kg

The main resources which can be used for pyrolysis are MSW and rice husk. Table 5.20 below indicates the potential for these two resources. Commercial availability of this technology is assumed only in 2030.

Table 5.20: Bio-diesel Potential from Wood Residues

Bio Diesel through Pyrolysis (toe)	2011	2020	2030	2040	2050
MSW			128,260	150,895	167,338
Rice Husk			4,648	4,648	4,648

[97] Nair, T. Muraleedharam. "Profile on the Setting up of Pyrolysis Plant for Plastic Wastes Conversion into Industrial Diesel (Pyrolysis Oil), Gaseous Fuel & Carbon Black". Common Faculty Service Centre. Manjeri. http://www.emergingkerala2012.org/pdf/Manufacturing,%20Engg%20&%20Automotive/plastic_waste%20_pyrolysis.pdf.

Bio-Ethanol

Global research is focused on converting the solid feedstocks into liquid fuels through different thermo-chemical processes. Liquid state is desired since it is much easier to handle, store, transport and use. The combustion of liquid fuels is much easier to ramp up and ramp down in order to meet the process requirements and reduce wastage that is incurred on burning solid biofuels.

Bio-ethanol is a form of fuel that can be produced from agricultural feedstocks. It can be made from very common crops such as sugarcane, potato and corn. There has been considerable debate about how useful bio-ethanol will be in replacing gasoline. Concerns about its production and use relate to increased food prices due to the large amount of arable land required for crops, as well as the energy and pollution balance of the whole cycle of ethanol production, especially from corn. Recent developments with cellulosic ethanol production and commercialization may allay some of these concerns. Cellulosic ethanol offers promises because cellulose fibres, a major and universal component in plant cells walls, can be used to produce ethanol.

Tapioca

Tapioca which is grown widely all over Kerala could also be considered for manufacturing of bio-ethanol. It can yield alcohol to the tune of about 180 liters/tonne in contrast to sugarcane, which produces about 70 liters/tonne.[98] Central Tuber Crop Research Institute (CTCRI), Trivandrum has carried out work on alcohol production from tapioca. Starch is extracted from the tubers which are then converted by alpha amylase and gluco-amylase into sugar. Sugar is then fermented into alcohol.

Although farmers in Kerala are trapped in the demand-supply cycle with regards to tapioca, in the long term scenario, part of the tapioca production could be used for production of bio-ethanol. This would not only help control market variations in the price of tapioca, but will also help farmers increase their earning, as conversion to a highly value added product like oil could fetch them more money. Considering the fact that Kerala's demand for petrol in the year 2011-12 was about 788,000 Kl,[99] even a 10 per cent shift in use of tapioca to manufacture bio-ethanol could save the usage by more than 5 per cent. It has also been found that not only the main tapioca roots, but the stalks which are usually a waste product could also be utilized to produce bio-ethanol. Each tonne of stalks could result in ethanol in the range of 265 to 300 liters.[100]

[98] Integrated Cassava Project. Ethanol from Cassava. http://www.cassavabiz.org/postharvest/ethanol01.htm.
[99] Ministry of Petroleum & Natural Gas. 2013. *Indian Petroleum & Natural Gas Statistics 2011–12.* Government of India. New Delhi, India. http://petroleum.nic.in/pngstat.pdf.
[100] Business Wire. 2012. "TMO Renewables Expands Production of 2G Ethanol with Cassava Stalk". *Business Wire* (3 May). http://www.businesswire.com/news/home/20120503005773/en/TMO-Renewables-Expands-Production-2G-Ethanol-Cassava.

Cashew-Nut Apples

Research is also being carried out to extract ethanol using cashew-nut apple[101] generated from cashew processing industries as discussed above. The reported ethanol yield from cashew-nut apple is about 18.5 liters for every 100 kg of cashew-nut apple.[102]

Although the area under cashew cultivation is on a decline, commercialization in the use of cashew nut shell for ethanol production would make the crop much more viable for farmers and the area under cashew cultivation in Kerala may see a boom instead of the decline as is being predicted because of the current trends.

Rice Straw

Rice straw also has a potential for being converted into bio-ethanol. Research shows that ethanol yield from rice straw is in the range of 241-328 litres per tonne of dry feedstock.[103]

For the sake of calculations, the moisture content in the straw available at farm has been considered to be 20 per cent.[104] The analysis has been done for different collection efficiency percentages ranging from 10 per cent to 50 per cent. There is a potential of manufacturing nearly 90,000 Kl of bio-ethanol using rice straw if it were to be implemented.

Algal Oil

Algal oil is an alternative to fossil fuel that uses algae as its feedstock material. Several companies and government agencies are funding efforts to reduce capital and operating costs, and make algae fuel production commercially viable. Like fossil fuel, the harvested algae releases CO^2 when burnt, but unlike fossil fuel the CO^2 is taken out of the atmosphere by the growing algae to foster its growth. The energy crisis and the world food crisis have ignited interest in alga-culture for making vegetable oil, bio-diesel, bio-ethanol and other biofuels, using land or water resources which are not suitable for agriculture or other purposes. Algae require nutrients, sunlight and water to grow and thrive on saline, brackish and waste waters. Considering the prominence of water bodies and a long coastline, there are possibilities of using high yielding stains of algal cultures in brackish waters and sea water.

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[101] Neelakandan, T. and Usharani, G. 2009. "Optimization and Production of Bioethanol from Cashew Apple Juice Using Immobilized Yeast Cells by Saccharomyces cerevisiae". *American–Eurasian Journal of Scientific Research.* Vol. 4 (2): 85–88. http://www.idosi.org/aejsr/4(2)09/7.pdf.

[102] Potty, V. P. "From Cashew Apple to Bioethanol". http://www.emergingkerala2012.org/pdf/Food%20Processing/BIOETHANOL%20Procudtion%20from%20Cashew%20Apple.pdf.

[103] Diep, N. Q. et al. 2012. "Comparison of the Potential for Ethanol Production from Rice Straw in Vietnam and Japan via Techno–economic Evaluation". *International Energy Journal.* Vol. 13. http://www.rericjournal.ait.ac.th/index.php/reric/article/viewFile/983/420.

[104] Liu, Zhiqiang, Xu, Aixiang and Tenglv Zhao. 2011. "Energy from Combustion of Rice Straw: Status and Challenges to China". *Energy and Power Engineering.* Vol. 3. http://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/epe.2011.33040

Kerala has 65,000 ha of area under brackish water, which could be partly utilized[105] for growing and harvesting algae and then converting it into oil. A maximum utilization of about 50 per cent of brackish waters is assumed in aggressive scenario. This is done assuming that existing life forms would be able to co-exist with algal culture and this would not impede commercial activities (fishing, etc.) in a significant way.

It is estimated that algae could be grown at a rate of 40 gm/m^2/day over a 300 day cycle.[106] The oil yield is usually 25 per cent implying a yield of 30,000 kg or 22 Kl of oil per hectare per annum. The heat value of algal oil is however considered to be about 21,900 KJ/kg,[107] which is approximately 73 per cent of that of ethanol.

Marine macro algae or seaweeds are plants adapted to the marine environment, generally in coastal areas. There are a very large number of species around the world, belonging to several phylogenic groups. Broadly, three types of seaweeds are defined according to their pigments, ie., the brown seaweeds (e.g., Laminaria, Fucus and Sargassum), the red seaweeds (e.g., Gelidium, Palmaria and Porphyra) and the green seaweeds (e.g., Ulva and Codium).

The only yield which can be reported as commercially achieved and sustained is the cultivation of *Laminaria japonica* in China, which yields 25 t/ha/year of dry matter.[108] An empirical yield of 22 m^3 methane yield per fresh tonnes of Laminariaspp is used as a productivity assumption.

As per the Central Marine Fisheries Research Institute (CMFRI), nutrient rich but calm and protected waters are suitable for seaweed cultivation. The CMFRI has successfully developed technology for commercial level seaweed culture. The Agency for Development of Aquaculture (ADAK) has now taken up a pilot project for cultivating *Kapaphycus alvarezii* at 10 selected sites from Varkala (Trivandrum) to Cheruvathur (Kasargod). Initial reports indicate good chances of success.[109]

The coast of Kerala constitutes approximately 10 per cent of India's total coastline. This coastline of 590 km and the exclusive economic zone (EEZ) extends up to 200 nautical miles far beyond the continental shelf, which covers an area of 218 536 km^2 provide opportunities. It is expected that technology should be in full scale commercial operation by 2030. In the aggressive scenario and based on assumption following Table 5.21, there is potential for biomass, bio-methane and oil extraction from macro-algae

[105] Department of Fisheries. "Inland Fisheries" http://www.fisheries.kerala.gov.in/index.php?option=com_content&view=article&id=77:inland-fisheries&catid=41:inland-fisheries&Itemid=45.
[106] Oilgae. "Algal Oil Yield". http://www.oilgae.com/algae/oil/yield/yield.html.
[107] Oilgae. "Theoretical Maximum of Algal Oil Production". http://www.oilgae.com/club/users/parkavi/blogs/122.
[108] SEI. 2009. *A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland. Cultivation of Laminaria japonica.* Sustainable Energy Ireland (SEI). Dublin. http://www.seai.ie/Publications/Renewables_Publications_/Bioenergy/Algaereport.pdf.
[109] Harikumar, G. and Rajendran, G. 2007. "An Over View of Kerala Fisheries – With Particular Emphasis on Aquaculture". *IFP Souvenir*. Cochin, India. http://ifpkochi.gov.in/IFPS2.pdf.

- Costal Economic Zone in km² : 218,536
- Costal economic Zone in ha : 21,853,600

Table 5.21: Sea Algae Based Biofuel Potential

Table 5.21 shows a tabulated summary of potential estimation process.

Sea Algae Resource Potential	2020	2030	2040	2050
% area under cultivation (aggressive scenario)		5	10	10
Estimated area under microalgae cultivation (ha)		1,092,680	2,185,360	2,185,360
Biomass production (t) dry basis		27,317,000	65,560,800	76,487,600
Bio-ethanol production (m^3)		60,100,000,000	144,000,000,000	25,240,908,000
Oil production (tonnes)		819,510	3,278,040	5,736,570
Bio- Crude (Rapid Thermal Processing RTF) in tonnes		6,829,250	16,390,200	19,121,900
TOE (equivalent)		4,780,475	11,473,140	13,385,330

- Oil production should also expected to double due to the improved strains from 2 per cent of the oil content to 7.5 per cent by 2051
- RTF: typically yielding 50 wt per cent to 75 wt per cent (bone dry basis) RTP green fuel based on the biomass composition. Macroalge need to be dried to almost no negligible moisture content 2-5 per cent

Based on the above estimation, the summary of biofuels production figures is shown in Table 5.22 below.

Table 5.22: Summary of Biofuels Availability

Bio-Ethanol (toe)	2020	2030	2040	2050
Tapioca		1,539,817	1,539,817	1,539,817
Cashew-nut Apple		539	418	325
Algal Oil (Brackish Water)		149,033	223,549	298,065
Algal Oil (Sea Water)		4,780,475	11,473,140	13,385,330
Total		**6,469,864**	**13,236,924**	**15,223,537**

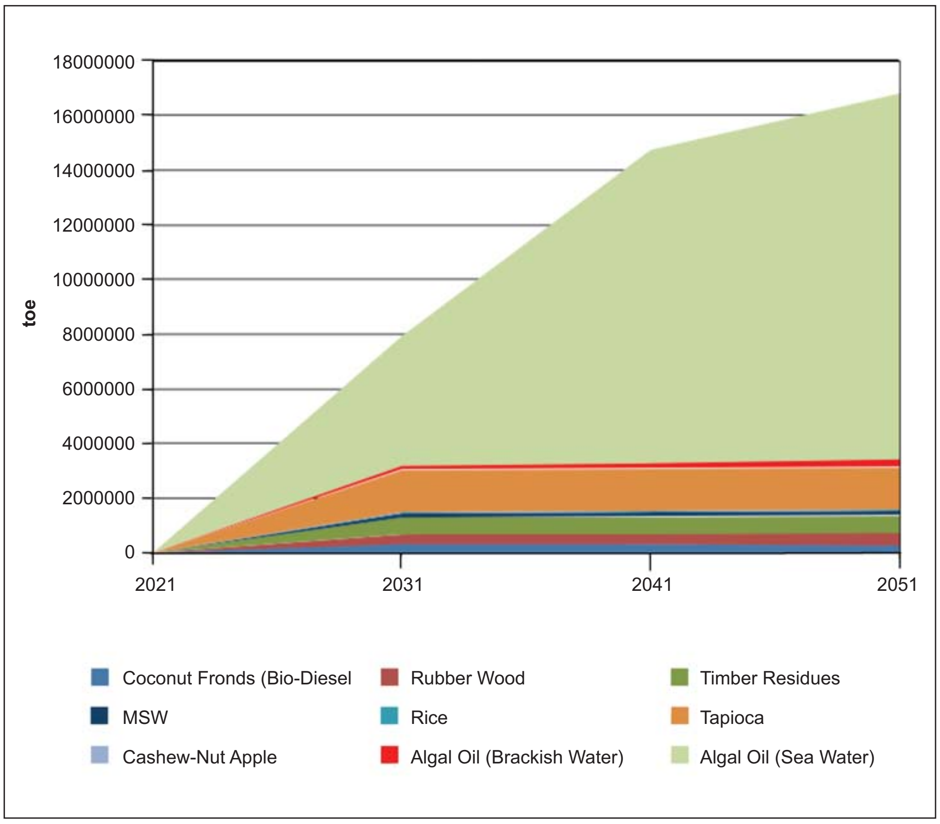
Summary of transport fuel from various sources of raw materials

Table 5.23 and Figure 5.6 summarize the possibility of total biofuels potential for aggressive scenario.

Table 5.23: Total Biofuel Potential in Kerala

Bio-Fuels (toe)	2020	2030	2040	2050
Coconut fronds (Bio-Diesel)		345,016	317,973	296,539
Rubber wood		325,919	365,964	410,930
Timber residues		619,657	625,502	641,318
MSW		128,260	150,895	167,338
Rice		57,841	57,841	57,841
Tapioca		1,539,817	1,539,817	1,539,817
Cashew-nut Apple		539	418	325
Algal Oil (Brackish Water)		149,033	223,549	298,065
Algal Oil (Sea Water)		4,780,475	11,473,140	13,385,330
Total		**7,946,557**	**14,755,099**	**16,797,503**

Figure 5.6: Biofuels Potential



5.3 SUMMARY OF POTENTIAL

The bioenergy assessment assumes use of limited residues for a variety of end use energy or fuel generation technologies. The technology potential assessment for one technology includes residues that have also been considered as fuel / feedstock for other technologies. Table 5.24 shows the residue use across various applications.

Table 5.24: Summary of Biomass Residues Used

Biomass Residues	End use in technologies
Rice Straw	Gasification, Combustion, Biofuels
Rice Husk	Gasification, Combustion, Biofuels
Coco Fronds	Gasification, Combustion, Biofuels
Tapioca Stalks	Gasification, Combustion, Biofuels
Rubber Wood	Gasification, Combustion, Biofuels
Timber Residues	Gasification, Combustion, Biofuels
Acrea Nut Husk	Gasification, Combustion
Cashew Nut Shell	Gasification, Combustion
MSW	Gasification, Combustion, Biofuels
Organic MSW	Biogas
Tapioca Waste	Biogas
Animal Waste	Biogas
Cashew Nut Apple	Bio-fuel
Algal Oil	Bio-fuel

To avoid resource conflict, it is assumed that areca-nut husk, cashew nut shell, rice husks and rice straw are used exclusively for gasification, mainly for decentralized power generation. Rubber wood and timber residues are used for combustion applications mainly for heat processes. MSW is mainly used for power generation through combustion route while coconut fronds and tapioca stalks are mainly used for biofuels. Based on the above categorization, the available potential is re-estimated in Table 5.25 below.

Table 5.25: Final Sustainable Bioenergy Potential

Rice Straw	2011	2020	2030	2040	2050
Acrea Nut Husk	0.2	0.3	0.4	0.4	0.5
Cashew Nut Shell	0.2	0.2	0.3	0.3	0.4
Rice Husk	6.3	9.5	15.8	22.1	31.6
Rice Straw	0.9	1.4	2.3	3.3	4.7
Total (MW)	**7.6**	**11.4**	**18.8**	**26.2**	**37.2**
Biomass Combustion- Electricity (MW)	**2011**	**2020**	**2030**	**2040**	**2050**
MSW	**48**	**66**	**79**	**90**	**101**
Biomass Combustion- Heat (PJ)	**2011**	**2020**	**2030**	**2040**	**2050**
Rubber Primary Wood	5.4	5.7	5.8	5.8	6
Timber Residues	0.8	1.3	2.5	3.9	6.2
Total	**6.2**	**7**	**8.3**	**9.7**	**12.2**
Biogas (PJ)	**2011**	**2020**	**2030**	**2040**	**2050**
Organic Fraction in MSW	2.6	4.4	5.2	6	6.6
Tapioca Wastes	6.5	6.5	6.5	6.5	6.5
Animal Wastes	5.5	5.5	5.5	5.5	5.5
Total	**14.59**	**16.4**	**17.15**	**17.92**	**18.6**
Bio-Fuels (mtoe)	**2011**	**2020**	**2030**	**2040**	**2050**
Coconut fronds			0.35	0.32	0.3
Tapioca			1.54	1.54	1.54
Cashew Nut Apple			0	0	0
Algal Oil (Brackish Water)			0.15	0.22	0.3
Algal Oil (Sea Water)			4.8	11.47	13.38
Total			**6.84**	**13.55**	**15.52**
Total Bio-Energy Availability	**2011**	**2020**	**2030**	**2040**	**2050**
Electricity (BU)	0.32	0.44	0.56	0.66	0.79
Heat (PJ)	20.79	23.4	25.45	27.62	30.8
Biofuels (mtoe)	0	0	6.84	13.55	15.52

In terms of bio-residues, numerous technologies like torrefaction, pyrolysis, biomass to hydrogen etc., are at different stages of development at the moment. These new technologies along with advancements in the current ones can help utilize these residues in a much more efficient manner and thus greatly increase the potential for energy generation. The key to utilization of most of the bio-resources would be effective practices in supply chain management. Resource and geography specific collection models would need to be devised in order to ensure that all the stakeholders within the chain are benefitted and the resource collection is at the most optimum level. Biomass to liquid technologies would hold the key to energy development in the future as transportation evolves as one of the major energy

Water Hyacinth: One alternative to Fossil Fuel

Kerala Agricultural University is in talks with the Mumbai based Institute of Chemical Technology to establish a facility to produce bio-ethanol from plants. Water hyacinths have been long used as a traditional medicine and to remove toxic elements from polluted water bodies. The highly nutrient plant can be turned into compost and used as a fertilizer. This compost can improve the physical, chemical and biological properties of soil. Another major resource that is obtainable from water hyacinth is biogas. Kerala already has a biogas plant meant to produce biogas and electricity from water hyacinth at Kuttanad, as part of the Kuttanad package.[110]

consuming sectors, fuelled majorly through liquid fossil fuels at present which have already reach the peak-oil stage. Thus, the use of such waste bio-resources would be a much sustainable strategy in the future. However, seaweed cultivation may compete for the space with other marine industries and protected conservation areas, and for cultivation and mechanized harvesting, long-term trials and careful monitoring of seaweed stocks, the surrounding ecosystem and the environmental consequences would be required to be better understood.

[110] Venu, Mukesh. 2012. "Water Hyacinth: The Alternative to Fossil Fuel". Yentha.com (29 May). http://www.yentha.com/news/view/4/water-hyacinth-the-alternative-to-fossil-fuel.

6. HYDRO POTENTIAL OF THE STATE

The history of hydropower development in Kerala began with the commissioning of the Pallivasal Hydro Electric Project in 1940. This project had an installed capacity of 37.5 MW. In due course several other hydro projects like Sabarigiri and Idukki came up. Later on, with the commissioning of more projects, Kerala achieved the status of a "power surplus" state, which lasted till the 1980's. During this power surplus period of 1969-85, the state resolved to set up power intensive industrial units.

In the late 1980's, Kerala experienced intermittent power deficits, which were attributed to "monsoon failure". However, the explanation of "monsoon failure" was too simplistic and overlooked several factors which had led to the reversal. The momentum to set up more hydropower projects was not carried forward owing to increased environmental objections and inter-state differences. Furthermore, no provisions were made to protect the catchments of the reservoirs to ensure water availability in the reservoirs, which would have guaranteed consistent power generation.

6.1 PROSPECTIVE FUTURE POTENTIAL FOR HYDROPOWER IN THE STATE

The prospects of meeting the ever increasing power demand though more centralized state-based generation look bleak. With no coal or gas reserves of its own, the best bet for Kerala is in tapping the available hydro resources for power generation. However, large scale hydro development in Kerala also seems a distant possibility considering the strong environmental opposition and public sentiment. The best way for the state could be to optimize existing resources to their fullest.

It is known that existing facilities like dams, weirs, barrages, which were basically constructed in the past for meeting irrigation requirements can be used for power generation by setting SHP units without making any significant constructional changes in the original structure. Under the Energy Sector Management Assistance Programme (ESMAP) 2001, of the World Bank, the possibility of using existing irrigation facilities for power generation was assessed. The study indicates that the water release sluices provided at the dam embankment could be utilized for power generation. ESMAP has recommended the design / construction methodology and turbine configuration for such schemes. The ESMAP study has covered four such dam locations from Kerala, namely, Mangalam, Maniyar, Peechi & Kuttiyadi. A siphon penstock could be installed if the conditions are suitable, to convey water over the top of the dam for power generation without disturbing the existing dam. Some of the benefits of such schemes are listed below:

- The hydraulic head between the water level in the reservoir and the level at the beginning of the canal or the toe of the dam provides scope for power production utilizing water discharged from the river and canal sluices located in the dams.

- The investment required to generate power at these structures is minimal since the cost of the main structures have been allocated to irrigation. Hence investment is only required for power generating equipment and modifications to the irrigation structures.

There are around 19 major irrigation schemes in Kerala where the hydro potential can be harnessed as per the methodology discussed above. The details of the irrigation schemes are given in the Table 6.1 below.

Table 6.1: Major Irrigation Schemes in Kerala

Sr No	Name of Dam / Barrage	District Location	River	Remarks
1	Malampuzha Project	Palakkad	Malampuza	Irrigation project
2	Walayar Project	Palakkad	Walayar	Irrigation project, Head sluice - sill level +182.575m & 188.975m
3	Peechi Irrigation Project	Thrissur	Manali	Irrigation project, Head sluice - sill level +55.78m
4	Neyyar Irrigation Project	Trivandrum	Neyyar	Irrigation project, Head sluice - sill level LBC + 59.70m, RBC + 56.65m
5	Chimoni Dam Project	Thrissur	Karuvannur	No canal Network , water laid down to the river
6	Kanhirapuzha Irrigation Project	Palakkad	Kanhirapuzha	Irrigation project
7	Pamba Irrigation Project	Pathanamthitta	Kakkad	Irrigation project, Head sluice - sill level +31.09m
8	Kuttiyadi Irrigation Project	Kozikode	Kuttiady	Irrigation project, Head sluice - sill level +25.52m
9	Kallada Irrigation Project	Kollam	Kallada	
10	Periyar Valley Irrigation Project	Ernakulam	Periyar	Barrage No head sluice
11	Pazhassi Irrigation Project	Kannur	Valapattanam	Irrigation project, , Head sluice - spill way 24.66m
12	Moolathara Regulator	Palakkad	Chitturpuzha	Diversion scheme, Head sluice - sill level LBC +178.58m, RBC + 182.00m
13	SIRUVANI	Palakkad	Siruvani	Dam to provide drinking water to Coimbtore in TN. Funds made available by TN work executed by Kerala PWD
14	Gayathri Project: Stage I - Meenkara	Palakkad	Meenakari	Irrigation project, earthen dam
15	Gayathri Project: Stage II - Chulliar	Palakkad	Chulliar	Irrigation project
16	Pothundy Irrigation Project	Palakkad	Ayilur	Irrigation project, Head sluice - sill level +91.44m
17	Vazhani Irrigation Project	Thrissur	Wadakkauchary	Irrigation project
18	Mangalam Irrigation Project	Palakkad	Charukunnampuzha	Irrigation project, Head sluice - sill level +64.00m
19	Muvattupuzha Irrigation Project	Idduki	Thodupuzha	Irrigation project

Source: Irrigation Design and Research Board, Government of Kerala.

In the absence of long term flow data and other technical details, the estimation of potential for these modifications could not be done. But this is a possibility that the state can explore on a priority basis.

The official figures of MNRE indicates SHP potential of 700 MW out of which 19 SHP schemes totalling 145 MW capacity are commissioned in the state as on date. The government of Kerala had come out with the 'Kerala Small Hydro Policy 2012' in October 2012. The policy envisages a targeted 150 MW SHP capacity addition during 2013-17 with the help of private sector participation. However, it is understood that there are still some procedural hurdles which are leading to slow uptake of projects by private investors.

Compared to large hydro development, SHPs brings in several distinct advantages such as low gestation period, no storage requirement, no settlement and rehabilitation, and negligible environmental impacts which are particularly important for a state like Kerala.

6.2 ANALYSIS OF RESULTS

The best prospects for hydropower in Kerala seem to be for small hydro development. It is assessed that full potential of 700 MW can be harnessed with adequate policy and technological support. This would mean scope for additional 560 MW of small hydro capacity.

7. OCEAN ENERGY POTENTIAL OF THE STATE

The two main technologies considered under ocean energy are: wave energy and tidal energy.

7.1 WAVE ENERGY

Waves are caused by wind blowing on the surface of water. The main energy content of a wave is in its width and height, which vary significantly across seasons. Wave energy can be captured directly from surface waves or from pressure fluctuations below the surface. Available technologies of wave power systems convert the motion of the waves into usable mechanical energy which is aggregated and used to generate electricity. Wave power can be defined as the rate of energy transfer per unit area across a plane normal to wave propagation.

The power in a wave is represented by the following equation

$P = 0.55\ H_s^2\ Tz$ kW/m length of wave crest.

Where H_s^2 are the significant wave height (defined as average of 1/3 of highest waves) in metres, and Tz is the zero-crossing period in seconds.

The main technologies presently in use or under consideration are:

Float or Buoy Systems: This technology uses the rise and fall of ocean swells to drive hydraulic pumps. The object can be mounted to a floating raft or to a device fixed on the ocean bed. The vertical movement of a series of anchored is used to run an electrical generator.

Oscillating Water Column Devices: This technology uses the in-and-out motion of waves at the shore. The wave is allowed to fill a column as it rises. The rise in the water level in the column compresses air, which is used to drive a turbine connected to an electric generator.

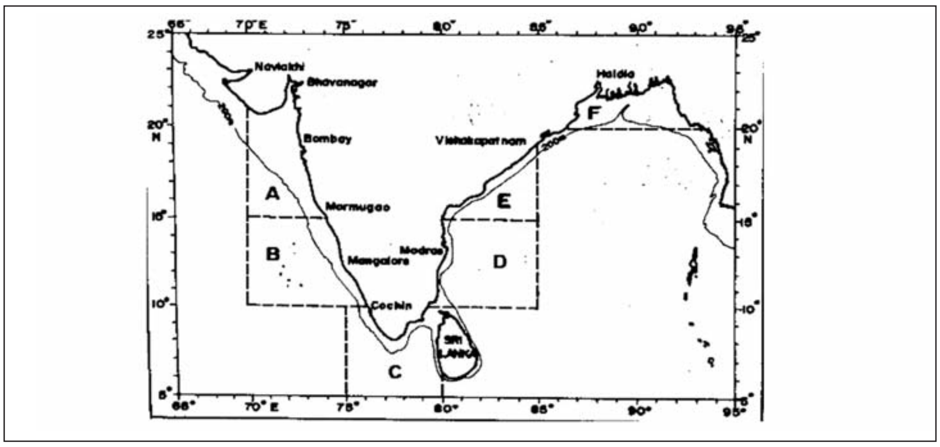
Tapered Channel: This technology relies on a shore mounted structure to channel and concentrate the waves driving them into an elevated reservoir. Water flow out of this reservoir is used to generate electricity using standard hydropower technologies.

In India the research and development activity for exploring wave energy started in 1982. A few estimates on wave power potentials along the Indian coast are mostly based on visual observations and differ in magnitudes, but show similar seasonal patterns.

An initial study on wave potential [Kesava Das et al] suggests that wave power along Indian coasts varies seasonally and geographically from 1.2 to 39.6 kW/m with an average of 9.4 kW/m.[111] The annual mean potential across locations varies between 8 and 11 kW/m, while the maximum wave power potential occurs along the Konkan coast. The study also suggested that the southwest monsoon period of May to September offers a greater potential all along the coast with a mean wave potential of about 15 kW/m.

The monthly wave power potential for six areas marked in Figure 7.1 is given in Table 7.1.

Figure 7.1: Map Showing Different Zones for which Wave Power Potential was Estimated.



Source: Das, V. Kesava. 1992. "Wave Power as a Source of Energy along the Indian Coast". Das, V. Kesava (ed). *Power Directory*. National Institute of Oceanography. Goa, India. http://drs.nio.org/drs/bitstream/2264/3091/2/Power_Directory_1992_141.pdf.

Table 7.1: Wave Power in kW/m along the Indian Coast for Areas Shown in Figure 7.1

Area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
A	3.02	3.73	3.91	4.47	6.98	26.77	39.57	24.84	10.03	2.69	3.58	4.74
B	5.13	5.05	2.24	1.56	6.31	17.21	27.04	17.14	8.15	4.55	3.52	5.40
C	9.26	4.45	4.05	5.50	11.44	18.85	17.69	15.34	10.11	7.21	6.67	7.52
D	5.78	5.13	3.30	3.58	10.60	16.67	14.79	12.57	8.49	7.94	10.98	14.05
E	4.03	1.69	2.35	3.69	11.14	17.24	17.45	16.16	9.18	6.90	9.71	5.62
F	1.24	1.39	3.28	12.34	14.30	11.90	13.24	16.67	16.07	6.28	2.80	1.85

From the above study and wave statistics data available, primary estimates indicate that the wave power potential for Indian coastline is of the order of 40,000 MW, where 47 kW/m is available off Mumbai during the southwest monsoon period. For the southern tip of India, a mean monthly wave power of 4-25 kW/m is estimated. The average wave potential along the Indian coast is around 5-10 kW/m. India has a coastline of approximately 6,500 km and even 10 per cent utilization would mean a resource of 3,750-7,500 MW.

[111] Das, V. Kesava. 1992. "Wave Power as a Source of Energy along the Indian Coast". Das, V. Kesava (ed). *Power Directory.* National Institute of Oceanography. Goa, India. http://drs.nio.org/drs/bitstream/2264/3091/2/Power_Directory_1992_141.pdf.

The Indian Wave Energy Programme

The Indian wave energy programme was started in 1983 at the Institute of Technology, Madras. It mainly concentrated on the OWC concept. A 150 kW prototype OWC with harbour walls was built onto the breakwater of the Vizhinjam Fisheries Harbour, near Tiruvananthapuram, India. The site was found to be best suited because of higher power availability, easy access to deeper waters, freedom from cyclones and availability of other local infrastructure facilities.

The power plant delivered average power of 75 kW during April to November and 25 kW from December to March. During the monsoon months of June to September, the system generated 120 kW. The nine month average value of the incident wave power was 10 kW/m and peak monsoon average was 20 kW/m.

Power generation projects based on wave energy are not yet commercially established in India. MEDA has taken an initiative for establishing Demonstration Power Generation Project at Budhal, Taluka: Guhagar, District: Ratnagiri. The Demonstrative Power Project is of 15 to 25 kW capacity. After successful completion of the pilot, more projects will be planned at other potential sites in India.

7.1.1 Wave Energy Potential of the State

Wave measurements by the Centre for Earth Science Studies (CESS) at Thiruvananthapuram, Alleppey, Calicut and Tellicherry, along the Kerala coast show that Thiruvananthapuram with a coastline of about 80 km has the maximum power potential all through the year.[112] Table 7.2 shows the measurements:

Table 7.2: Average Wave Power in kW/m off the Kerala Coast

Stations	Annual	Monsoon	Non-monsoon
Trivandrum	10.9	17.4	4.3
Alleppey	4.5	7.5	1.4
Calicut	2.8	3.5	0.6
Tellicherry	0.7	0.9	0.4

The wave power along the Thiruvananthapuram coast is usually less than 10 kW/m during the non-monsoon season and exceeds 10 kW/m during the monsoon season with an observed maximum of 60 kW/m. The annual average wave power for Thiruvananthapuram and Alleppey is 10.9 kW/m and 4.5 kW/m respectively. Tellicherry has a considerably low wave power when compared to other measured stations.

However, considering a total coastline of about 600 km with an average wave potential of around 5-10 kW/m, the total potential is assessed at 4,200 MW. However, considering resource, environmental and other commercial constraints, only 10 per cent implementation potential is assumed with a total implementable potential of 420 MW.

[112] Joseph, Paimpillil S. and Baba, M. 2012. "Linking of Coastal Wave Energy Utilization with Coastal Protection". *ARPN Journal of Science and Technology.* Vol. 2. http://www.ejournalofscience.org/archive/vol2s/vol2s_12.pdf.

7.2 TIDAL ENERGY

Tides are generated through a combination of forces exerted by the gravitational pull of the sun, the moon and the rotation of the earth. The relative motion of the three bodies produces different tidal cycles affecting the range of the tides. Energy can be extracted from tides by creating a reservoir or basin behind a barrage and then passing tidal waters through turbines in the barrage to generate electricity. Tidal energy is site specific and requires mean tidal differences greater than 4m in addition to favourable topographical conditions, such as estuaries or certain types of bays in order to bring down costs of dams.

Tidal power can be classified into the following generating methods:

Tidal stream generator: It uses the kinetic energy of moving water into power turbines. The technology is similar to wind turbines, which uses wind to move turbines. Tidal generators can be built on structures of existing bridges.

Tidal barrage: A tidal barrage is a dam-like structure used to capture the energy from masses of water moving in and out of a bay or river due to tidal forces. Tidal barrages make use of the potential energy in the difference in height (or head) between high and low tides. The ebb and flow of the tides is used to turn a turbine.

India has a long coastline with the estuaries and gulfs where tides are strong enough to move turbines for electrical power generation. The Gulf of Cambay and the Gulf of Kutch in Gujarat on the west coast have the maximum tidal range of 11m and 8m with an average tidal range of 6.77 m and 5.23 m respectively. The Ganges delta in the Sunderbans in West Bengal also has good locations for small scale tidal power development. The maximum tidal range in Sunderbans is approximately 5m with an average tidal range of 2.97 m. The identified economic power potential is of the order of 8,000-9,000 MW with about 7,000 MW in the Gulf of Cambay, about 1,200 MW in the Gulf of Kutch and about 100MW in the Gangetic Delta in the Sunderbans region.[113]

The government of Gujarat has signed an MoU in 2011 for establishing a 250 MW tidal power project in the Gulf of Kutch with the Gujarat Power Corporation Ltd. (GPCL), Atlantis Resource Corporation, United Kingdom and Perfect Mining Energy Solutions, Singapore. A special purpose vehicle has been incorporated and in the first phase a 50 MW tidal power project will be set up at the Gulf of Kutch. It will be India's first commercial-scale tidal energy plant.

West Bengal Renewable Energy Development Agency (WBREDA) has set up a 3.75 MW demonstration tidal power plant at Durgaduani Creek in the Sunderbans. The project had been sanctioned by the Ministry of Power and National Hydro Power Corporation Ltd. (NHPC) was executing the project on a turnkey basis. But recently, the government of West Bengal has decided to discontinue the project due to the very high cost.

Tidal power generation is new in Kerala. However, in the absence of any robust data on tidal flows, no tidal power availability is assumed in this report.

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[113] Thrope, T. W. 1999. "An Overview of Wave Energy Technologies: Status, Performance and Costs". *Wave Power: Moving towards Commercial Viability* (30 November). Broadway House. Westminster, London. http://waveberg.com/pdfs/overview.pdf.

8. SUMMARY OF RENEWABLE POTENTIAL ASSESSMENT

The results of the potential assessment based on the derived methodology assumptions and base data are striking. Table 8.1 captures the final numbers of the assessed RE potential in the state.

Table 8.1: Summary of RE potential in Kerala by 2050

Technology	Independent potential by 2050	Remarks
Electricity	**Billion Units**	**MW (CUF)**
Grid Tied Solar PV (Wasteland)	5.99	4,273 (16%)
Grid Tied Solar PV (Grassland)	3.56	2,543 (16%)
Grid Tied Solar CSP (Wasteland)	0.00	2,457 (0%)
Grid Tied Solar CSP (Grassland)	0.00	193 (0%)
Rooftop PV (Domestic)	18.33	13,079 (16%)
Roof top PV (Institutional)	25.32	18,066 (16%)
Floating PV	5.39	3,845 (16%)
Solar Water Pumping		304 (400 hrs)
Onshore wind (Farmland) (WPD > 200)	5.98	3,103 (22%)
Onshore wind (No Farmland) (WPD > 300)	0.86	447 (22%)
Onshore Wind (Plantations) (WPD > 200)	8.60	4,465 (22%)
Offshore wind (WPD > 250)	29.4	13,447 (25%)
Biomass gasification	0.21	37.2 (65%)
Biomass Combustion	0.57	101 (65%)
Large Hydro + existing small hydro	11.37	1,998 (65%)
New Small Hydro	2.37	540 (50%)
Wave	0.37	420 (10%)
Tidal	0	0
Total	**118.4**	
Electricity	**Billion Units**	**MW (CUF)**
Biomass Combustion	12,206	
Biogas	18,600	
Total	**30,806**	
Fuels	**MTOE (Max)**	**Share**
Bio-fuels	15.52	
Total	**15.52**	

PART III

100% RENEWABLE ENERGY FOR KERALA

9. STATE ENERGY DEMAND PROJECTIONS: THE BAU SCENARIO

Overview of Methodology

This chapter assesses the future growth trajectory of economic activity and energy use for Kerala assuming a BAU growth up to 2050. A BAU growth in this context essentially means a market-guided growth that takes existing policy interventions into consideration, but does not make any aggressive assumptions about future market disruptions, policy changes, technology improvements etc. In simple words, BAU growth represents the automatic growth that happens without the interference of any 'new' intervention.

The demand estimation has been done utilizing an energy modelling software the Long Range Energy Alternatives Planning (LEAP) systems [Software version 2012.0049].[114] LEAP model has been utilized to link future activity levels with energy demand using both bottom-up or top-down energy demand estimation methodology.

In addition, the energy use estimated here includes energy use in the form of electricity, heat (cooking and industrial heat) and fuels (transport fuels).

9.1 WHERE IS KERALA HEADING

Kerala is witnessing a growth revolution powered mainly by rapid services sector growth. The economy as represented by the gross state domestic product (GSDP) has increased at a CAGR of 8.3 per cent from 2000-2001 to 2011-12, while the population growth over this period has been only 0.4 per cent. This has resulted in steep increase in consumption levels, especially for luxury goods and personal vehicles. Penetration of white goods in Kerala has crossed the national average, while the vehicle ownership in the state is more than that of many other developed states. As compared to other sectors, the growth in personal transport vehicles has been truly phenomenal. Based on latest vehicle registration data, motorcycles and cars account for nearly 87 per cent of the total non-freight vehicle population. Number of personal cars have increased at a CAGR of 14.32 per cent from 2000-2001 to 2011-12, while motorcycles have grown at a CAGR of 12.3 per cent over the

[114] Heaps, C. G. 2012. *Long-range Energy Alternatives Planning (LEAP) System.* Stockholm Environment Institute. Somerville, MA, USA. www.energycommunity.org.

same period. In contrast, industrial output as measured by GSDP industry, has grown by about 6.6 per cent annually from 2000-01 to 2011-12.

These high levels of economic growth indicators, while not directly related to energy use, are expected to have a significant impact on energy demand. The following sections in this chapter make an attempt to size these dimensions of future economic activity levels and the associated energy needs for different sectors in Kerala.

9.1.1 Future of Energy Sector Development in Kerala

The following sectors are considered for demand estimation: Domestic, Commercial, Industrial, Agriculture, Utilities (public works, lighting and bulk) and Transport.

However, as many of the future projections of activity levels derived from regression are dependent on projections of designated independent variables (the significant variables assumed for regression included population, per capita income, urban population, GSDP industry, GSDP agriculture, etc), it was imperative to derive the future projections of these key parameters. The implicit assumptions considered for projection of these key parameters and the projected values are covered separately in Appendix 1. Interestingly, the key takeaways from these projections were in two demographic features: population growth and household size. The projection results indicated a negative population growth as early as 2021-22. This finding was consistent with a recent assessment by the Centre for Development Studies.[115] In addition the projections indicated a drop in average household size from about 4.34 in 2011 to approximately about 2.9 by 2050; still more than the present average household size of industrialized nations.

9.2 DOMESTIC SECTOR

Domestic sector in Kerala presently consumes about 50 per cent of total electricity and a lion's share of total cooking fuels. The BAU scenario for domestic sector is based on assessment of electricity and heating (cooking) demand.

9.2.1 Domestic Electricity Demand: Inputs

For projection of electricity demand, a bottom-up approach is proposed to factor in the actual appliance ownership levels across urban and rural households.

Appliance ownership values and monthly per capita expenditure (MPCE) values for Kerala are taken from NSSO survey on Household Consumer Expenditure in 1999-2000, 2004-05 and 2009-10. Table 9.1 below indicates the appliance ownership level (for every thousand households) across urban and rural households.

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[115] Deccan Chronicle. 2013. "Kerala Heralds Population Fall". *Deccan Chronicle* (12 May). http://www.deccanchronicle.com/130512/commentary-op-ed/commentary/kerala-heralds-population-fall.

Table 9.1: Appliance Ownership Levels per 1,000 Households in Kerala

Kerala	Urban			Rural		
Consumer Goods penetration	2000	2005	2010	2000	2005	2010
Tube lights and bulbs	1,000	1,000	1,000		1,000	1,000
Fans	718	828	922	487	645	839
TV	569	680	811	338	492	771
Refrigerator	286	395	492	138	208	322
Space conditioning	10	27	75	3	8	17
Washing machine	108	177	245	35	70	105
Others	139	303	467	65	266	467
Average MPCE	**937**	**1,291**	**2,413**	**766**	**1,013**	**1,835**

The penetration of water heaters is not covered in NSSO. It is assumed that the penetration of water heaters is equal to that of washing machines. Others category includes goods like VCD/DVD players, music systems, computers, game consoles, etc.

Hundred per cent electrification is assumed for both rural and urban households based on report from the Rural Electrification Corporation.[116] Penetration of lighting is assumed to be 100 per cent or 1000 per 1000 households. To make future projections of penetration levels, a simple linear regression model is used with penetration level of each appliance as dependent variable and MPCE as independent variable.

Interim annual values of penetration level from 2000 to 2010 have been interpolated after assuming a constant CAGR between interim years equal to the calculated CAGR of each five-year interval. CAGR for future projections of MPCE for urban and rural populations are based on the CAGR of actual MPCE values from 2000 to 2010, which are 9.97 per cent for urban and 9.13 per cent for rural. Incidentally, this high level of growth of MPCE indicates a shift towards a consumption oriented economy from subsistence based economy and seems to be consistent with the present expenditure levels because of high services sector growth.

Brief Methodology

The general equation for estimating penetration level is based on the following equation

$$P_{uij} = C_{uj} \times MPCE_{ui}$$

Where

P_{uij} = Penetration level in urban area in year i for appliance j

C_{uj} = Regression coefficient of MPCE for penetration of appliance j in urban area across all years

$MPCE_{ui}$ = MPCE value for urban households in Year i

[116] Central Electricity Authority. 2013. *Progress Report on Village Electrification on 31.03.2013.* Rural Electrification Corporation, New Delhi, 2013

The results of all regression are found to be statistically significant and are attached as Appendix 2.

To factor in the actual appliance numbers for fans and lights per household and decide on the saturation level of appliance numbers (saturation of air conditioners), the data from Census 2011 was referred ("HH-4: Households by ownership status of the census houses, size of the household and number of dwelling rooms"). The weighted average of dwelling size (in terms number of rooms and household numbers) indicates an average room size of 4.2 for urban and 4.0 for rural households. On the other hand, the average household size in Kerala based on Census 2011 is 4.26 for rural and 4.4 for urban HHs.

Based on above considerations, the following level of household ownership of appliance numbers and their saturation level are assumed.

Lights: 4 points per household

Fans: 3 fans per household but only two fans are considered for the purpose of energy estimation. This is because it is assumed that low household size would actually result in lower usage.

TV, refrigerator and washing machines: 1 each per possessor household with a saturation of 1 each.

Space cooling and water heating: 1 each per possessor household with a saturation of 1.5 each. This level of saturation is assumed to reflect the trend of decrease in average household size. It is assumed that after population stabilization in 2020 and subsequent drop in growth, new households may not find it effective to have two appliances. At the same time many existing households with reduced members may also not choose to increase the appliance penetration beyond a necessary level.

Others: 1 per possessor household with a saturation of 4 (Computer, DVD/Music player, Microwave and Others)

Assumptions

Based on the above assumptions the change in appliance penetration level is mapped in the Table 9.2 below:

Table 9.2: Appliance Numbers across Projection Period per 100 Households

Urban Appliance Penetration	2011	2020	2030	2040	2050
Lighting	100	100	100	100	100
Fans	100	100	100	100	100
TV	100	100	100	100	100
Refrigerator	65.4	100	100	100	100
Air conditioning	6.2	8.5	24.4	86.7	150
Washing machines	29.9	60.3	100	100	100
Water heater	29.9	52.7	150	150	150
Others	52	82.1	291.1	400	400
Rural Appliance penetration	**2011**	**2020**	**2030**	**2040**	**2050**
Lighting	100	100	100	100	100
Fans	100	100	100	100	100
TV	88.8	100	100	100	100
Refrigerator	37.1	73.5	100	100	100
Air conditioning	1.6	3.5	8.3	19.9	47.7
Washing machines	11.9	17.2	52	100	100
Water heater	11.9	16.3	45.1	149.9	150
Others	45.8	66.4	200.4	400	400

Energy Estimation: Outputs

For each appliance, there are different versions of appliance technologies and efficiency ratings. In addition, it was also imperative to arrive at possible appliance share between existing and efficient models. An EMC sponsored study undertaken by Winrock[117] was referred, which estimated the sales share of star-rated appliances in Kerala and the resultant savings in total energy consumption. Even though the study does not provide any information on the existing penetration level of various technologies, it clearly captures a trend towards adoption of more energy efficient appliance level. However, in the absence of exact date, and in order to factor in the trends in consumer behaviour as well as the changing appliance efficiency levels, a 2008 study by World Bank on Indian Household Electricity was also referred.[118]

The study has made long term projections (up to 2031) of residential electricity demand based on a bottom up exercise using individual appliance level ownership and energy intensity values. The energy intensity values are slightly varied in the study to account for changes in appliance sizes (small screen TVs to large screen TVs, small refrigerators to large refrigerators) and moderate level of migration to efficient appliances. A similar transition in energy intensity is assumed for Kerala. Values for energy intensity beyond 2031 have been derived assuming linear extrapolation.

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[117] WINROCK. 2010. *Survey and Collection of Data Concerning Manufacturing, Sales of Household Appliances and Other Equipment at Kerala State Falling under the EC Act and Other Selected Equipments / Appliances and Submission of Data, Analysis, Presentation and Report complete.* WINROCK International India. http://www.keralaenergy.gov.in/emc_reports/Survey%20of%20Appliances%20and%20Equipments%20falling%20under%20EC%20Act%202001.pdf.

[118] World Bank. 2008. *Residential Consumption of Electricity in India: Documentation of Data and Methodology.* Background Paper for India: Strategies for Low Carbon Growth. The World Bank. India.

Based on the study, the presumed annual appliance energy consumption across the years is shown in Table 9.3 below:

Table 9.3: Annual Unit Appliance Energy Consumption (UEC)

Appliance	Annual UEC (kWh)				
	Urban and Rural				
	2011	2021	2031	2040	2050
Lighting	35.2	35.1	35	34.8	34.5
Fans	96.4	92.6	91.8	91	89.2
TV	135	185	203	220	240
Refrigerators	568	431	418	400	390
Space cooling	1,083	1,044	1,040	990	950
Washing machine	41	54	64	74	84
Water heater	589	559	554	548	540
Others*	35	36	37	38	39

* Others include year average of computers, microwave and DVD/VCD player

Based on the above assumptions, the estimated electricity demand for the domestic sector is shown in Table 9.4 below.

Table 9.4: Estimated Domestic Electricity Demand up to 2050

Domestic Electricity Demand (BU)	2011	2020	2030	2040	2050
Domestic Electricity (BAU)	7.2	10.3	19	29.7	47.9

Interestingly, the projected domestic demand in 2020 is about 16 per cent less than that projected by CEA in the 18th EPS report[119] that projects sector-wise demand up to 2021-22. However, past estimates of CEA have usually been higher than actual levels of consumption and hence it can be assumed that the projected demand provides reasonably good picture of actual demand evolution in Kerala.

9.2.2 Domestic cooking energy demand: inputs

The data on fuel use for household cooking in Kerala was taken from four NSSO surveys on 'energy sources for cooking and lighting in Indian households' (1993-94, 1999-2000, 2004-05 and 2009-10). The data available for both urban and rural households indicates that LPG and wood are majorly used as cooking fuels; both accounting for more than 92 per cent of the fuel type use for household cooking. The remaining share is made up of kerosene, biogas, electricity and other fuels.

The share across the years clearly indicates a gradual shift from wood to LPG in both in rural and urban households, though the shift is perceptibly higher in urban areas. At the same time the share of other fuels is decreasing at a high rate indicating increasing dominance of LPG and wood as preferred fuel types.

Assumptions

Based on the data for the four years, it is assumed that LPG and wood together would stabilize their share at 98 per cent, phasing out other fuels, especially kerosene whose share has declined substantially.

[119] CEA. 2011. *Report on Eighteenth Electric Power Survey of India.* Central Electricity Authority. New Delhi, India.

Analysis of the data indicated that LPG penetration is steadily increasing with a decreasing CAGR across the years. To model the future penetration level, LPG share is assumed to increase at a CAGR equal to that of its CAGR between the intervals 2005-10. Assuming 98 per cent share of LPG and wood across the projection period, the share of wood is arrived at after taking a difference between the saturation value of 98 per cent and the penetration of LPG in that year.

For other fuels, historical growth rates are taken (or average CAGR where the share is fluctuating) to project share.

Based on the above assumptions, the projection results indicate a complete phase out of wood between 2020-25 and 2030-35 in urban and rural areas, respectively. Table 9.5 indicates the projection of fuel share across the years. It is assumed that one household uses only one fuel.

Table 9.5: Cooking Fuel Share Projections up to 2050

Cooking Fuel Share	Urban										
(Per 100 HH)	1994	2000	2005	2010	2011	2015	2020	2025	2030	2035	2040	2050
LPG	169	310	437	555	555	708	904	980	980	980	980	980
Wood	701	541	484	368	368	272	76	0	0	0	0	0
Kerosene	52	68	8	6	6	5	4	3	2	1	1	0
Biogas		2	1			0	0	0	0	0	0	0
Electricity				8	8	8	8	8	8	8	8	8
Other	3	7		2	2	2	2	2	2	2	2	2
CAGR Rate (%) Urban												
LPG		10.64	5.89	4.064	0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Wood		-4.23	-1.84	-4.46	0	-9.9	-4.2	0.0	0.0	0.0	0.0	0.0
Kerosene		4.573	-30	-4.68	0	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	
Biogas					0	0	0	0	0	0	0	0
Cooking Fuel Share	**Rural**											
(Per 1000 HH)	**1994**	**2000**	**2005**	**2010**	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2050**
LPG	41	116	182	265	265	340	466	637	871	980	980	980
Wood	921	847	791	700	700	640	514	343	109	0	0	0
Kerosene	13	20	4	3	3	2	2	2	1	1	1	0
Biogas	3	2	3	4	4	4	5	5	6	6	7	8
Electricity		1		1	1	1	1	1	1	1	1	1
Other	9	5	1			0	0	0	0	0	0	0
CAGR Rate (%) Rural												
LPG		0.189	0.078	0.065	0	6.5	6.5	6.5	6.5			
Wood		-0.01	-0.01	-0.02	0	-2.2	-4.3	-7.8	-20			
Kerosene		0.074	-0.24	-0.05	0	-4.7	-4.7	-4.7	-4.7	-4.7	-4.7	
Biogas		-0.07	0.07	0.049	0	1.7	1.7	1.7	1.7	1.7	1.7	1.7

To arrive at the quantitative requirement of cooking fuels at the household level, TERI's technology vision 2030 study was referred.[120] According to the study, per head cooking energy requirement is 620 Kcal/per capita per day for rural and 520 Kcal/per capita per day for urban population. To arrive at the energy requirement

[120] TERI. 2006. *National Energy Map for India Technology Vision 2030: Summary for Policy-makers.* Office of the Principal Scientific Advisor, Government of India. The Energy and Resources Institute. New Delhi, India. http://www.teriin.org/div/psa-summary.pdf.

per year per household, the per capita figure is multiplied with 365 and the average household size for urban and rural sectors for all the given years.

Output

Based on the above assumptions, the total estimated fuel demand for cooking fuels in Peta Joules (PJ) is shown in Table 9.6 below.

Table 9.6: Estimated Demand for Cooking Fuels in the Domestic Sector

Domestic Cooking Fuel Demand (PJ)	2011	2020	2030	2040	2050
LPG (BAU)	11.6	20.5	26.8	27.3	26.7
Wood (BAU)	16.6	8.2	1.1	0	0
Total	**28.2**	**28.7**	**27.9**	**27.3**	**26.7**

The apparent decrease in the total fuel demand after 2020 clearly indicates a reduction in cooking demand brought about by the negative population growth rate after 2020.

Based on the above methodology, the final energy demand for the domestic sector in the BAU scenario is shown in Table 9.7 below.

Table 9.7: Estimated Final Energy Demand for the Domestic Sector up to 2050

Domestic Energy Demand (PJ) - BAU	2011	2020	2030	2040	2050
Electricity	25.9	37.8	66.3	103.3	142.3
Cooking	28.5	28.9	28.2	27.6	26.9
Total	**54.4**	**66.7**	**94.5**	**131**	**169.3**

9.3 COMMERCIAL SECTOR

Commercial sector in Kerala mainly includes ITES, retail, tourism, hospitals and other commercial establishments. Commercial sector is witnessing a phenomenal growth in Kerala for the past 5 years with substantial increase in the share of ITES and retail in the total gross state domestic product from services.

Commercial establishments mainly use two forms of energy in the form of electricity and heating. Heating is mainly used for cooking in the tourism and commercial sectors. However, there are considerable data gaps in assessing the current energy usage trends within sub-sectors making a bottom up energy estimation of this sector difficult. Available literature on commercial energy demand estimation has mostly used a top down analysis. In view of the data gaps and the difficulty in actually simulating usage and appliance pattern variations, a top-down analysis of energy demand for the commercial sector is done.

9.3.1 Estimation of Commercial Electricity Demand: Inputs

The 18th Electric Power Survey (EPS) report was published by CEA[121] where the projection of sectoral electricity demand for Kerala is available up to FY 2021/22. CEA has used the partial end use methodology (PEUM) for electricity demand forecasting. This methodology is a combination of time series analysis and end use method. The projected electricity demand by CEA along with past data from KSEB is considered for projections of future electricity demand.

[121] CEA. 2011. *Report on Eighteenth Electric Power Survey of India.*

The sectoral consumption data, as available from CEA from its 18th EPS report, is used as the final consumption data for the period FY 2013/14 to FY 2021/22. Data from 2005-06 to 2009-10 have been collected from the Kerala State Electricity Regulatory Commission's (KSERC) order on tariff petition filed under annual revenue requirement for the year 2013-14. Data from 2009-10 to 2021-22 have been collected from 18th EPS report. From FY 2022/23 onwards, sectoral electricity consumption projection has been calculated on the basis of projected data. In order to predict the future electricity demand in the commercial sector, a second order polynomial curve has been fitted to the existing data. The estimated polynomial equation of order two is as follows.

Electricity demand in the commercial sector at period
$t = 11.22\, t^2 + 149.4\, t + 1469 \qquad R^2 = 0.999$

Where, t denotes time and takes values from 1 to 45 [1 = 2006, 2 = 2007,........, 45 = 2050]

The R^2 for the estimated equation is 0.999, which is quite high. The estimated equation has been used to forecast demand for electricity in the commercial sector from 2023 to 2050. Forecasted demand for electricity in the commercial sector appears to be 12,216.5 million units in 2030 and 30,912.5 million units in 2050.

Output

The projected values of absolute annual increase for the commercial sector are shown in Table 9.8 below.

In order to estimate the electricity demand of individual sub-sectors with the commercial sector (IT parks, hotels, etc), a Bureau of Energy Efficiency (BEE) study[122] was referred which indicated that the percentage break-up of consumption across large consumers (those consuming more than 500 kW in Kerala) was 45 per cent for hotels, 29 per cent for IT parks, 9 per cent each for government buildings and malls and 4 per cent each for hospitals and other office buildings. However, as these large consumers accounted for only 24.6 per cent of the total consumption, a similar break-up across the low-end consumers (representing 73.4 of total energy consumed) was assumed, except that the share of IT parks, malls, government buildings and half the share of hotels was assumed for retail shops and outlets. Based on the above assumptions, the assessed percentage share across commercial sector is shown in Table 9.9.

Table 9.8: Estimated Electricity Demand for the Commercial Sector up to 2050

Sector Electricity Demand (MU)	2011	2020	2030	2040	2050
Commercial	2,809.7	6,227	12,216.5	20,442.5	30,912.5

Table 9.9: Share of Sub-sectors in Total Commercial Electricity Demand

Commercial	% Share
Malls	2.4
Hospitals	4
Office Buildings	6.4
IT Parks	7.7
Hotels	22.5
Retail	57

[122] Bureau of Energy Efficiency (BEE). *State-wise Electricity Consumption and Conservation Potential in India.* Prepared by the National Productivity Council (NPC), Energy Management Group. http://www.emt-india.net/eca2009/14Dec2009/CombinedSummaryReport.pdf.

This share is assumed to be constant throughout the projection period. In addition, the breakup of various electricity consuming activities like lighting space conditioning has been assumed based on electricity usage norms adopted in TERI's report.[123] Based on the report, it has been assumed that lighting, space conditioning and refrigeration respectively account for 60, 32 and 8 per cent of total electricity usage in the commercial sector. The same norms are assumed for hotels, malls, hospitals and retail. For office buildings and IT parks, the share is assumed as 60 per cent for lighting, 32 per cent for space conditioning and 8 per cent for IT and other applications. For space conditioning a share of 70 per cent is assumed for fans and 30 per cent for air conditioners.

No changes in any of the shares are considered for the base (BAU) scenario. Furthermore, as the electricity demand is top driven, the breakup of end-use activities in terms of appliances has not been considered in the base (BAU) scenario, but is included in intervention scenarios covered later.

9.3.2 Estimation of Commercial Heating Demand: inputs

The commercial sector uses heat mainly for cooking and water heating. As mentioned, the absence of granular data on commercial sector necessitates its analysis using a top down methodology. The main fuels used for heat requirements of the commercial sector are LPG and kerosene.

The all India share of LPG and kerosene consumption in the commercial sector for the past three years from 2009-10 to 2011-12 are shown in the Table 9.10.

Table 9.10: Usage Share of LPG and Kerosene in the Commercial Sector (All India)

LPG Consumption (000' tonnes)	2010	%	2011	%	2012	%
Commercial	872	6.8	985	6.9	1,045	6.6
Total	13,122	100	14,331	100	15,358	100
LPG Consumption (000' tonnes)	**2010**	**%**	**2011**	**%**	**2012**	**%**
Commercial	69	0.7	67	0.8	61	0.7
Total	9,304	100	8,928	100	8,229	100

Based on the recent statistics of the Ministry of Petroleum and Natural Gas, the total consumption of LPG and kerosene in Kerala for the year 2011-12 was 656,000 tonnes and 155,000 tonnes, respectively. However, to arrive at the share of LPG and kerosene in the commercial sector, all India statistics that provided break-up of the consumption of each petroleum product in terms of end-use sector were referred. The sector-wise consumption pattern included commercial / industrial as one category, but also included Bulk LPG as a separate category for the manufacturing sector. As the manufacturing sector was accounted for separately, the category 'commercial / industrial' was assumed to represent the demand of the commercial sector.

Assumptions

It is assumed that the share of LPG and kerosene in the state's commercial sector will also reflect national average giving a figure of 43,952 tonnes of LPG and 1,085 tonnes of kerosene, respectively for 2011-12. These values are assumed to represent commercial sector's fuel requirement in the base year (2011).

From the above figures it appears that the all India percentage share of LPG and

[123] TERI. 2006. *National Energy Map for India Technology Vision 2030.*

kerosene has not changed significantly in the past three years. The average percentage share of LPG for commercial sector vis-á-vis total consumption is about 6.7 per cent, while for kerosene it is 0.7 per cent.

Further, for projecting future demand, it has been assumed that heating requirement will grow at the same rate as that of electricity requirements in the categories 'hotels' and 'malls'.

Output

Based on the above assumptions, the total commercial sector heat demand is estimated as shown in Table 9.11 below.

Table 9.11: Estimated Total Commercial Sector Energy Demand up to 2050

Commercial Sector Total Energy (PJ) - BAU	2011	2020	2030	2040	2050
Electricity	10.1	22.4	44	73.6	111.3
Heat (LPG and Kerosene)	2.1	4.6	9	15.1	22.8
Total	**12.2**	**27**	**53**	**88.7**	**134.1**

9.4 INDUSTRY SECTOR IN KERALA: INPUTS

The industry sector in Kerala is dominated by a large numbers of MSMEs and SMEs with very few large industries. Consequently, energy estimation using bottom up methodology was not possible considering that the energy consumption by industry is spread into a huge numbers of small scale engineering and industrial goods manufacturers, plastic and ceramics manufacturers, food processing and agro industries, with few large petrochemicals, chemicals, metals and minerals industries. A bottom up approach would have necessitated availability of sectoral production data and specific energy consumption data for each sector accounting for the differences in product variations. Analysis of literature review[124] on industry demand projections (TERI and IEA) indicated that energy demand could be assessed only for a handful of sectors using a bottom up methodology. The sectors covered in these studies included only a small portion of the industry sectors in Kerala leaving out scope for a bottom up demand estimation for complex industry sectors like engineering and industrial goods, food processing, etc, which also play a major role in the overall industrial ecosystem.

In contrast, comprehensive data on electricity projection for industry sector and fuel requirements across industry sectors in Kerala was available from the CEA's report[125] and Annual Survey of Industry (ASI),[126] respectively. In view of the above, a top down analysis was used to project electricity demand for the industry sector.

Based on the ASI survey, the industry sector was clustered into ten major sectors: agro and food processing, textiles, paper and pulp, petrochemicals, chemicals

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124 Ibid.; IEA. 2011. *Energy Transition for Industry: India and the Global Context.* International Energy Agency. Paris, France. http://www.iea.org/publications/freepublications/publication/india_industry_transition_28feb11.pdf.

125 CEA. 2011. *Report on Eighteenth Electric Power Survey of India.*

126 Central Statistics Office. 2013. *Annual Survey of Industries* 2010-2011. Vol. I. Ministry of Statistics and Programme Implementation. Kolkata, India. http://mospi.nic.in/mospi_new/upload/asi/ASI_2010-11_Vol-1.pdf.

(including fertilizers), rubber products, minerals and materials (including cement and abrasives), metals and alloys, engineering and industrial goods, and others. Table 9.12 below captures the categorization in detail.

Categories	NIC	code	Industry
Agriculture and Food	10		Food Process Industries
	11		Manufacture of beverages
	12		Manufacture of Tobacco products
	16		Wood industry
Textiles	13		Textile industry
	14		
Paper and Pulp	17		Pulp & Paper industry
Petrochemicals	19		Refined petroleum products
		222	Plastic products
Chemicals	20		Chemical Industry
	21		Pharmaceuticals/Medicinal Chemical/botanical products
	23	231	Glass & Glass products
Rubber Products	22	221	Rubber products
Minerals and Materials		239	Non-metallic mineral products (cement)
Metals and Alloys	24	241	Manufacture of basic iron & steel
		242	Manufacture of basic precious and other non ferrous metals
Engineering and Mechanical		243	Casting of metals
	25		Metal Fabrication
	27		Electrical manufacturing sector
	28		Manufacture of machinery
	29		Automobile sector
	30	301	Building of ships & boats
		302	Manufacture of railway locomotives and rolling stock
Others	31		Manufacture of furniture
	32	321	Manufacture of jewellery
		325	Manufacture of medical instruments
		329	other manufacturing n.e.c
	33		Repair/ installation of machinery
	58		Publishing of books/periodicals/publishing activities
			Others

Table 9.12: Categorization of Industry Sub-sectors

Based on the above categorization, the electricity and heat demand for different sectors of the industry was determined separately.

9.4.1 Electricity Demand for Industry Sectors: Inputs

The sectoral consumption data, as available from the 18th EPS report, is used as final consumption data from FY 2013/14 to FY 2021/22 period. Data from 2005-06 to 2009-10 has been collected from the Kerala State Electricity Regulatory Commission's (KSERC) order on tariff petition on matters of annual revenue requirement for the year 2013-14. Data from 2009-10 to 2021-22 have been collected from 18th Electric Power Survey. From FY 2022/23 onwards, a linear trend has been fitted to the existing data. The estimated linear trend equation is as follows.

Electricity demand in industry at period t = 233.9 t + 2682 $R^2 = 0.976$

Where, t denotes time and takes values from 1 to 45 [1 = 2006, 2 = 2007,........, 45 = 2050]

The R^2 for the fitted equation is 0.976 which is quite high. The estimated equation has been used to forecast demand for electricity in industry from 2023 to 2050.

Output

Forecasted demand for electricity in industry sectors appears to be 8,529.5 million units in 2030 and 13,207.5 million units in 2050.

Based on the above, the total electricity demand for Industrial sector (HT and LT) is shown in Table 9.13 below.

Table 9.13: Estimated Electricity Demand for Industry Sector up to 2050

Sector Electricity Demand (BU)	2011	2020	2030	2040	2050
Industry	3.8	6.3	8.5	10.9	13.2

To break down the total projections across industry sectors, data from *Annual Survey of Industries* was used. Table 9.14 indicates the actual consumption data and the percentage share across industry sectors.

Table 9.14: Percentage Share of Electricity Consumption across Industry Sub-sectors

Industry Energy Share	% Share	Elec (MU)
Agro and Food Sector	12.07	313.4
Textiles	10.23	265.75
Paper and pulp	4.82	125.37
Petrochemicals	5.88	152.61
Chemicals	15.2	394.70
Rubber	9.85	255.94
Minerals and Materials	13.1	339.34
Metals and Alloys	24	624.25
Engineering and Industrial Goods	2.9	76.43
Others	1.95	48.21
TOTAL	**100**	**2596.04**

It was observed that the total industrial electricity consumption as per the ASI data (2,596 MU) seemed to closely match the actual consumption of Industry HT category (2,599 MU) in 2010-11. This effectively left out the electricity requirement of Industry LT category, which was about 1,066 MU in 2010-11. Therefore, instead of using the actual electricity consumption data, the percentage share of electricity consumption across sectors was derived and used for allocating consumption share in the base year.

For projecting the future intra-sectoral demand, Kerala's Industrial and Commercial Policy 2011 (draft)[127] was studied. Some of the key extracts from the policy document are reproduced below.

> ***Page 4 Large Industries***
>
> *Large industries in the State have significant potential because of good infrastructure facilities available in the State like power, transport system,*

[127] Government of Kerala. Industrial & Commercial Policy 2011 (Draft). http://kerala.gov.in/docs/policies/draftic_policy11.pdf.

airports, ports and availability of rare minerals. However, availability of land and its high price are the major hurdles faced by the State in the implementation and execution of large industries.

Government will encourage suitable Industries that are non-polluting, environmental / eco friendly and employment oriented that have the potential to pay wages at par with the living standards of Kerala'. Interactions of project teams with government officials and other experts also seems to indicate a clear shift from large polluting industries to more dynamic small scale sector growth in focus areas like food processing, engineering and high technology sector, etc.

Page 5 Micro Small and Medium Enterprises

The importance and contribution of the MSME sector to the economic growth and prosperity is well established. Their role in terms of employment creation, upholding the entrepreneurial spirit and innovation has been crucial in fostering competitiveness in the economy. It can lead the State economy by acquiring exports through quality production techniques and products.

Page 10 Forest Based Industries

Environmental friendly industrial development is the new Global trend. Government will not encourage enterprises which use forest wood as raw materials. Redeemable wood / plantation based wood (bamboo, softwood, plywood etc.) industries should be seen as a green alternative and will be promoted.

Page No. 11 Mining and Geology

Mining is generally seen as a destructive activity. Hence, steps will be taken towards conservation, preservation and selective utilization of mining resources. Safety and security of people / workers will get high priority.

- *Effective utilization of scarce mineral resources in the State through value addition will be given high priority. A Natural Mineral Research Institute will be set up for Research and Development in mineral sector in the State.*
- *Mining of Rare Earth will be allowed only in the Public Sector and strictly for value added products.*

In view of the clear policy focus, it was assumed that even though the total electricity consumption for the industrial sectors will increase, the absolute increase in consumption level of large industries like chemicals, paper and pulp, petrochemicals, minerals and materials will increase initially till 2017 and will remain constant after 2017. Subsequently, the total increase in electricity will be distributed across other sectors keeping their relative share as constant. So even as the total electricity demand remains the same, the intra-sectoral demand changes with focus industries capturing a higher share of total industrial electricity consumption.

9.4.2 Industrial Heat Requirements: inputs

Data from the ASI was used to assess the fuel requirements of selected sectors. Even though the data on fuel usage across sectors for coal was available in tonnes, for petroleum products and other fuels it was available in terms of value of fuels in Indian rupees. To arrive at the actual tonnage requirements of petroleum products, data on petroleum product prices as on 31 March 2010 was accessed from the Petroleum Statistics released by Ministry of Petroleum and Natural Gas. The main petroleum derived fuel used across the majority of selected industry sectors was Furnace Oil (FO) and it was taken as a representative fuel for all sectors except petrochemicals. The value of petroleum fuels consumed was divided by the price of FO at the end of FY 2010/11 to arrive at the tonnage of FO requirement for each sector. For the petrochemical sector, the high petrochemical consumption value indicated use of petroleum (Naphtha or Crude) as raw material rather than mainly as a heating fuel. Consequently, the heating demand for the petrochemical sector was assumed to come from gas and other fuels.

It was further assumed that coke and wood were the best representations of 'other fuels' category. Based on the existing process-requirements of the industry sub-sectors, it was assumed that coke (pet coke) represented 'other fuels' in petrochemicals, chemicals, minerals and materials, and metals and alloys. For all other sub-sectors, it was assumed that 'other fuels' represented wood.

Based on available market data, the price of pet coke (produced by Reliance Industries Limited) in 2011-12 was taken as Rs 6,200/tonnes. Further, based on informal interactions with industry experts, a value of Rs 3/kg was assumed for wood. Based on the above assessment, the total fuel requirement (kl for furnace oil and tonnes for coal, coke and wood) was arrived at. Table 9.15 below shows the estimates of fuel usage in Kerala in 2010-11.

Output

Table 9.15: Fuels Used across Industry Sub-sectors in Kerala

Industry Fuel Use	POL (FO Kl)	Coal (Tonnes)	Coke (Tonnes)	Wood (Tonnes)
Agro and Food Sector	29,068	4,000		124,037
Textiles	6,102	0		69,203
Paper and pulp	6,378	163,000		30,274
Petrochemicals	278,008	453,000	2,967	
Chemicals	6,722	0	67,463	
Rubber	22,231	17,000		18,252
Minerals and Materials	2,335	76,000	160,768	
Metals and Alloys	14,856	22,000	1,425	
Engineering and Industrial Goods	2,613	5,000		26,765
Others	4,156	0		1,886

Based on the above fuel usage, the final heat requirement across sectors was derived. Table 9.16 shows the total heat requirement across industry sub-sectors.

Table 9.16: Heat Requirements across Industry Sub-sectors

Industry Energy Share	Heat Demand (TJ)
Agro and Food Sector	1,229
Textiles	1,304
Paper and pulp	5,483
Petrochemicals	13,300
Chemicals	2,348
Rubber	1,632
Minerals and Materials	7,305
Metals and Alloys	1,256
Engineering and Industrial Goods	660
Others	189
Total	34,706

For projections, heat requirement of each sub-sector was linked to the electricity demand of that sub-sector. As the electricity demand of large industries like chemicals, petrochemicals, pulp and paper, and minerals and materials is assumed as constant after 2017, the heating requirement for these industry sectors is also expected to remain constant.

Table 9.17 captures the estimated energy demand for the industry sector.

Table 9.17: Estimated Energy Demand for Industries up to 2050

Industry Energy Demand (PJ) - BAU	2011	2020	2030	2040	2050
Electricity	14	22	31	39	48
Heat	34.8	53	59.3	65.7	72.2
Total Demand (Electricity and Heat)	**48.3**	**75.5**	**90**	**104.8**	**120**

9.5 AGRICULTURE: INPUTS

Kerala has been undergoing structural changes in agriculture with steady decline in the area under cultivation of important food crops from the mid-1970s. Out of a gross cropped area of 20.71 lakh ha in 2010-11[128] (about 53 per cent of total geographical area of the state), food crops comprising rice, pulses and tapioca occupy only 11.74 per cent with about 18.22 lakh ha (88 per cent of the total cropped area) being used for commercial crops. In 2010-11, the area under food crops reduced further to 8.13 per cent. Table 9.18 gives the area and production of principal crops of Kerala.

[128] State Planning Board. 2012. *Economic Review 2011.* Thiruvananthapuram, Kerala. Chapter 6 – Agriculture and Allied Sectors. 123p.

Table 9.18: Area, Production and Productivity of Principal Crops in Kerala

S. No	Crops	Area (ha)		Production (MT)	
		2009-10	2010-11	2009-10	2010-11
1	Rice	23,4013	213,185	598,337	522,739
2	Pulses	4,449	3,823	3,390	2,908
3	Pepper	171,489	172,182	28,497	45,267
4	Ginger	5,408	6,088	28,603	33,197
5	Turmeric	2,438	2,391	6,066	6,216
6	Cardamom	41,593	41,242	7,800	7,935
7	Areca-nut	99,188	99,834	116,763	99,909
8	Banana	51,275	58,671	406,242	483,667
9	Other Plantains	47,802	49,129	338,546	353,772
10	Cashew nut	48,972	43,848	35,818	34,752
11	Tapioca	74,856	72,284	2,525,384	2,360,081
12	Coconut	77,8618	770,473	5,667	5,287
13	Coffee	84,796	84,931	59,250	65,650
14	Tea	36,845	36,965	57,810	57,107
15	Rubber	525,408	534,230	745,510	770,580

Source: State Planning Board. 2012. *Economic Review 2011*. Thiruvananthapuram, Kerala. Chapter 6 - Agriculture and Allied Sectors. 124-25pp.

This change in agricultural cropping has had a very deleterious impact on the state's food security with the state depending on importing about 85 per cent of its rice requirement (the state's main staple food) from outside.

Surprisingly, despite this change in the choice of crop sworn, the absolute value of state gross domestic product from agriculture and allied sectors GSDP (A) has fallen marginally from Rs 20,843 Cr in 2004-05 to about Rs 20,486 Cr in 2010-11.[129] The main reason for this drop in the sector's performance stems from high input costs of agriculture, mainly on account of high costs of labour and fertilizers.

Energy use in agriculture is mainly spread across electricity and diesel requirements for irrigation, fuel requirements for tractors and input energy investment in fertilizers.

9.5.1 Estimation of Electricity Demand for Agriculture: inputs

Based on the KSEB data, the total electricity consumption from 2005-06 to 2010-11 is shown in Table 9.19 below.

Table 9.19: Historical Agricultural Demand for Electricity

Electricity (MU)	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Irrigation	199.11	229.6	239.78	233.98	265	239.56

In addition, the sectoral consumption data, as available from the 18th EPS report, is used as final consumption data from FY 2013/14 to FY 2021/22 period. Sectoral electricity consumption projection has been done, considering the actual consumption data as available from KSEB and EPS from FY 2022/23 onwards.

[129] Ibid.

Methodology

The future sectoral electricity consumption (from FY 2022/23 onwards) is calculated on the basis of the projected data on absolute annual increase of electricity consumption. Utilizing the data of KSEB and CEA, historical absolute annual increase has been analyzed and projection of the absolute annual increase of sectoral consumption has been done. The sector-wise absolute annual increase is mapped over time. The trend has been analyzed with several options and finalized the suitable option for each sector.

Based on the above methodology the best fit curve for the irrigation demand is defined by the following equation

Irrigation demand for year t = Irrigation demand in Year (Y-1) +19.59 - 4.45 log(t)

Where t is the number of the year with 2006 indexed to 1

Output

Based on the above equation, Table 9.20 summarizes the electricity demand for irrigation.

Table 9.20: Estimated Electricity Demand for Agriculture

Electricity (MU)	2013-14	2019-20	2029-30	2039-40	2049-50
Irrigation	307	362	425.33	470.7	502.97

9.5.2 Estimation of Fuel Requirements for Agriculture

The main fuel demand in the agricultural sector is for pumps and tractors. The following narrative covers the methodology for estimation of fuel demand.

Estimation of Fuel Demand for Irrigation Pumps: Methodology

According to the Input Survey 2006-07, Kerala had about 35,000 diesel pump-sets in 2006-07.[130] Assuming a standard pump size of 5 hp with a specific fuel consumption of 169.28 g/bhp-hr (standard 5 hp diesel pump of B. S. Agriculture Industry) and a standard annual operating time of 170 hrs/year (derived), the total annual diesel requirement in 2006-07 per pump works out to be 187 litres. It is also assumed that diesel pumps will be phased out completely by 2020. As the proportion of diesel pumps is small, it is assumed that phased out diesel pumps are reflected in the growing electricity demand for irrigation.

Estimation of Fuel Demand for Tractors: Methodology

According to the Motor Vehicles Department, Government of Kerala, the total number of registered tractors in Kerala has grown from 12,940 to about 13,576 between 2000-01 and 2011-12, registering a CAGR of 0.4 per cent. Tractor population is assumed to be dependant on GSDP (A) and accordingly regression is done with registered tractor population as a dependant variable and GSDP (A) as an

[130] Agriculture Census Division. 2012. *All India Report on Input Survey 2006–07.* Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India. New Delhi, India.

independent variable. Based on regression results it is found that GSDP (A) is explaining maximum variability of registered tractor population.

The results of the regression are as shown below:

Registered Tractor Population = 0.66475 X GSDP (A)

The figure for fleet availability (ratio of on-road to registered vehicles) is assumed to be 70 per cent. Based on the above logic the number of on-road tractors are shown in Table 9.21.

Table 9.21: On-road Tractor Population

Tractors Numbers	2011	2020	2030	2040	2050
Tractors on-road	9503	9143	9408	9681	9961

Considering the cropping choices in Kerala and the low average land holding size, a standard tractor size of 18.5 hp/2700rpm (Shakti MT180D Model of VST Tillers and Tractors Ltd.) with a specific fuel consumption of 230 gm/hp-hr is assumed as a representative machine. Assuming 300hrs (100 days for 3hrs per day) of on-farm running and 400hrs of other running including transportation and other uses, the total fuel requirement per tractor per year is estimated at 2,978 kg/tractor. This is multiplied by the number of tractors to arrive at a total annual fuel consumption of tractors.

Energy Intensity of Fertilizer Application: Methodology

Another area of major energy use in agriculture is applying fertilizers. Nitrogen, phosphorous and potassium fertilizers (generally termed as NPK fertilizers) are the main fertilizers used in Kerala and the quantity used in the year 2009-10 was 264.89 lakh tonnes for Kerala. This level of consumption is much larger than the total production of fertilizers in the state (6.05 lakh tonnes of Factomphos in 2009 by Fertilizers and Chemicals Travancore Ltd.) implying that a large portion of fertilizers are imported from other states.

Energy intensity of fertilizer production in India is 34.20 GJ/tonnes of total fertilizer produced in the year 2001-02. This translates into a total energy input of approx 906 TJ in the form of fertilizer input in 2009-10 for Kerala alone.

As the energy invested in fertilizers manufactured in the state is already deemed to be captured in the industrial demand sector assessment and as a large portion of the fertilizer supply is assumed to come from other state, no separate projections are made in terms of energy input of fertilizers in the reference (BAU) scenario. The effects of reducing fertilizer intensity through alternative farming techniques have been discussed but have not been factored in any scenarios.

Output

Based on the discussed methodology the total energy demand for the agricultural sector is shown in Table 9.22 below.

Table 9.22: Estimated Energy Demand for Agriculture up to 2050

Agricultural Demand (PJ) - BAU	2011	2020	2030	2040	2050
Electricity	0.9	1.3	1.5	1.7	1.8
Fuel	1.2	0.9	1	1	1
Total	**2**	**2.2**	**2.5**	**2.7**	**2.8**

9.6 PUBLIC LIGHTING, PUBLIC WORKS AND BULK SUPPLY: INPUT

Public Lighting and works mainly covers electricity consumption of utilities and state entities towards street/road lighting, government offices lighting and load and water supply and sewage treatment. Data, as available in the 18th EPS report, is used as the final consumption data for the FY 2013/14 to FY 2021/22 period.

Methodology

From FY 2022/23 onwards, historical absolute annual increase has been analyzed and projection of the absolute annual increase of sectoral consumption has been done. The sector-wise absolute annual increase is mapped over time. The trend has been analyzed with several options and the finalized equation for projections for public lighting and water works is as shown below:

Public Lighting and Public Works demand in MU in year t = Demand MU (Y-1) + 16.11 + 0.2667 t

Where t is the value of year with year 2006 indexed as 1.

Furthermore, CEA has also projected electricity demand for bulk customers which included entities like, Cochin Port Trust, Cochin SEZ, Rubber Park, Thrissur Corporation, and others. As the load pattern and usage of these entities is similar to that of the commercial sector, the electricity demand for bulk consumers is also included as part of public energy. The electricity consumption in bulk supply is increasing and a linear trend is assumed for bulk electricity demand. The resultant figures give reasonable growth rate of electricity consumption in bulk supply.

The derived equation for bulk power is:

Bulk electricity demand for Year t = Demand MU (Y-1) + 7.35 + 2.32t

Output

Table 9.23 shows the estimated electricity demand for these sectors up to 2050.

Table 9.23: Estimated Electricity Demand for Public Utilities and Bulk Customers

Sector Electricity Demand (MU)	2011	2020	2030	2040	2050
Public Water Works	26.56	38.1	53.6	72.4	91.1
Public Lighting	239.12	476.8	670.9	882.9	1139.6
Bulk	448.11	626	1,170	1,930	2,922
Total	**713.79**	**1141.0**	**1,898.8**	**2,911.5**	**4,198.4**

As this is a top-down energy estimation, it has been assumed that expected system improvements through policy and other interventions are already factored in the final demand in the reference (BAU) scenario.

No heating or fuel requirement is separately assessed for this sector.

The summary of energy demand for these sectors is as shown in Table 9.24 below.

Table 9.24: Estimated Total Energy Demand for Public Utilities and Bulk

Public and Bulk (PJ) - BAU	2011	2020	2030	2040	2050
Public Water Works	0.1	0.1	0.2	0.3	0.5
Public Lighting	0.8	1.2	2.1	3.1	4.5
Bulk Supply	1.7	2.8	4.6	7	10.1
Total	**2.6**	**4.1**	**6.8**	**10.5**	**15.1**

9.7 TRANSPORT SECTOR: METHODOLOGY

Kerala already has a draft transport policy which has laid out many interventions in the transport sector aiming both at energy reduction and traffic decongestion. Even though the policy is comprehensive and talks about variegated measures that can impact the transport architecture of the state, there are no quantifiable targets mentioned in the policy document. In the absence of a top-down map on quantifiable interventions, the derivation of future transport traffic volumes and technology matrix (availability, penetration and energy intensity) is difficult to assess for the BAU scenario using a top down methodology.

This section tries to assess the total transport volume and the transport energy demand using a bottom-up methodology. It covers passenger and freight transport separately. Within each branch, the traffic volumes are estimated for different transport modes including road, rail, water and air. The units used for estimating transport volumes are Passenger Kilometre (PKm) for passenger transport and Tonnes Kilometre (TKm) for freight transport. The projections for the BAU traffic volumes for roads covered in this chapter are derived on the basis of growth in vehicle population. For other sectors, the demand estimation uses CAGR based projections.

The assessment of transport technologies is mainly based on empirical data or available studies. However, in order to factor in the future of new and near-commercialization technologies, a maximum penetration level of 20 per cent by 2050 for new technologies (technologies with 0 per cent share in the base year) is assumed in the base (BAU) scenario. This moderate level of penetration is assumed to emphasize that *new technology adoption will be primarily based on market drivers and not on specific transport policy actions*.

Furthermore, in the absence of clarity on evolution of fuel efficiency norms for transport, a moderate level of reduction in energy intensities by up to 10 per cent for proven technologies (ICE petrol, ICE diesel, CNG, hybrid petrol) and a maximum reduction of 15 per cent in energy intensity of commercially unproven technologies (hybrid diesel, electric vehicles) is assumed over the projection period (by 2050). Based on the above considerations, the main assumptions for transport energy projections for each vehicle category for the BAU scenario are covered in the following sections.

9.7.1 Passenger Transport

In the face of rapid growth in personal modes of transport, passenger transport in Kerala is expected to account for major share in transport energy consumption. The following narrative captures the methodology of demand estimation across different modes of transportation.

Road Transport: Methodology

The major vehicle categories considered for road based passenger transport are buses (stage and contract carriages), cars, taxi cars, jeeps, autorickshaws and two wheelers. Data on category-wise growth of motor vehicles from 2000-01 to 2011-12 in Kerala have been assessed from the motor vehicles department of Kerala. For predicting the number of motor vehicles of different categories, a simple linear regression model has been used for each category of motor vehicles.

The basic methodology for projecting passenger volumes (PKm) involves four steps:

- **Step 1:** Projection of registered vehicle population based on regression (X_{ij})
  Where X_{ij} is the number of registered vehicles of type i in year j

- **Step 2:** Estimating the number of in-use vehicles assuming standard retirement age or percentage fleet utilization (Y_{ij})
  Where $Y_{i,J}$ is the number of in-use vehicles of type i in year j

- **Step 3:** Assigning average annual kilometres run based on standard literature (Km_{ij})
  Where Km_{ij} is the average annual km run for category of vehicle i for year j

- **Step 4:** Assigning average passenger carried (P_{ij})
  Where P_{ij} is the average passenger occupancy rate for category of vehicle i for year j

Based on the above, the total road passenger traffic is estimated by the following equation

Total passenger traffic in passenger kilometre (PKm) = $Y_{i,J} \times Km_{ij} \times P_{ij}$

Buses (Stage Carriages): Methodology

Based on available data from Motor Vehicles Department, government of Kerala, the categorization of goods vehicles is done in terms of two categories: stage carriages (city buses with multiple stops) and contract carriages (Inter-city, inter-state buses). Considering the difference in definition, both the categories have been considered separately.

Stage Carriages: Estimation of Passenger Volumes

STEP 1: Based on available data from Motor Vehicles department, government of Kerala, the number of registered stage carriages has grown from 11,961 to about 26,272 between 2000-01 and 2011-12, registering a CAGR of 7.4 per cent. The future population of registered buses (stage carriage) is estimated using the available data. Based on literature review, regression of log (registered number of buses) on log (population) is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of number of registered buses to population.

$$\text{Log (Registered number of buses)} = -265.75 + 15.92 \times \text{Log (Population)}$$

t-statistic (-15.85) (16.43)
p-values (0.000) (0.000)

$R^2 = 0.96$

The independent variable and the intercept are found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.96 which indicates that 96 per cent of variation in registered number of buses is explained by population. The regression equation is used to predict future number of registered buses up to 2050. The forecasted number of registered buses is 25,208 in 2050 as compared to 24,712 in 2011.

STEP 2: Based on stakeholder interaction and available literature for the state, it appears that buses are the primary mode of transport in Kerala and almost all of Kerala including the remotest village is served by a bus. In that sense, it is assumed that no new routes are to be serviced in Kerala. This would indicate that increase or decrease of on-road bus population can only be on account of increasing population or increasing frequency on existing routes (which again is a function of population). The population growth figures derived in Appendix 1 indicate that the absolute growth in population is very low and negative population growth occurs as early as 2020-21. Intuitively this means that the current on road bus fleet size would largely remain the same except for some minor variations on account of population.

The figures for fleet availability (ratio of on-road to registered vehicles) estimated in All India Transport Study[131] was about 57.95 per cent of registered passenger bus population in 2009-10. Based on this input, same ratio of on-road to registered vehicles for stage carriages is assumed.

Intermediate output

The results of the derivation are shown in Table 9.25 below.

Table 9.25: Estimated On-road Stage Carriage Bus Numbers

Bus Numbers ('000)	2011	2020	2030	2040	2050
Stage Carriage	14.3	16.5	16.6	16.1	14.6

STEP 3: The average annual utilization for stage carriages assumed in various studies on transport indicate a value between 40,000 km[132], and 46,365 km[133]. The values indicated in TERI's Study,[134] which assumed a base average annual running of 40,000 km in 1995 increasing by 400 m every year. In line with TERI's estimate, a value of 46,400 km annual average run was assumed in 2011. However, no increase

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[131] JPS Associates. 2011. *Study on Volume of Goods & Passenger Traffic on Indian Roads.* JPS Associates (P) Ltd., Consultants. New Delhi, India.

[132] IEA. 2004. *SMP (Sustainable Mobility Project) Model Documentation and Reference Case Projections.* International Energy Agency. Paris, France.

[133] Bose, R. K. and Chary, V. S. 1993. "Road Transport in India Cities: Energy Environment Implications". *Energy Exploration and Exploitation.* 2 (2): 154–80.

[134] TERI. 2006. *National Energy Map for India Technology Vision 2030.*

in the kilometres of these buses over time was assumed as these buses serve fixed routes and it is assumed that there are no new routes to be introduced.

STEP 4: In line with TERI's study,[135] the average passenger occupancy is assumed to be 50 throughout the projection period.

Intermediate output

Based on the above estimates, the total passenger traffic of stage carriage buses is estimated as shown in Table 9.26 below.

Table 9.26: Estimated Passenger Traffic for Stage Carriages

Bus (Stage Carriage) Billion PKm Year	2011	2020	2030	2040	2050
Bus Stage Carriage per km	33.2	38.1	38.5	37.3	33.9

Stage Carriages: Technology Assumptions

For stage carriages diesel, CNG, hybrid diesel and full electric based technologies have been considered. Diesel driven Internal Combustion Engine (ICE Diesel) is assumed to have a share of 100 per cent in the base year (2011).

Even though presently, CNG is not available in Kerala, considering the state government's plans to use CNG for transport, a moderate growth in share of CNG penetration from 2 per cent by 2015 to 5 per cent by 2020, 15 per cent by 2025 and a constant share of 20 per cent after 2030 is assumed.

Diesel hybrid penetration is assumed to increase after 2020 to about 5 per cent by 2025, 10 per cent by 2030, and up to 15 per cent by 2050. The penetration of all electric vehicles is assumed to remain muted up to 2025 and increase up to 5 per cent by 2030 and remain constant till 2050.

The energy intensity values have been mainly derived from existing studies and actual data provided by manufacturers. The following table indicates the values assumed for different technologies. The values assumed for energy intensity for various technologies for stage carriages are shown in Table 9.27 below.

Table 9.27: Energy Intensities of Technologies for Stage Carriages

Stage Carriages	Energy Intensity (EI)	EI Units	Reference
Diesel	0.215	lit/km	TERI, 2006*
CNG	0.26	kg/km	TERI, 2006*
Hybrid	0.15	lit/km	TERI, 2006*
Electricity	1.2	kWh/km	www.byd.com

* TERI. 2006. *National Energy Map for India Technology Vision 2030.*

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm. For the BAU scenario, a reduction of 10 per cent in the energy intensity of diesel and CNG technologies and about 15 per cent for diesel hybrid and electric technologies is assumed over the projection period.

[135] Ibid.

Buses (Contract Carriage): Methodology

Contract Carriages: Estimation of Passenger Volumes

STEP 1: Based on available data from the Motor Vehicles Department, government of Kerala, contract carriages have grown from 40,520 to about 124,920 between 2000-01 and 2011-12, registering a CAGR of 10.7 per cent. Based on literature review, regression of log (registered number of contract carriages) on log (population) is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of number of omni buses to population.

Log (Registered number of omni buses) =	-409.831 +	24.34 *Log (Population)	
t-statistic	(-15.85)	(16.43)	
p-values	(0.000)	(0.000)	
			$R^2 = 0.93$

The independent variable and the intercept are found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.93 which indicates that 93 per cent of variation in registered number of contract carriages is explained by population. The regression equation is used to predict future registered number of contract carriages up to 2050. The forecasted number of registered contract carriages is 147,807 in 2050 as compared to 119,150 in 2011.

STEP 2: The figures for fleet availability (ratio of on-road to registered vehicles) estimated in the All India Transport Study[136] was about 57.95 per cent of registered passenger bus population in 2009-10. The same ratio of on-road to registered vehicles for contract carriages is assumed. Based on the above logic, the number of on-road passenger buses (stage carriage) is shown in Table 9.28.

Intermediate Output

Table 9.28: Estimated Number of On-road Contract Carriages

Bus Numbers ('000)	2011	2020	2030	2040	2050
Contract Carriage	69	102.8	104.2	99.2	85.6

STEP 3: The average annual utilization for stage carriages assumed in various studies on transport indicated a value between 40,000 km[137], and 46,365 km[138]. The values indicated in TERI's study, which assumed a base average annual running of 40,000 km in 1995 increasing by 400 km every year. In line with TERI's estimate, a value of 46400 km annual average run was assumed in 2011. However, considering that contract carriages travel long distance, an annual increase in travel distance by 400 km is also assumed.

STEP 4: In line with TERI's study, the average passenger occupancy is assumed to 50 throughout the projection period.

[136] JPS Associates. 2011. *Study on Volume of Goods & Passenger Traffic on Indian Roads.*
[137] Bose, R. K. and Chary, V. S. 1993. "Road Transport in India Cities: Energy Environment Implications".
[138] TERI. 2006. *National Energy Map for India Technology Vision 2030.*

Intermediate Output

Based on the above estimates, the total passenger traffic of contract carriage buses is estimated as shown in Table 9.29 below.

Table 9.29: Estimated Passenger Traffic Volume for Contract Carriages

Bus (CC) Billion PKm	2011	2020	2030	2040	2050
Bus Contract Carriage	160.2	257.1	281.4	287.8	265.5

Contract Carriages: Technology Assumptions

For contract carriages diesel, CNG and hybrid technologies are considered. All electric versions are not considered because they are not presently amenable to long distance travel. Diesel driven Internal Combustion Engine (ICE Diesel) is assumed to have a share of 100 per cent in the base year (2011).

Even though presently, CNG is not available in Kerala, considering the state government's plans to use CNG for transport, a low level growth in CNG is assumed as compared to that of stage carriages to account for slow pace of development of associated CNG refilling infrastructure along long distance routes. CNG penetration is assumed to increase to 2 per cent by 2020 and up to 5 per cent by 2025, and to remaining constant thereafter. However, diesel hybrid penetration is assumed to increase after 2020 to about 15 per cent by 2025, and reach 20 per cent by 2030 and stay constant thereafter. Table 9.30 shows the assumed technology share for contract carriages.

Table 9.30: Energy Intensities of Technologies for Contract Carriages

Contract Carriages	Energy Intensity (EI)	EI Units	EI Reference
Diesel	0.215	lit/km	TERI, 2006*
CNG	0.26	kg/km	TERI, 2006*
Hybrid	0.15	lit/km	TERI, 2006*

* TERI. 2006. *National Energy Map for India Technology Vision 2030.*

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm.

For BAU scenario, a 10 per cent reduction in the energy intensity of diesel and CNG technologies and 15 per cent in the energy intensity of diesel hybrid is assumed over the entire projection period.

Cars: Estimation of Passenger Volumes

STEP 1: Based on available data from the Motor Vehicles Department, government of Kerala, cars have grown from 282,996 to about 1,226,691 between 2000-01 and 2011-12, registering a CAGR of 14.2 per cent. However as cars are considered to be a superior personal transport option and also have other advantages as compared to motorcycles, it is assumed that car sales are dependant more on the per capita income than on any other market or demographic factors. Based on common perception, regression of per head car sales on per capita GSDP is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of per head car sales to per capita GSDP.

Per head car sales = 0.000064 * Per Capita GSDP
t-statistic (11.64)
p-value (0.000)

The independent variable is found to be statistically significant as indicated by the t-value and p-value given within brackets. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The regression equation is used to predict future per head car sales up to 2050. The forecasted per head car sales is 0.05,796 in 2050 as compared to 0.00,477 in 2011. The results indicate car sales of 1,943,795 units in 2050 as against 159,198 units in 2011.

STEP 2: Based on literature review,[139] the average age of a car is assumed to be 8 years. The total in-use vehicles are arrived at by summing up the sales of past 8 years. The results of the derivation for on-road car population are shown in Table 9.31 below.

Table 9.31: Estimated On-road Car Population

Cars Numbers (million)	2011	2020	2030	2040	2050
Cars on-road	0.595	1.41	2.803	5.671	11.473

Intermediate Output

Incidentally, this car population would mean that in 2050, every third person will probably have a car. In terms of households, assuming an average household size of 2.9 in 2050, the car ownership level in 2050 will be 0.96 cars/household; much less than the assumed maximum saturation level of car ownerships in OECD countries at 1.3 cars/household.

STEP 3: Different studies estimate different levels of average mileage for cars. IEA study[140] assumes a total annual mileage of 8,000km constant up to 2035. Other study by LBNL[141] and Kapoor[142] assume average mileage of cars to be 12,600km and 7,000km, with an increase of 0 km and 100km annually, respectively. In addition, interactions with state based experts indicate that car owners usually also own two wheelers and usually use cars mainly for family travel or long-distance trip; preferring to commute to office by two wheelers. Considering the same, the lower of the three values (7,000km) is assumed in addition to an annual increase of 100km in the run kilometres.

STEP 4: The average estimated occupancy figures vary widely between different studies. IEA assumes 1.89 occupancy declining to 1.64 persons in 2035. Kapoor assumes 1.5 as the occupancy rate, while LBNL assumes 3.5 as the occupancy rate. In line with Kapoor's estimation, occupancy of 1.5 persons per car is assumed throughout the projection period.

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[139] TERI. 2006. *National Energy Map for India Technology Vision 2030.*
[140] IEA. 2004. *SMP (Sustainable Mobility Project).*
[141] Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us? A Bottom-Up Assessment of Energy Demand in India Transportation Sector,* Ernest Orlando Lawrence Berkeley National Laboratory, USA. http://der.lbl.gov/sites/der.lbl.gov/files/NZhou_ECEEEIndiaTransport.pdf.
[142] Kapoor, Manish. 2002. *Vision 2020: Transport.* Report Prepared for the Planning Commission. New Delhi, India. http://planningcommission.gov.in/reports/genrep/bkpap2020/11_bg2020.pdf.

Intermediate Output

Based on the above assumptions, the total passenger traffic of cars is estimated as shown in Table 9.32 below.

Table 9.32: Estimated Car Passenger Traffic

Cars Year	2011	2020	2030	2040	2050
Cars (Billion P Km)	6.3	16.8	37.4	84.2	187.6

Cars: Technology Assumptions

For private cars gasoline, diesel, CNG, hybrid gasoline, and electric vehicle technologies are considered.

For the BAU scenario, 35 per cent penetration of diesel cars and 65 per cent of petrol cars share is assumed for the base year (2011) based on CRISIL's research.[143] Even though, CRISIL's research assumed that the share of diesel will grow to 45 per cent by 2015-16, the base year relative share of petrol diesel is kept constant throughout the projection period based on recent media reports that indicate a possible slump in diesel car market.[144]

CNG share is assumed to increase to 5 per cent by 2020, 10 per cent by 2030 and remain constant thereafter. The reason for low penetration of CNG is assumed to factor in personal choices of buyers related to fuelling convenience and availability. Considering a 20 per cent energy intensity reduction potential of hybrid technologies based on TERI's study,[145] a steady increase in hybrid technology (both diesel and petrol) from 0 per cent in 2020 to 10 per cent by 2040 and 15 per cent by 2050 is assumed. The penetration of EV is assumed to increase after 2020 to about 5 per cent by 2030 and 10 per cent by 2040 and to remain constant thereafter.

It is assumed that the proposed technology shift will be brought about by market forces without any specific policy intervention. The energy intensity for various technologies for cars is shown in the table below. The energy intensity for full electric version is based on actual performance data of Tesla Motor's Model S 85

Table 9.33: Energy Intensities of Technologies for Cars

Cars	Energy Intensity (EI)	EI Units	EI Reference
Gasoline	0.081	Lit/Km	TERI, 2006*
Diesel	0.074	Lit/Km	TERI, 2006*
CNG	0.074	Kg/Km	TERI, 2006*
Hybrid Gasoline	0.068	Lit/Km	TERI, 2006*
Hybrid Diesel	0.062	Lit/Km	TERI, 2006*
EV	0.15	kWh/Km	TESLA Motors‡

* TERI. 2006. *National Energy Map for India Technology Vision 2030.*
‡ Model S Efficiency and Range. http://www.teslamotors.com/blog/model-s-efficiency-and-range.

143 CRISIL. 2012. *Sector Focus: Automobiles. CRISIL CRB Customer Research Bulletin.* September.
144 Poovanna, Sharan and Saha, Samiran. 2013. "Car Makers Run Into Diesel Dilemma". *The Indian Express* (19 May). http://www.newindianexpress.com/business/news/Car-makers-run-into-diesel-dilemma/2013/05/19/article1596282.ece.
145 TERI. 2006. *National Energy Map for India Technology Vision 2030.*

kWh at 50 miles/hr.[146] Table 9.33 shows the assumed technology share for cars.

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm.

For the BAU scenario, a 10 per cent reduction in energy intensity of dominant ICE technologies and 15 per cent for diesel hybrid and EVs is assumed over the projection period.

Taxi Cars: Methodology

Taxi Cars: Estimation of Passenger volumes

STEP 1: Based on available data from the Motor Vehicles Department, government of Kerala, it appears that taxi cars have grown from 75,628 registered taxis in 2000-01 to 175,638 taxis in 2011-12, a CAGR of 7.9 per cent. However, as taxi cars are mostly used for commercial purposes, that too mainly in urban areas it is assumed that their numbers are dependant more on urbanization level of the state than on individual income or demographics.

Based on common perception, regression of log (taxi car sales) on log (urban population) is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of taxi car sales to urban population.

Log (taxi car sales) = 0.553605*Log (urban population)
t-statistic (85.27)
p-value (0.000)

The independent variable is found to be statistically significant as indicated by the t-value and p-value given within brackets. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The regression equation is used to predict future taxi car sales up to 2050. The forecasted taxi car sales are 13,745 in 2050 as compared to 11,874 in 2011.

STEP 2: Based on TERI's study,[147] average taxi car life of 8 years is assumed. Thus, the total in use vehicles are arrived at by summing up the sales of past 8 years.

Intermediate Output

The results of the derivation for on-road taxi car population are shown in Table 9.34 below.

Table 9.34: Estimated Taxi Car Population

Year	2011	2020	2030	2040	2050
Taxi cars on-road ('000)	69.2	86.02	92.4	100.0	107.0

Even though the 2050 figure may seem small for a service-based economy like Kerala, the estimated 2050 on road taxi population would mean about 3.4 taxis per

[146] Model S Efficiency and Range. http://www.teslamotors.com/blog/model-s-efficiency-and-range.
[147] TERI. 2006. *National Energy Map for India Technology Vision 2030.*

thousand persons, which is in many cases more than the average taxi penetration in metropolitan areas of developed countries.

STEP 3: In line with the LBNL study,[148] an annual average run of 35,000 km in 2011 is taken with an increase of 300 km every year.

STEP 4: Estimation of average occupancy assumed by various studies varies from 3 persons[149] to 3.18[150]. The higher value of 3.18 is assumed as average occupancy. It is assumed to be constant over the projection period.

Based on the above assumptions the total passenger volume catered by taxis is shown in Table 9.35 below.

Table 9.35: Estimated Passenger Traffic for Taxi Cars

Year	2011	2020	2030	2040	2050
Taxi Car (billion PKm)	7.7	10.3	12	13.9	15.9

Taxi Cars: Technology Assumptions

Gasoline, diesel, hybrid diesel and hybrid gasoline technologies are considered for taxi cars. Even though there may be cost savings in CNG based taxis, the same has not been factored because there may be problems in large scale off-take of CNG for taxis unless CNG infrastructure is developed across the state. EVs are also not considered in the BAU scenario because of limitations in distance and infrastructure.

For the BAU scenario, 90 per cent penetration of diesel cars and 10 per cent of petrol cars is assumed in the base year (2011). This is done because the predominant buying criterion in diesel vehicle purchase is the level of mileage (annual kilometres run), which is considerably high for taxis.

Considering a 20 per cent energy intensity reduction potential of hybrid technologies,[151] a steady increase in hybrid technology penetration (both diesel and petrol) from 0 per cent in 2020 to 10 per cent in 2040 and 15 per cent in 2050 is assumed. The ratio between petrol and diesel based ICE technologies is assumed to remain constant at 9:1 throughout the projection period.

The energy intensity for various technologies for taxi cars is assumed to be equal to that of large cars and is shown in Table 9.36 below.

Table 9.36: Energy Intensities of Technologies for Taxi Cars

Taxi Cars	Energy Intensity (EI)	EI Units	EI Reference
Gasoline	0.081	lit/km	TERI, 2006*
Diesel	0.074	lit/km	TERI, 2006*
Hybrid Gasoline	0.068	lit/km	TERI, 2006*
Hybrid Diesel	0.062	lit/km	TERI, 2006*

* TERI. 2006. *National Energy Map for India Technology Vision 2030.*

148 Zhou, Nan. 2007. What Do India's Transport Energy Data Tell Us?
149 TERI. 2006. National Energy Map for India Technology Vision 2030.
150 Zhou, Nan. 2007. What Do India's Transport Energy Data Tell Us?
151 TERI. 2006. National Energy Map for India Technology Vision 2030.

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm.

For the BAU scenario, a 10 per cent reduction in energy intensity in dominant technologies (ICE gasoline, ICE diesel and CNG) and 15 per cent in hybrids is assumed.

Jeeps: Methodology

Jeeps: Estimation of Passenger Volumes

STEP 1: Historical data indicate that registered jeep population has changed from about 69,621 in 2000-01 to about 73,700 in 2011-12 (a CAGR of 0.05 per cent), with zero new additions from 2009-10 to 2001-12. Based on stakeholder consultations, it became apparent that jeeps are mostly used in plantation and forest areas, and are used in only a limited way for general transportation. The zero growth in jeep population could be on account of the consistent fall in GSDP agriculture from 2009-10 to 2011-12 (Rs 20,333 cr to Rs 19,203 cr).

The regression of registered number of jeeps on GSDP from agriculture (GSDP(A)) is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of registered number of jeeps to (GSDP(A)).

Registered number of jeeps	= 3.632756*GSDP from agriculture
t-statistic	(86.30)
p-value	(0.000)

The independent variable is found to be statistically significant as indicated by the t-value and p-value given within brackets. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The regression equation is used to predict future registered number of jeeps up to 2050. The forecasted number of jeeps is 77,767 in 2050 as compared to 73,700 in 2011.

STEP 2: To arrive at the on-road population of jeeps, an average life of 10 years is assumed on account of the fact that jeeps usually meet small and medium travel needs of plantations. Even though the value of historical sales figures were fluctuating and one value was even negative, the on-road figures were arrived at after assigning a value of zero to the negative sales value. Table 9.37 below indicates this trend of the on-road jeep population

Table 9.37: Estimated On-road Jeep Population

Year	2011	2020	2030	2040	2050
Jeeps on-road	5,741	1,614	1,866	1,920	1,976

Intermediate Output

STEP 3: The average annual mileage of a jeep is assumed to be between that of private cars and taxi cars. This assumption is taken based on the fact that while jeeps usually perform commercial functions (plantation related hauls) and also ferry passengers (city to plantation or city to forest areas). This would mean that the average mileage would be more than that of a private car but would be less than that of commercial taxi, which also performs regular intercity and inter-state trips.

Consequently, an annual average running of 25,000 km is assumed for jeeps throughout the projection period.

STEP 4: The average occupancy rate of a jeep is also assumed to be between that of a car (1.5 persons) and a taxi (3.18 persons) at 2.34 persons. This occupancy rate is also assumed to be constant throughout the projection period.

Intermediate Output:

Based on the above assumptions, the total passenger traffic of jeeps is shown in the Table 9.38 below.

Table 9.38: Estimated Passenger Traffic for Jeeps

Year	2011	2015	2020	2025	2030	2035	2040	2045	2050
Jeeps (Million PKm)		234.4	96.8	104.4	112.0	113.6	115.2	116.9	118.6

Jeeps: Technology Assumptions

For jeeps, diesel and hybrid diesel technologies are considered. CNG and EVs are not considered because jeeps usually operate in remote areas and fuel availability and fuelling range may be important considerations. For the BAU scenario, 100 per cent penetration of diesel ICE is assumed in the base year. Diesel hybrid share is assumed to increase after 2025 to 5 per cent by 2030 and 10 per cent by 2040, and is assumed to remaining constant thereafter.

The energy intensity of jeeps is assumed to be equal to that of large diesel car. Table 9.39 shows the assumed technology share for jeeps.

Table 9.39: Energy Intensities of Technologies for Jeeps

Jeeps	Energy Intensity (EI)	EI Units	EI Reference
Diesel	0.092	lit/km	TERI, 2006*
Hybrid Diesel	0.062	lit/km	TERI, 2006*

* TERI. 2006. *National Energy Map for India Technology Vision 2030.*

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm.

For the BAU scenario, a 10 per cent and 15 per cent reduction in energy intensity is assumed for diesel and hybrid diesel technologies, respectively.

Autorickshaws: Methodology

Autorickshaws: Estimation of Passenger Volumes

STEP 1: Historical data indicates that registered rickshaw population has changed from about 248,350 in 2000-01 to about 575,763 in 2011-12, a CAGR of 7.9 per cent. As rickshaws serve general population, it is assumed that the future population of rickshaws will be largely dependent on population. Regression is done with respect to the registered vehicle population and population. Regression of log (registered number of autorickshaws) on log (population) is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of registered number of autorickshaws to population.

Log (Registered number of autorickshaws) = -258.895 + 15.70288*Log (Population)

t-statistic (-18.33) (19.24)

p-values (0.000) (0.000)

$R^2 = 0.97$

The independent variable is found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.97 which indicates that 97 per cent of variation in registered number of autorickshaws is explained by population. The regression equation is used to predict future registered number of autorickshaws up to 2050. The forecasted registered number of autorickshaws is 543,999 in 2050 as compared to 518,741 in 2011.

However, as the number of rickshaws are deemed to be dependent on population, future results indicate a decrease in registered vehicles after the inflexion point when population takes a downward trend. This decrease in registered vehicles is assumed as the decrease in the number of on-road rickshaws that are retired but not replaced.

STEP 2: Based on stakeholder interaction and available literature for the state, it appears that availability of rickshaws is spread across both rural and urban areas, though the availability in urban areas is more as compared to rural areas. However, it is assumed that rickshaw population is a function of population and would tend to vary based on the population that will use autorickshaw as a mode of travel. Based on the estimates of population projection of the state (refer Appendix 1), it is seen that the absolute growth in population is very low and negative population growth occurs as early as 2020-21. Intuitively this means that the current on-road rickshaw numbers would largely remain the same except for some minor variations on account of population.

Assuming a life of q0 years, historical sales of past 10 years are summed to arrive at on-road figures for 2010-11 and 2011-12. Comparing these numbers with the registered vehicles, on-road vehicles seem to comprise about 52 per cent and 53 per cent of the registered vehicles for 2010-11 and 2011-12, respectively. Based on this ratio, on-road rickshaw population is assumed to be 53 per cent of registered rickshaw population. Based on the above logic, the number of rickshaws in the state is shown in Table 9.40 below.

Table 9.40: Estimated On-road Rickshaw Population

Year	2011	2020	2030	2040	2050
Rickshaws ('000)	274.9	324.4	327.2	317.0	288.3

STEP 3: An average annual run of 33,500km is assumed based on the LBNL study.[152] No increase in the annual run is assumed.

STEP 4: The average passenger carried for stage carriages is taken from TERI's study[153] to be 2.

[152] Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*

[153] TERI. 2006. *National Energy Map for India Technology Vision 2030.*

Intermediate Output

Based on the above estimates, the total passenger traffic of rickshaws is estimated as shown in Table 9.41 below.

Table 9.41: Estimated Passenger Traffic for Auto Rickshaws

Year	2011	2020	2030	2040	2050
Rickshaw (Billion PKm)	18.4	22.1	21.9	21.2	19.3

Autorickshaws: Technology Assumptions

For rickshaws gasoline, CNG, hybrid gasoline, hybrid CNG and all electric technologies are considered. No distinction is made between a two stroke and a four stroke engine; it being assumed that future environmental regulations will ensure that four stroke population outnumbers two stroke population.

For the BAU scenario, 100 per cent penetration of gasoline rickshaws is assumed in base year (2011). Considering the significant cost savings of CNG based rickshaws, a quick uptake of CNG rickshaws is assumed to take place after the proposed distribution network is set in place. It is assumed that the CNG share will go up to 10 per cent by 2020, 20 per cent by 2030 and remain constant thereafter. Share of hybrid gasoline and hybrid CNG are assumed to grow after 2025 reaching a penetration of 10 per cent each, by 2050. All electric rickshaws are assumed to achieve a penetration of 5 per cent by 2050 starting from 0 per cent in 2030.

The energy intensity (four stroke engines for ICE technology) for various technologies for rickshaws is shown in Table 9.42 below.

Table 9.42: Energy Intensities of Rickshaw Technologies

Rickshaws	Energy Intensity (EI)	EI Units	EI Reference
Gasoline	0.024	lit/km	TERI, 2006*
CNG	1	MJ/km	TERI, 2006*
Hybrid Gasoline	0.0083	lit/km	TERI, 2006*
Hybrid CNG	0.0083	lit/km	TERI, 2006*
All Electric (EV)	0.36	MJ/km	TERI, 2006*

* TERI. 2006. *National Energy Map for India Technology Vision 2030.*

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm.

For the BAU scenario, a 10 per cent reduction in energy intensity in diesel and CNG technologies and 15 per cent in electric version is assumed over the entire projection period.

Two-wheelers: Methodology

Two-wheelers: Estimation of Passenger Volumes

STEP 1: Two-wheelers are preferred mode of travel for majority of Kerala's population. Based on historical data, registered numbers of two-wheelers have grown from 1,151,735 to 4,127,227 between 2000-01 and 2011-12, a CAGR of 12.3

per cent. Regression of two-wheeler sales on log (per capita income) is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of two-wheeler sales to per capita income (PCY).

Two wheeler sales =	-1137601.045 +	376030.28*Log(PCY)
t-statistic	(-4.77)	(5.92)
p-values	(0.001)	(0.000)
		$R^2 = 0.80$

The independent variable is found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.80 which indicates that 80 per cent of variation in two-wheeler sales is explained by per capita income. The regression equation is used to predict future two-wheeler sales up to 2050. The forecasted two wheeler sales are 1,425,040 in 2050 as compared to 394,715 in 2011.

STEP 2: Assuming an average two-wheeler life of 8 years,[154] the on-road two wheeler population was deemed to be summation of sales of past 8 years. Based on the above logic, the total number of two wheeler population is as shown in Table 9.43 below.

Table 9.43: Estimated On-road Two-wheeler Population

Year	2011	2020	2030	2040	2050
Two Wheelers (million)	1.92	4.18	6.18	8.30	10.43

The 2050 level of penetration would mean 311 on-road two-wheelers for every thousand persons, this will be on par with the current highest level of two-wheeler penetration for Malaysia of 325 on-road two wheelers per thousand population.[155]

STEP 3: Different studies estimate different annual mileage for motorcycles. LBNL[156] indicates average annual mileage of 6,300 km, while IEA 2004[157] estimates 10,000 km as the annual mileage. In line with LBNL study, an annual average run of 6,300 km is assumed without any increase.

STEP 4: The estimated average occupancy of a two-wheeler also varies across studies (1.7 for IEA, 1.2 by Kapoor[158]). An average occupancy rate of 1.5 is assumed throughout the projection period.

Intermediate Output:

Based on the above estimates, the PKm for two-wheelers is shown in Table 9.44 below.

Table 9.44: Estimated Two-wheeler Passenger Traffic

Year	2011	2020	2030	2040	2050
Two Wheelers (Billion PKm)	18.2	39.5	58.4	78.5	98.6

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154 TERI. 2006. *National Energy Map for India Technology Vision 2030.*
155 Ministry of Road Transport & Highways. 2012. *Road Transport Year Book (2009–10 & 2010–11).* Ministry of Road Transport & Highways, Government of India. New Delhi. India. Table 1.13.
156 Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*
157 IEA. 2004. *SMP (Sustainable Mobility Project).*
158 Kapoor, Manish. 2002. *Vision 2020.*

Two-wheelers: Technology Assumptions

The technologies considered in two-wheelers are ICE petrol, and EV. However, even within the ICE petrol category, there are two technologies: two-stroke ICE and four-stroke ICE. Presently, two-stroke ICE dominate the market, but are no longer being manufactured and four-stroke engines are penetrating in a big way. The major advantages of four-stroke ICE are comparatively high-fuel efficiency and lower emissions. Considering the large difference between fuel economics of two-stroke and four-stroke engines, ICE gasoline is divided into ICE two-stroke and ICE four-stroke.

For the BAU scenario, ICE two-stroke share is taken as 80 per cent in the base year and ICE four-stroke is assumed to have a share of 20 per cent. The relative share of ICE four-stroke is however assumed to grow to 50 per cent by 2020 and 100 per cent by 2030. EV penetration is assumed to increase to 5 per cent of the total volume in 2020, increasing steadily to reach 20 per cent in 2050.

For assigning energy intensity value, motorcycles are taken as representative for the two-wheeler category. Table 9.45 below shows the assumed energy intensity values for two-wheeler technologies.

Table 9.45: Energy Intensities of Two-wheeler Technologies

Two Wheelers	Energy Intensity (EI)	EI Units	EI Reference
Petrol Two Stroke	0.019	lit/km	TERI, 2006*
Petrol Four Stroke	0.012	lit/km	TERI, 2006*
EV	0.06	MJ/km	IEA ESTAP, 2013†

* TERI. 2006. *National Energy Map for India Technology Vision 2030*.
† ESTAP. 2013. *Two- and Three-wheeled Vehicles and Quandricycles*. Technology Brief. Energy Technology Systems Analysis Programme, International Energy Agency (19 January).

The vehicle energy intensity is divided by the average occupancy of this vehicle category to arrive at the value of energy intensity in terms of PKm.

For ICE technologies, a 10 per cent reduction in energy intensity and for EV a 15 per cent reduction in energy intensity is assumed over the entire projection period.

Rail Passenger Volumes

Rail: Estimation of Passenger Volumes: Methodology

There are three railways divisions in Kerala: Palakkad, Thiruvananthapuram and Madurai. Kerala has a total of 1,257 km railway route as compared to the all India figure of about 64,600 km. This translates into a share of 1.95 per cent for Kerala in railway route. As the passenger volume data is available on all India basis, this share of route length is taken as the basis of arriving at the passenger volumes in Kerala.

Historical annual time series data from 2000-01 to 2011-12 on railways PKm and regressors have been used for regression. Year-wise PKm for India is available from the Working Group reports on Railways for 11th and 12th five year plans. This has been translated into Kerala's passenger volume assuming the share would be equal to its share in the route length.

Regression of billion PKm on population is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of PKm to population.

Billion PKm = -244.634 + 0.0000079 *Population
t-statistic (-12.52) (13.255)
p-value (0.000) (0.000)
$R^2 = 0.95$

The independent variable is found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.95 which indicates that 95 per cent of variation in rail passenger volume is explained by population. The regression equation is used to predict future billion PKm up to 2050.

Intermediate Output

The forecasted billion passenger volume is 20.36 billion PKm in 2050 as compared to 19.59 billion PKm in 2011.

Table 9.46: Estimated Rail Passenger Traffic

Year	2011	2020	2030	2040	2050
Rail Passenger(Billion PKm)	19.59	22.36	22.51	21.97	20.36

Rail: Technology Assumptions

Two technologies are considered for rail: electric traction and diesel. At present, the rail electrification in Kerala is at 51.43 per cent. It is assumed that track electrification will progress at a CAGR of 5.81 per cent. The CAGR for electrification has been derived by assuming that railway meets its electrification target set in its Vision 2020 document.

The share of passenger kilometre between different modes (electrified and diesel) is assumed to be the same as the ratio of electrified tracks to non-electrified tracks.

The LBNL study on transport[159] has been referred to assess the energy intensity potential of the two technologies.

Table 9.47: Energy Intensities of Rail Modes

Rail Passenger	Energy Intensity (EI)	EI Units	EI Reference
Electric Traction	0.12	MJ/P Km	LBNL, 2009*
Diesel	0.24	MJ/P Km	LBNL, 2009*

* Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*

No decrease in energy intensity is assumed for rail over the projection period for the BAU scenario.

Water Passenger Traffic: Methodology

Kerala has 590 km long coastline and 1,895 km long inland waterways. Waterways occupy an important place in the transportation sector of Kerala carrying both passenger and freight in coastal and inland transportation mode.

159 Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*

Water: Estimation of Passenger Volumes

For the purpose of this study, both coastal and inland water transportation have been considered for passenger transportation. The data for the analysis has been gleaned from a variety of online sources and studies.

Data on passenger traffic is available in terms of passenger numbers. For converting this data into passenger traffic in terms of PKm, Deloitte India study was referred.[160] The study identifies potential for shifting freight and passenger traffic from road to coastal route. The findings of the study indicate that there may be an economic case for moderate modal shift for freight from road to coastal transport but there is very little scope for modal shift in passenger transport because of economic and other considerations.

Coastal Passenger Volumes

In line with the report findings, no growth in coastal passenger transport and the passenger volume levels is assumed after 2011 (38.73 million PKm) (State Water Transport Department).

Inland Passenger Volumes

Data on number of inland passengers carried from 2008 to 2012 by State Water Transport Department (SWTD) is accessed from *Economic Review 2012,* Kerala.[161] The passenger numbers are multiplied with average distance of inland transport to arrive at the PKm volume. The average distance for inland transport is taken as the average distance between stations served by the SWTD. This figure is found to be 17.04 km.

Past growth rate for the available data in passenger volumes (2.41 per cent) is used to project future inland passenger volumes. The projected figures indicate an increase in passenger volume from 276.83 million PKm in 2012 to 684.12 million PKm in 2050. Table 9.48 shows the estimated values.

Intermediate Output

Table 9.48: Estimated Water Passenger Traffic

Year	2011	2020	2030	2040	2050
Coastal Passenger (Million PKm)	38.73	38.73	38.73	38.73	38.73
In land Passenger (Million PKm)	333.6	362.6	469.8	576.9	684.1

Water: Technology Assumptions

For water based passenger transport, diesel fired engines are considered the assessment. The energy intensity is assumed to be 0.38 MJ/PKm and 0.49

[160] Deloitte. 2011. *Preparation of Strategy Road Map cum Action Plan for Development of Coastal Shipping in Kerala.* Submitted to the Directorate of Ports, Government of Kerala. Deloitte Touche Tohmatsu India Private Limited. http://www.keralaports.gov.in/images/Final%20Report%20-%20Kerala%20Coastal%20Shipping%20-%20v%204.0%2020%20Jun%202011.pdf.

[161] State Planning Board. 2013. *Economic Review 2013.* Thiruvananthapuram, Kerala.

MJ/PKm for inland and coastal passenger movement, respectively.[162] No reduction in energy intensity is assumed for the projection period.

Air Passenger Traffic: Methodology

Air: Estimation of Passenger Volumes

Only domestic air travel is considered because of data constraints. Projections of India's air passenger traffic (in million passengers) at the end of 12th, 13th, 14th and 15th plan periods are obtained from the Working Group Report on Civil Aviation.[163] The projections assume a CAGR of 11.7 per cent for air passenger traffic up to 2022, 10.4 per cent up to 2027 and 9 per cent up to 2032. The consistent drop of 1.3 per cent in CAGR is assumed to continue and air traffic projections for India have been estimated based on reduction in CAGR.

To arrive at the value of air passengers in Kerala, data related to the share of passengers handled by Kerala's three airports in all India passengers handled data for 2010 is referred. Based on the data available in the *Infrastructure Statistics 2010,*[164] the share of Kerala's passengers in all India passengers is found to be 2.58 per cent. This ratio is assumed to be constant and is used to arrive at the passenger volume (million passengers) for Kerala. To estimate the passenger traffic volume in PKm, an average flight distance between Kochi and Ahmedabad was assumed and was multiplied with passenger volume to arrive at the air PKm.

In addition, in line with other studies, only originating traffic, assumed as 50 per cent of the total traffic, was considered for analysis.

Intermediate Output

Based on the above assumptions the estimated air passenger traffic volume is shown in Table 9.49 below.

Table 9.49: Estimated Air Passenger Volume

Year	2011	2020	2030	2040	2050
Air Passenger Volume (Billion PKm)	1.045	2.78	7.37	15.12	23.83

Air: Technology Assumptions

For air passenger transport, only Jet Kerosene based turbine is assumed. The share of Jet Kerosene is assumed to be 100 per cent throughout the projection period. The energy intensity is assumed to be 2.5 MJ/PKm.[165] No reduction in energy intensity is assumed for the projection period.

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162 Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*
163 National Transport Development Policy Committee. 2012. *Report of Working Group on Civil Aviation Sector.* Ministry of Civil Aviation, Government of India. http://civilaviation.gov.in/cs/groups/public/documents/document/moca_001680.pdf.
164 Central Statistics Office. 2010. *Infrastructure Statistics 2010.* Ministry of Statistics and Programme Implementation, Government of India. New Delhi, India. http://mospi.nic.in/mospi_new/upload/infra_stat_2010.htm.
165 Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*

9.7.2 Freight Transport: methodology

Freight Transport in Kerala is expected to increase at high rate mainly because of the eminent transition of Kerala from a subsistence economy to a consumerist economy. The following sub-sections try to capture the demand across different transport modes

Road Freight Traffic

The basic methodology for projecting freight volumes for roads is shown below

- **Step 1:** Projection of registered vehicle population based on regression (X_{ij})
  Where X_{ij} is the number of registered vehicles of type i in year j

- **Step 2:** Estimating the number of in-use vehicles assuming standard retirement age or percentage fleet utilization (Y_{ij})
  Where Y_{ij} is the number of in-use vehicles of type i in year j

- **Step 3:** Assigning average annual kilometres run based on standard literature (Km_{ij})
  Where Km_{ij} is the average kilometres run for category of vehicle i for year j

- **Step 4:** Assigning average tonnage based on standard literature (T_{ij})
  Where T_{ij} is the average tonnage for category of vehicle i for year j

Based on the above, the total road freight traffic is calculated as

Total freight traffic in tonnes kilometre (TKm) = Y_{ij} X Km_{ij} X T_{ij}

HCVs and LCVs

HCVs and LCVs: Estimation of Freight Volumes

STEP 1: Based on available data from the Motor Vehicles department, government of Kerala, the categorization of goods vehicles is done in terms of two categories: 'Three Wheelers including Tempos' and 'Four wheelers and above'. For the purpose of the analysis, the category of three wheelers and tempos is considered as LCV and the category four wheelers and above is assumed as HCV.

The future population of registered goods vehicle is estimated using the available data. Regression is done with respect to the registered vehicle population and GSDP from Industry and Agriculture (GSDP IA).

Regression of registered number of HCVs on GSDP from industry and agriculture is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of registered number of HCVs to GSDP from industry and agriculture.

Registered number of HCVs = -177201 + 7.642173*GSDP from industry and agriculture

t-statistic	(-5.63)	(12.46)
p-values	(0.000)	(0.000)

$R^2 = 0.93$

The independent variable and the intercept are found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.93 which indicates that 93 per cent of variation in registered number of HCVs is explained by GSDP from industry and agriculture. The regression equation is used to predict future registered number of HCVs up to 2050. The forecasted number of registered HCVS is found to be 1,923,276 in 2050 as compared to 294,395 in 2011.

Based on literature review, regression of registered number of LCVs on GSDP from industry and agriculture is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of registered number of LCVs to GSDP from industry and agriculture.

Registered number of LCVs = -139597 + 4.264208*GSDP from industry and agriculture

t-statistic	(-14.01)	(21.98)
p-values	(0.000)	(0.000)

$R^2 = 0.98$

The independent variable and the intercept are found to be statistically significant as indicated by the t-values and p-values given within brackets. R^2 is 0.98 which indicates that 98 per cent of variations in registered number of LCVs are explained by GSDP from industry and agriculture. The regression equation is used to predict future registered number of LCVs up to 2050. The forecasted number of registered LCVs is found to be 1,032,435 in 2050 as compared to 117,266 in 2011.

STEP 2: Assuming 10 years as the retirement age for HCVs, the total in-use vehicles are arrived at by summing up the sales of past 10 years. The sales figure are arrived at by taking the difference between registered vehicles in year 'Y' with registered vehicles in year 'Y-1'. For past data where sales figures are not available, average value of available figures is taken and substituted for the missing years. For LCVs, a useful life of 10 years is assumed and a similar process is executed to arrive at the number of in-use LCVs. Table 9.50 shows the estimated on-road population of HCVs and LCVs.

Table 9.50: Estimated On-road HCVs and LCVs Population

Year	2011	2020	2030	2040	2050
HCVs ('000)	134	225.5	299	441.7	652.4
Three Ws and LCVs ('000)	70.6	94.7	138.4	204.5	302.1

STEP 3: Based on TERI's study,[166] the average annual utilization of HCVs is assumed to increase by 400km every year starting from 46,400 km in base year. For LCVs, the average annual kilometre run data is taken as 27,000 km with no increase in route kilometre. This is done because, LCVs mostly ferry consumer goods and agricultural products on fixed routes (usually from bulk markets to end retailers).

STEP 4: Based on assessment in TERI's study, an average tonnage of 7.1 tonnes and 1.7 tonnes is assumed for the HCV and LCV categories, respectively. In line with the study, an increase of 0.1 tonnes carrying capacity per year is assumed for HCVs up to 2050.

166 TERI. 2006. *National Energy Map for India Technology Vision 2030.*

Intermediate Output

Based on the above analysis the existing and estimated freight traffic is shown in Table 9.51 below.

Table 9.51: Estimated Freight Traffic for HCVs and LCVs

Year	2011	2020	2030	2040	2050
HCVs (Billion TKm)	44.1	90.2	145.3	256.2	445
Three Ws and LCVs (Billion TKm)	5.3	7.1	10.4	15.4	22.8
Total Freight (Billion TKm)	**49.4**	**97.3**	**155.7**	**271.6**	**467.8**

HCVs and LCVs: Technology Assumptions

The technologies considered in HCVs are ICE diesel and ICE diesel hybrid. Diesel hybrid for HCVs is still not commercialized. DHL is however running a Hybrid HCV of 18 tonne capacity (manufactured by Volvo), which is supposed to have 15 per cent higher fuel efficiency[167] as compared to a normal ICE diesel. EVs are not considered because HCVs usually have high mileage, which may need recurrent refueling of EV technologies that limited run range per charge.

For the BAU scenario, ICE diesel is expected to have a share of 100 per cent in the base year. Subsequently, the share of Hybrid diesel is expected to increase to 5 per cent by 2020 and increase by 5 per cent every decade to reach 20 per cent by 2050.

Based on the information, the assumed energy intensities of HCV technologies are as shown in Table 9.52 below

Table 9.52: Energy Intensities of Technologies for HCVs

HCVs	Energy Intensity (EI)	EI Units	EI Reference
Diesel	0.2	lit/km	LBNL, 2009*
Hybrid Diesel	0.174	lit/km	DHL, 2010†

* Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*
† Deutsche Post DHL. 2010. *Annual Report 2010.* Deutsche Post DHL. Bonn, Germany. http://www.dpdhl.com/content/dam/Investors/Publications/DPDHL_Annual_Report_2010.pdf.

The vehicle energy intensity is divided by the average tonnage capacity of the vehicle category to arrive at the value of energy intensity in terms of TKm.

A 10 per cent reduction in energy intensity of ICE diesel and 15 per cent for hybrid diesel is assumed over the projection period for HCVs.

The technologies considered for LCVs are ICE diesel, ICE hybrid diesel and EV. EVs are also considered for LCVs because of the comparatively low running of LCVs.

For the BAU scenario, 100 per cent penetration of ICE diesel is assumed in the base year. The hybrid diesel penetration is assumed to increase to 5 per cent by 2020 and by 5 per cent every decade thereafter to reach 20 per cent by 2050. EV penetration is assumed to increase from 0 per cent in 2020 to about 5 per cent by 2030 and 10 per cent by 2040, remaining constant thereafter.

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[167] Deutsche Post DHL. 2010. *Annual Report 2010.* Deutsche Post DHL. Bonn, Germany. http://www.dpdhl.com/content/dam/Investors/Publications/DPDHL_Annual_Report_2010.pdf.

The energy intensity of ICE diesel is assumed to be 0.117 lit/km. In line with the assumption for HCVs, the energy intensity of ICE hybrid diesel technology is assumed to be 15 per cent less than that of conventional ICE diesel technology. For EV, the energy intensity data is taken from a study by CARB.[168] Table 9.53 shows the value of energy intensity considered for different technologies.

Table 9.53: Energy Intensities of Technologies for LCVs

LCVs	Energy Intensity (EI)	EI Units	EI Reference
Diesel	0.117	lit/km	LBNL, 2009*
Hybrid Diesel	0.102	lit/km	DHL, 2010†
EV	1.762	MJ/km	LBNL, 2009*

* Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*
† Deutsche Post DHL. 2010. *Annual Report 2010.*

The vehicle energy intensity is divided by the average tonnage capacity of this vehicle category to arrive at the value of energy intensity in terms of TKm.

A 10 per cent reduction in energy intensity of ICE diesel and 15 per cent for hybrid diesel and EV technologies is assumed over the projection period.

Rail Freight Traffic: Methodology

Rail: Estimation of Freight Volumes

The data on rail freight is available in NtKm (net tonnes Kilometre). According to Planning Commission's *Total Transport System Study,*[169] the share of freight volume of Kerala is about 0.72 per cent of the national rail freight volume in 2011. In the absence of any major large scale industrial development in Kerala (existing or planned), it is assumed that the freight share of Kerala will be constant at 0.72 per cent throughout the projection period. Historical annual time series data from 2000-01 to 2011-12 on railways freight kilometre and regressors have been used for regression. Year wise freight kilometre for India is available from the Working Group reports on Railways for 11th and 12th five year plan periods.

Based on literature review and common perceptions, regression of billion freight tonnes kilometre on GSDP from industry and agriculture is found to be appropriate. Therefore, the following estimated regression equation is used to find out responsiveness of freight km to population.

Billion tone freight kilometre (net) = 0.000073*GSDP from industry and agriculture

t-statistic (13.65)
p-value (0.000)

[168] Aguirre, Kimberly et al. 2012. *Lifecycle Analysis Comparison of a Battery Electric Vehicle and a Conventional Gasoline Vehicle.* California Air Resources Board. http://www.environment.ucla.edu/media_IOE/files/BatteryElectricVehicleLCA2012-rh-ptd.pdf.

[169] Planning Commission. 2013. *Total Transport System Study on Traffic Flows & Modal Costs (Highways, Railways, Airways & Coastal Shipping).* A Study Report by RITES Ltd. http://planningcommission.nic.in/reports/genrep/index.php?repts=rites.html.

The independent variable is found to be statistically significant as indicated by the t-value and p-value given within brackets. The regression equation is used to predict future billion tonnes kilometre up to 2050. The forecasted billion freight tonnes kilometre is 20.04 in 2050 as compared to 4.38 billion freight tonnes kilometre in 2011.

However, the freight volumes are expressed in NtKm (only revenue earning tonnage), whereas energy intensity data is usually available in terms of gross tonnes kilometre (Net tonnage + weight of train and carriages). Based on data derived from CAG India 2002,[170] the ratio of net tonnes to gross tonnes has been found to be nearly constant at 48 per cent for diesel and 50 per cent for electric traction. For the present study, NtKm is multiplied with 2 to arrive at gross tonnes kilometre.

Intermediate Output

The estimated freight volume for rail in gross tonnes kilometre is shown in the Table 9.54 below.

Table 9.54: Estimated Rail Freight Traffic

Year	2011	2020	2030	2040	2050
Rail Freight (Billion TKm)	8.76	44.72	45.02	43.94	40.72

Rail: Technology Assumptions

The share of freight traffic in TKm between different modes (electrified and diesel) is assumed to be the same as the ratio of electrified tracks and non-electrified tracks. The rate of electrification has been estimated separately.

The values assumed for energy intensity for rail are shown in Table 9.55 below.

Table 9.55: Energy Intensities of Rail Mode

Rail Passenger	Energy Intensity (EI)	EI Units	EI Reference
Electric Traction	0.064	MJ/TKm	LBNL, 2009*
Diesel	0.117	MJ/TKm	LBNL, 2009*

* Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*

A 10 per cent reduction in energy intensity is assumed over the entire projection period.

Water Freight Traffic: methodology

Separate assessments have been done for coastal and inland freight traffic.

170 TRFCA. Average Load of Goods Train. http://www.irfca.org/docs/stats/stats-goods-train-load.html.

Water: Estimation of freight volumes

Coastal Freight Traffic

Data on volume of coastal cargo (tonnes) from 2001 to 2012 has been taken from the Basic Port Statistics.[171] The CAGR of freight volume growth in coastal freight from 2001 to 2012 was found to be 1.4 per cent. In view of past fluctuations in traffic volumes and the absence of clear data for projections, the historical CAGR was used to project future freight volumes up to 2050.

The forecasted data is available in tonnes of cargo and to convert it into tonnes kilometre, an average distance of 1,027.56 km is assumed as the median distance for coastal travel. This value is derived from Deloitte's study on Kerala's coastal transport,[172] which assessed that coastal transport could be economically better than road transport for select routes between ports in other states (mainly Gujarat, Maharashtra, Tamil Nadu, Karnataka) and other major and non-major ports in Kerala. It was assumed that the average distance of these identified routes was representative of the distance for coastal freight.

Intermediate Output

The results indicate that coastal cargo traffic is expected to increase from 4,971.3 million TKm in 2012 to 12,197.26 million TKm in 2050.

Inland Freight Traffic

Data on inland freight traffic from 2008-12 was derived from the annual report of Inland Waterways Authority of India. The CAGR of inland freight volumes across these years was found to be 10.6 per cent. In view of past fluctuations in traffic volumes and the absence of clear data for projections, the historical CAGR was used to project future freight volumes up to 2050.

To convert the forecasted tonnage into TKm, the median distance travelled was assumed to be to the average distance between all non-major ports connected to inland waterway and was assessed as 17.03 km.

Inland cargo transportation is expected to increase from 14.2 million TKm in 2012 to 609.50 million TKm in 2050 which is almost 46 times increase over the period 2012 to 2050.

Intermediate Output

Based on the above assumptions, the projected freight volumes for coastal and inland water transport are as shown in Table 9.56 below.

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[171] Transport Research Wing. 2012. *Basic Port Statistics of India 2010–11.* Ministry Of Shipping, Government of India. New Delhi, India.
http://shipping.nic.in/showfile.php?lid=925.

[172] Deloitte. 2011. *Preparation of Strategy Road Map cum Action Plan for Development of Coastal Shipping.*

Table 9.56: Estimated Water-based Freight Traffic

Water Freight Traffic	2011	2020	2030	2040	2050
Coastal TKm (Billion TKm)	4.9713	7.9371	9.1593	10.5697	12.1973
Inland TKm (Billion TKm)	0.0142	0.0297	0.0813	0.2225	0.6095
Total Freight (Billion TKm)	4.9856	7.9668	9.2405	10.7922	12.8068

Water: Technology Assumptions

For water based passenger transport, only diesel based coastal and inland traffic movement is assumed. The energy intensity is assumed to be 0.28 MJ/TKm for both inland and coastal passenger movement, respectively.[173] A 10 per cent reduction in energy intensity is assumed over the entire projection period.

Air Freight Traffic: Methodology

Air: Estimation of Freight Volumes

Only domestic air travel considered because of data constraints. Projections of India's air freight traffic (in million tonnes) at the end of 12th, 13th, 14th and 15th plan periods are obtained from the *Report of Working Group on Civil Aviation*.[174] The projections assume a CAGR of 11.3 per cent for air passenger traffic up to 2022, 9.9 per cent up to 2027 and 8.4 per cent up to 2032. The consistent drop of 1.4 per cent CAGR is assumed to continue and air traffic projections for India have been estimated based on the reduction in CAGR.

To arrive at the value of air freight volume in Kerala, the *Infrastructure Statistics 2010*[175] was referred, which indicated that Kerala's share in cargo handled per day in all India cargo handling volume was 1.44 per cent. It is assumed that this ratio will be constant throughout the projection period. In addition, average travel distance is assumed to be the distance between Kochi and Ahmedabad (1,510 km).

Based on these assumptions, the total air freight traffic projections are shown in Table 9.57 below.

Table 9.57: Estimated Air Freight Traffic

Year	2011	2020	2030	2040	2050
Air Freight (mTKM)	10.3	6.9	6.9	6.9	6.9

Air: Technology Assumptions

For air freight transport, only domestic freight traffic and Jet Kerosene based fuelling are considered. The share of Jet Kerosene is assumed to be 100 per cent throughout the projection period. The energy intensity is assumed to be 17.3 MJ/TKm.[176] A 10 per cent reduction in energy intensity is assumed over the entire projection period.

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[173] Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*
[174] National Transport Development Policy Committee. 2012. *Report of Working Group on Civil Aviation Sector.*
[175] Central Statistics Office. 2010. *Infrastructure Statistics 2010.*
[176] Zhou, Nan. 2007. *What Do India's Transport Energy Data Tell Us?*

Transport Output

9.7.3 Summary of Transport sector projections

Tables 9.58 and 9.59 below indicate the summary results of transport energy demand.

Table 9.58: Transport Sector Energy Demand (PJ)

Transport Energy Demand (PJ)	2011	2020	2030	2040	2050
Passenger	70.9	118.1	166.1	250.2	408.5
Freight	57.3	107.1	163.3	270.7	445
Total	**128.2**	**225.2**	**329.3**	**520.9**	**853.5**

Table 9.59: Transport Fuel Demand for BAU Scenario

Fuel Demand (mtoe) - BAU	2011	2020	2030	2040	2050
Diesel	2.4	4.1	5.6	8.6	13.9
Gasoline	0.5	1	1.4	2.2	3.8
Jet Kerosene	0.1	0.2	0.4	0.8	1.3
Natural Gas	0	0.1	0.4	0.6	1.1
Electricity	0	0.1	0.1	0.2	0.3
Total	**3.1**	**5.4**	**7.9**	**12.4**	**20.4**

9.8 Summary Results of Total Energy Demand for all Sectors

The BAU projections for the total energy demand for the state are shown in Tables 9.60, 9.61, 9.62 and Figures 9.1 and 9.2 below.

Table 9.60: Final Energy Demand (BAU Scenario)

State Energy Demand (PJ) - BAU	2011	2020	2030	2040	2050
Transport	128.2	225.2	329.3	520.9	853.5
Domestic	54.4	66.7	94.5	131	169.3
Commercial	12.2	27	53	88.7	134.1
Industry	48.3	75.5	90	104.8	119.7
Agriculture	2	2.2	2.5	2.7	2.8
Public and Bulk	2.6	4.1	6.8	10.5	15.1
Total	**247.7**	**400.8**	**576.2**	**858.6**	**1294.5**

Figure 9.1: Total Sector-wise Energy Demand for BAU Scenario

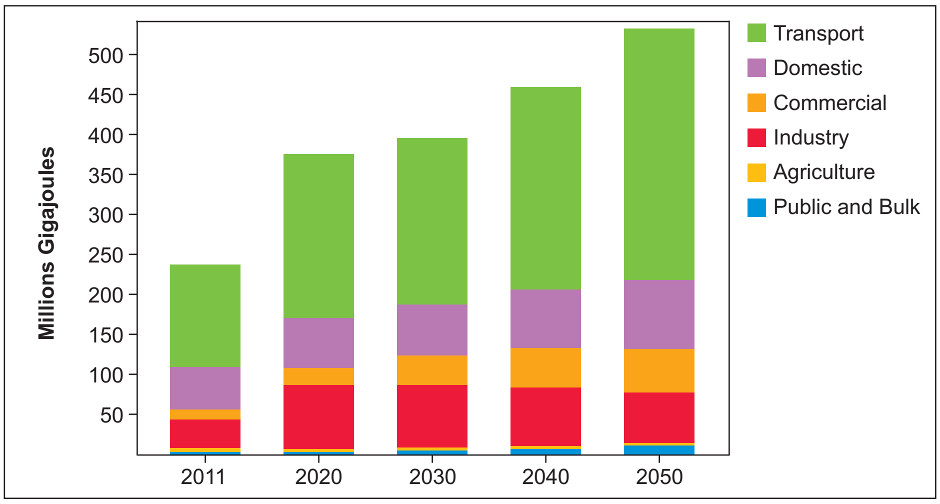


Table 9.61: Energy Demand by Fuel Source (BAU Scenario)

Total Fuel Demand (PJ) - BAU	2011	2020	2030	2040	2050
Diesel	102.8	172	234	362.1	583.8
Electricity	54.5	90.4	153.5	235.7	330
Gasoline	22.4	40.3	58.8	91.6	158.5
Jet Kerosene	2.8	6.9	17.6	35.1	53.7
LPG	13.6	24.9	35.6	42.1	49
Natural Gas	0	4.8	15.8	25.7	46.7
Coal	21.7	32.2	33.6	35.1	36.5
Residual Fuel Oil	3.6	6.3	9.3	12.4	15.5
Pet Coke	7.2	10.6	10.6	10.7	10.7
Wood	18.9	12.1	6.8	7.5	9.4
Kerosene	0.2	0.2	0.3	0.4	0.5
All Others**	0.1	0.1	0.1	0.1	0.1
Total	**247.7**	**400.8**	**576.2**	**858.6**	**1,294.5**

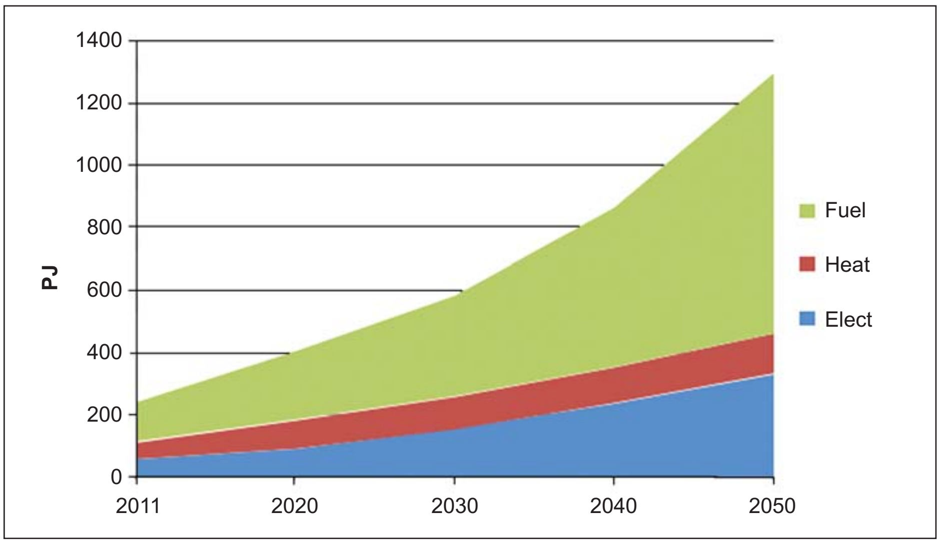
** All others includes non-woody biomass and solar. Non-woody biomass is not recorded as a fuel in NSSO surveys. All non-woody biomass is separately accounted for in biomass resource assessment in Part II.

Table 9.62 shows the demand evolution in terms of electricity, fuels and heat.

Table 9.62: Energy Demand by Fuel Carriers (BAU Scenario)

Total Fuel Demand (PJ) - BAU	2011	2020	2030	2040	2050
Electricity	55	90	154	236	330
Heat	64.7	86.8	96.2	107.6	121.5
Fuel	128	224	326	515	843
Total	**247.7**	**400.8**	**576.2**	**858.6**	**1,294.5**

Figure 9.2: Energy Demand by Fuel Carriers



Surprisingly, the projections indicate that transportation in Kerala accounts for slightly more than 50 per cent share in total energy demand for the state. This is much higher than expected transport share of about 30-40 per cent in industrialized economies. However, the figures derived for fuel demand were cross checked with available data. Based on data from the Ministry of Petroleum and Natural Gas,[177] the total diesel consumption in the state was reported to be 2,105,000 tonnes (2.1 million tonnes) in 2012-12. As compared to that, the estimated diesel requirement for the base year (2011) works out to be 2.4 million tonnes of oil equivalent (mtoe) or about 2.24 million tonnes of diesel. Even though this is slightly on the higher side, it is still comparable.

The demand for other sectors, especially electricity demand has also been cross checked. The estimated demand for the BAU scenario in the base year is 15.1 BU as compared to the actual demand of 14.54 BU. Heat demand for Industry, mainly represented by furnace oil, was estimated in the scenario at 631,000 toe in 2011 as compared to the actual consumption of 659,000 tonnes spread across fuel oil, LSHS, lubes and bitumen in 2011-12.

Based on the above assessment, it appears that the high share of transport represents a realistic scenario for the state. The possible reason for this high share of transport could be the low per capita electricity consumption coupled with relatively low industrial development as compared to industrialized economies. Another reason could be the large spatial spread of population across independent houses that necessitate increased reliance on private transport.

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177 Ministry of Petroleum and Natural Gas. 2012. *Basic Statistics on Indian Petroleum & Natural Gas 2011–12.* Ministry of Petroleum and Natural Gas, Government of India. New Delhi, India. http://petroleum.nic.in/petstat.pdf.

10. TOWARDS 100% RE: THE CURTAILED DEMAND SCENARIO

Summary

The curtailed energy demand modelling is done using the modelling software Long Range Energy Alternatives Planning (LEAP) [Software version 2012.0049].[178] With the BAU scenario as the base scenario, three new scenarios are created representing energy conservation, energy efficiency and carrier substitution, with each scenario inheriting its data and characteristics from the preceding scenario. The first intervention scenario titled 'Intervention Scenario 1 – Energy Conservation' (IS1-EC) inherits its characteristics from the BAU scenario, while 'Intervention Scenario 2 – Energy Efficiency' (IS2 -EE) derives its characteristics from IS1-EC. The third intervention scenario 'Intervention Scenario – Carrier Substitution' (IS3-CS) derives its characteristics from IS2-EE. In effect, the tiered scenario approach helps to establish the energy reduction potential across each scenario individually and also helps to identify the cumulative energy reduction potential with the proposed sequence of interventions.

10.1 INTERVENTIONS: DOMESTIC SECTOR

The domestic sector in Kerala accounts for a major share of electricity and cooking heat. The three main intervention strategies: energy conservation, energy efficiency and carrier substitution considered here primarily focus on the energy curtailment potential of these two carrier fuels.

10.1.1 Intervention Scenario 1– Energy Conservation

The main intervention strategies considered for domestic sector under this scenario are a move towards a sustainable buildings and materials including better building, architectural and material management practices to optimize natural environment use (natural cooling/lighting).

Kerala is already facing shortage of low-cost conventional materials for housing. The available construction material is often prohibitively expensive and transportation costs add even more to real estate development costs. However, there are alternative ways of building residential houses and this experiment had already begun in Kerala with the work of Laurie Baker. The Laurie Baker concept of using locally available construction materials is not only sustainable but, in many cases, is also cost effective both in terms of capital expenditure and the building's energy footprint. Bamboo based and other wood based architectural concepts have been adopted only on a very limited level in Kerala. Interactions with practicing architects indicated that use of naturally available material reduced lighting and space cooling requirements substantially besides imparting an exotic look to the built façade.

178 Heaps, C. G. 2012. *Long-range Energy Alternatives Planning (LEAP) System.*

At the other end of spectrum, there are also modern architectural concepts (green buildings, net energy zero buildings, etc) that draw heavily on integrated planning and modern material use. Many of these designs have in fact achieved huge energy savings. One case in point is CII Godrej's office complex of 20,000 ft^2 (LEED Certified Green Building), which consumes 63 per cent less energy than a conventional building of the same size.[179] This level of reduction in energy use is much beyond even the highest possible savings from known energy efficiency or energy conservation measures. Europe, which is at a much advanced development stage, is already working on norms for low energy buildings with built in generation sources that can meet all or part of the building's energy demand. Many of these low energy buildings with integrated RE generation sources have already been built and the proof of concept is already established.

In addition there is great scope for energy reduction in existing buildings through retrofit. One case in point is that of the Godrej Bhavan Building in Mumbai, where retrofit involving new lighting, glazed windows, roof garden and other measures reduced the energy consumption by about 12.3 per cent.[180]

According to a recent report released by NRDC (Natural Resource Defense Council) 'Constructing Change', 70 per cent of the buildings that will exist in 2030 have not been built.[181] This observation clearly points out the rapid growth of real estate sector in India, but on a more important note, also indicates that there is huge scope for facilitating a shift towards environment friendly green buildings. This will be true for Kerala also, where housing and real estate are developing at a frenetic pace. What this leads to is the possibility of consciously affecting a shift towards better building practices through ECBC, green building compliance, mandatory retrofits of existing building. This would mainly mean diverting present appliance level efforts on energy conservation to more integrated building level energy efficiency improvements.

Fortunately, many of these aspects are taken cognizance of and are covered in the state's Green Building Policy (policy briefly covered in the previous section). A strengthened policy with aggressive targets and compliance norms will be able to affect an aggressive intervention in target based compliance in energy use standards of existing and new buildings.

Even though, the energy saving potential of residential structures is very site and plan specific, based on TERI's study *India's Energy Security: New Opportunities for a Sustainable Future,* a 30 per cent reduction in energy demand is possible through aggressive retrofits and new building standards.[182] However, considering the long gestation time of real estate development, it is assumed that targeted policy

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179 Kumar, D. Sendil and Pugazhvadivu, M. 2012. "Green Buildings: Prospects and Potential". *Journal of Engineering Research and Studies.* http://www.technicaljournalsonline.com/jers/VOL%20III/JERS%20VOL%20III%20ISSUE%20IV%20OCTOBER%20DECEMBER%202012/Article%202%20Vol%20III%20Issue%20IV.pdf.

180 NRDC. 2013. *Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai.* Natural Resources Defense Council. http://www.nrdc.org/international/india/files/energy-retrofit-godrej-bhavan-CS.pdf.

181 NRDC. 2012. *Constructing Change: Accelerating Energy Efficiency in India's Buildings Market.* Natural Resources Defense Council. http://www.nrdc.org/international/files/india-constructing-change-report.pdf.

intervention in 2015 will accrue in these 30 per cent energy savings from all buildings starting 2030.

10.1.2 Intervention Scenario 2 – Energy Efficiency

The main strategy identified in energy efficiency is a policy driven migration towards super efficient appliances. Bureau of Energy Efficiency has already initiated super efficient equipment programme (SEEP) in India to accelerate the market transformation to super efficient appliances and equipments in India.

Furthermore, recent studies of appliance sales indicate that consumers in Kerala are more quality conscious and sensitive to operational costs of appliances.[183] Considering this, it is assumed that the move to super efficient appliance can be very successful in Kerala. To understand the possibilities of intervention, a discussion paper authored by Prayas Energy Group, Pune was referred.[184] The paper titled *Potential Savings from Selected Super Efficient Electric Appliances in India* compares the appliance efficiency level of the most efficient available product (5 star) to the best available model, super efficient appliance (SEA).

Table 10.1: Energy Intensity Comparison between 5 star and SEA

Appliance Efficiency	Unit	5 Star	SEA	% decrease UEC
Room Air conditioners	EER	3.1	4.86	36
Frost-Free Refrigerators	kWh/Y	411	128	69
Television	W	62	36	41
Ceiling Fans	W	51	35	32

For all other appliances, a reduction potential of 30 per cent is assumed. It is further assumed that policy intervention in pushing for 100 per cent SEA penetration in urban households by 2040 and in rural households by 2050 will be successful.

On the domestic cooking side, a move towards more sustainable and efficient cooking appliances is projected. A counter trend by shifting cooking fuel share towards sustainable fuel source, namely biogas is also proposed. The general perception is that biogas availability in normal household biogas digesters is not sufficient to meet all the cooking requirements. Field interaction with experts, biogas users, and local households revealed that daily biogas generation could just about sustain a maximum of two hours of cooking on a single burner. Households with biogas were generally using it for water heating or other non essential activities.

Furthermore, the major problem cited by households in installing new biogas systems was the quality of work and the cost of labour for installing an underground system. To overcome these constraints, a number of manufacturers have come up

[182] TERI. 2009. *India's Energy Security: New Opportunities for a Sustainable Future.* The Energy and Resources Institute. New Delhi, India. http://www.teriin.org/events/CoP16/India_Energy_Security.pdf.
[183] WINROCK. 2010. *Survey and Collection of Data Concerning Manufacturing.*
[184] Chuenkar, Aditya et al. 2011. *Potential Savings from Selected Super-Efficient Electric Appliances in India: A Discussion Paper.* Prayas Energy Group. Pune, India. prayaspune.org/peg/.../308_51f0c8d873553949a7ebccda983615d7.html.

with portable biogas systems. Portable plants enable the users to install the plants anywhere on the ground or on the roof top without much effort. Besides household wastes and bio-wastes can be disposed of in a useful manner and the slurry obtained from the digester is a good source of manure and can substitute the demand for fertilizers. Furthermore, as majority of the houses in Kerala are independent, there is a huge scope for installing new individual household level systems. And even a partial use of biogas, can significantly reduce the dependence on LPG. It is also assumed that future demand would spur more R&D leading to better efficiencies and yield. Considering improved penetration and better future yields, a 50 per cent substitution of LPG with biogas in urban areas and 40 per cent in rural areas by 2050 (starting with 5 per cent in 2020) is assumed. (Shift to biogas also considers availability of biogas. A detailed resource assessment of biogas potential is covered in Part II of this report).

The second sustainable cooking source considered is wood. Wood and wood residues are available in almost all households with moderate land size. In the case of shift to LPG, this sustainably generated wood (mainly natural fellings) is not often used and is allowed to rot away. The difficulties related to labour availability and wages also preclude the possibility of collecting wood and bringing it to a centralized location. This would suggest that converting some cooking to wood (counter to present trend) would, in fact, be a very good localization strategy. A policy driven push for including sustainable wood fellings as a cooking fuel would be a step in the right direction. In addition, using improved cooking stoves in place of traditional cooking stoves can save about 40 per cent of fuel wood and 100 per cent penetration of efficient wood stoves is assumed by 2020. It is further assumed that there will be stabilization in wood use in cooking after 2030. The projected penetration of wood use in 2030 in rural areas (34.3 per cent) is assumed to stabilize after 2030.

10.1.3 Intervention Scenario 3 – Carrier/Supply Substitution

The two major interventions in carrier substitution for electricity demand include a switch to an all electric home and substituting water heating demand with solar water heating.

An all electric home (net zero energy building) is an integrated building that includes passive design aspects (site, orientation, materials, resources, infrastructure, electrical design, plumbing and spec condition design, water management plan, etc) with active power generation devices like building integrated PV (BIPV), small wind generating system, biogas digester, etc. The overall design in effect makes the building net energy zero as the annual consumption is met almost entirely by built-in generation sources even though the direction of energy flow may vary across seasons. This concept is already in popular in Europe and it will be a matter of time before India embraces this concept. However, real operational net energy zero buildings are very few and are also very expensive. Considering this, a penetration of about 15 per cent and 5 per cent (starting with 0 per cent in 2030) low energy residential buildings/houses with built-in generation sources by 2050 is assumed in urban and rural areas, respectively. It is assumed that these buildings will be able to meet stringent emissions norms and will be able to meet almost 60 per cent of their annual demand through internal sources. It is expected that incremental improvements in technologies and increase in demand will bring the costs (mainly on account of materials) down.

Based on the potential assessment of solar water heating estimated in Part II, it is assumed that 20 per cent of the water heating demand can be met by solar in the substituted demand by 2050. This level of solar water heating penetration is well below the potential, but the reason for the reduced value is the assumption that water heating may not be very effectual in monsoon months and households would still rely on electricity for water heating for 6-7 months.

In line with the change in living standards in Kerala, a move towards increasing use of electricity for cooking is also factored in. In general, electric cooking stoves (induction heaters, microwave) are significantly more efficient than simple combustion-based gas stoves resulting in time savings. According to research conducted by EMC Kerala, the thermal efficiency of induction plates is about 23 per cent more than that of an efficient LPG stove.[185] This would result in quicker heating and may prompt working families to migrate to electricity. Even though this may be desirable from the point of view of total energy demand, the switch may create electrical load balancing problems as the cooking demand generally coincides with system peaks. A basic estimation indicates a 100 per cent switch to electric cooking would be equivalent to an additional electricity demand of about 7.9 BU in 2011 and about 7.4 BU in 2050 in the BAU scenario. In view of the same, a moderate level of penetration of electric heating to about 15 per cent in urban areas and 5 per cent in rural areas in 2050 is assumed. It is assumed that the increase in electric cook stoves displaces other cooking fuels (LPG, wood, biogas, equally).

The third main intervention is use of solar cooker. Field discussions indicated that solar cookers are not very popular because of the specific cooking practices, which may not give good results in solar cooker.

However, commercial level solar systems are capable of meeting these requirements and it may be a matter of time before these systems are available at the household unit size. However, in view of the lack of clarity in technology evolution a moderate substitution of about 6 per cent of cooking LPG with solar cookers is assumed by 2050 for both rural and urban areas.

Output

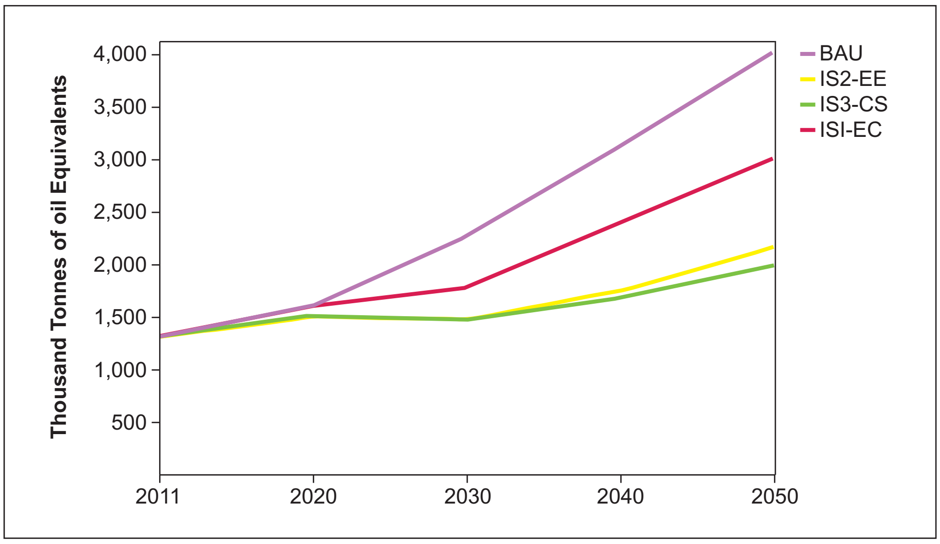
The results of all the above interventions are shown in the Figure 10.1 and the Table 10.2 below.

Table 10.2: Energy Demand Reduction through Three Step Interventions in the Domestic Sector

Total Energy (PJ)	2011	2020	2030	2040	2050
BAU	54.4	66.7	94.5	131	169.3
ISI-EC	54.4	66.7	78	105.1	133.7
IS2-EE	54.4	62.4	64.1	76.2	94.9
IS3-CS	54.4	62.4	63.9	73.3	87.7

[185] Harikumar, R. *Induction Cooker: A Brief Investigation.* Energy Management Centre, Kerala. http://www.keralaenergy.gov.in/emc_reports/Induction%20Cooker_a%20brief%20investigation.pdf.

Figure 10.1: Energy Demand Reduction through Three Step Interventions in the Domestic Sector



10.2 COMMERCIAL SECTOR

Commercial sector energy requirements are going to dominate electricity sector in the state. It is assumed that the base (BAU) scenario for electricity demand (based on CEA's 18th EPS projections) has assumed moderate intervention scenario in terms of energy conservation and energy efficiency. The intervention scenarios assumed work on aggressive intervention at appliance share and appliance energy intensity level.

10.2.1 Intervention Scenario 1: Energy Conservation

The main intervention in energy conservation for commercial sector is assumed to come from better end-use practices like switching off unwanted equipments (lights and fans), running ACs at optimum temperature between 25-27° C, periodic maintenance in case of commercial AC units, high volume air conditioners (HVAC), refrigerators and mainly from increasing penetration of energy positive buildings.

According to the BEE document indicating state-wise potential for energy conservation,[186] the total energy saving potential in commercial sector is to the tune of 20-30 per cent. However, the strategies and role of pure conservation activities is not demarcated. As the commercial sector is generally more aware of the need to conserve power, a moderate reduction potential of about 20 per cent is assumed to accrue from core energy conservation activities.

There is huge scope for green / environment friendly buildings in the commercial sector. Two cases in energy efficient buildings include Wipro's and ITC's Gurgaon office complexes having a floor area of nearly 1,70,000 ft^2. The percentage reduction in electrical energy consumption of these two buildings as compared to conventional buildings is to the tune of 40 per cent and 45 per cent, respectively.[187]

186 Bureau of Energy Efficiency (BEE). *State –wise Electricity Consumption and Conservation Potential in India.*

187 Kumar, D. Sendil and Pugazhvadivu, M. 2012. "Green Buildings: Prospects and Potential". *Journal of Engineering Research and Studies.* http://www.technicaljournalsonline.com/jers/VOL%20III/JERS%20VOL%20III%20ISSUE%20IV%20OCTOBER%20DECEMBER%202012/Article%202%20Vol%20III%20Issue%20IV.pdf.

Even at a small scale level, the building of CII Godrej with a floor area of 20,000ft^2 is 63 per cent less energy intensive as compared to a conventional building of same size. The main difference comes from integrated planning and better use of materials. Even though these buildings generally cost on par, these levels of energy footprints can help them achieve breakeven very early. The move to green buildings can perhaps be the most effective way to manage future energy without compromising the growth of services sector that is going to be the centre piece of the state's economy.

The state government has already defined these objectives in the Housing Policy 2012 and the Green Building Policy 2011. It is assumed that these policies are strengthened further by formulation of progressive regulations that specify compliance targets for all new and old buildings. It is assumed that all new malls, IT parks, large commercial buildings and hotels are encouraged to adopt green building norms starting 2020 with mandatory compliance by 2025. In line with this, a gradually increasing penetration of green buildings from 5 per cent by 2025 to 10 per cent by 2030, 30 per cent by 2040 and 70 per cent by 2050 is assumed with an energy reduction potential increasing from 15 per cent by 2025 to 20 per cent by 2030, 40 per cent by 2040 and 60 per cent by 2050. These level of savings are not ambitious considering that the effective reduction in energy intensity in 2050 would be only be about 42 per cent as compared to the current level.

For other categories like hospitals and retail, a reduced penetration of energy efficient building and with a reduction in electricity consumption by 10 per cent starting 2030 increasing to 20 per cent by 2040 and 30 per cent by 2050 is assumed.

10.2.2 Intervention Scenario 2: Energy Efficiency

At the first intervention level, certain appliance penetration levels in the base year (2011) are assumed. For factoring in aggressive intervention, targeted changes in appliance shares and appliance energy intensities have been factored over the BAU share projections

Assumptions

Even though the relative shares of end-use activities (lighting, space conditioning and refrigeration) have been assumed to be constant throughout the projection period, it is further assumed that 50 per cent of the total lighting demand is met by incandescent lamps (GLS), 25 per cent by tube lights (FTL) and 25 per cent by CFLs in the base year (2011). The space conditioning demand is assumed to be met from fans and air conditioners. For fans and air conditioners, categorization is done in terms of efficiency of a normal air conditioner vis-à-vis a super efficient air conditioner. Refrigeration is also categorized as existing and super efficient.

The energy intensity values of different appliances are normalized assuming a value of 1 for the lowest efficiency device. The reference for appliance efficiency is taken from Prayas Energy Group's study on potential saving from super efficient appliances in household.[188] It is assumed that commercial establishments will be

[188] Chuenkar, Aditya et al. 2011. *Potential Savings from Selected Super-Efficient Electric Appliances in India: A Discussion Paper.* Prayas Energy Group. Pune, India. prayaspune.org/peg/.../308_51f0c8d873553949a7ebccda983615d7.html.

quick to migrate to super efficient appliances considering the immense saving potential. Table 10.3 elaborates the assumptions related to appliance present and future level of penetration and the resultant energy intensity reductions.

Table 10.3: Energy Intensity Reductions through Appliance Share Shifts

Lighting Share	EI Scale	2011	2020	2030	2040	2050
GLS	1	50	40	35	20	
FTL	0.55	25	30	30	25	10
CFL	0.32	25	30	35	55	90
EI Evolution		1	0.92	0.87	0.72	0.48
Fans Share	**EI Scale**	**2011**	**2020**	**2030**	**2040**	**2050**
Existing	1	100	90	60	30	0
Efficient	0.68	0	10	40	70	100
EI Evolution		1	0.97	0.87	0.78	0.68
ACs Share	**EI Scale**	**2011**	**2020**	**2030**	**2040**	**2050**
Existing	1	80	50	10	0	0
Efficient	0.63	20	50	90	100	100
EI Evolution		1	0.88	0.72	0.68	0.68
Refrigeration Share	**EI Scale**	**2011**	**2020**	**2030**	**2040**	**2050**
Existing	1	90	80	50	20	0
Efficient	0.31	10	20	50	80	100
EI Evolution		1	0.93	0.70	0.48	0.33

10.2.3 Intervention Scenario 3: Carrier Substitution

No specific carrier substitution interventions are assumed for the commercial sector.

Output

The results of all the above interventions are shown in the Figure 10.2 and the Table 10.4 below.

Figure 10.2: Energy Demand Reduction through Three Step Interventions in the Commercial Sector

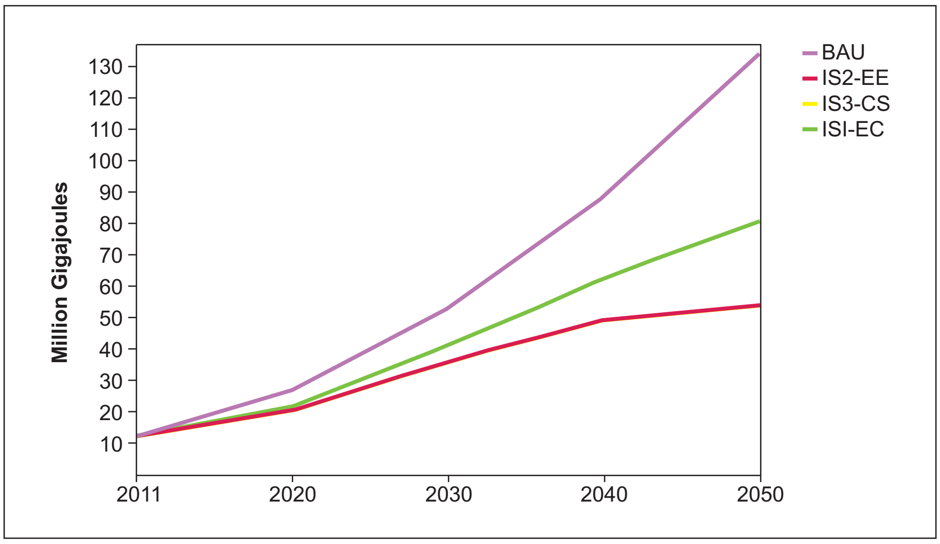


Table 10.4: Energy Demand Reduction through Three Step Interventions in the Commercial Sector

Total Energy (PJ)	2011	2020	2030	2040	2050
BAU	12.2	27	53	88.7	134.1
IS1-EC	12.2	21.8	41	62.7	81
IS2-EE	12.2	20.6	36	49.2	54.1
IS3-CS	12.2	20.6	36	49.2	54.1

10.3 INDUSTRY SCENARIO

In Kerala, large energy intensive industry sectors like petrochemicals, chemicals, cement, paper and pulp, etc are represented by a handful of units, with a relatively large industrial energy share spread across small-scale and medium-scale enterprises involved in engineering, textiles, metals, food processing, etc. The WWF global energy report[189] assumes drastic levels of reduction in industrial energy use mainly on the basis of the intensity of use hypothesis. While this hypothesis can in theory be applied to a closed system, it is difficult to apply it to an open system, where free trade and free movements of goods would delink production levels in a particular region from per capita income. For this study, the three main strategies assumed are that of energy conservation, energy efficiency and a limited level of carrier substitution.

For some industry sectors, even less capital intensive technologies may be more effective than others. Base level strategies on energy conservation could start from something as simple as switching off excess lights, optimizing space condition/refrigeration temperature, better heat insulation, better material use, etc. The next level of strategies could be oriented towards equipment efficiency involving equipment upgradation / replacement aimed at increasing process efficiency: switch to efficient motors, efficient lighting solutions, variable frequency drives for motor, waste heat recovery system, etc. The highest level of intervention would involve an overhauling of entire process or unit and reduction in energy intensity of manufacturing through natural technological evolution.

In intervention strategy for industry, energy saving potential through all the three levels of strategies is factored. But considering the fact that industry sector is capital intensive and capacity intensive, the inertia associated with changing industrial processes will be large and not all sectors and industrial units will be in a position to shift to better process technologies in the near future because of multiple constraints in capital availability, technology availability, future plans, etc. In cases, where strategies involve process level interventions, a time lag in adoption is assumed to factor in slow pace of process overhauls in existing industries and adoption in new greenfield projects.

For ease of understanding, all the passive base level strategies are covered under Intervention Scenario 1 – Energy Conservation, while Intervention Scenario 2 – Energy Efficiency mainly focuses on the expected technological evolution and consequent reductions in energy intensity of industrial processes.

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[189] WWF International. 2011. *The Energy Report: 100% Renewable Energy by 2050.* Avenue du Mont-Blanc, Switzerland.

10.3.1 Intervention Scenario 1: Energy Conservation

Considering the diversity of industry in Kerala, the best option to understand intervention possibility in energy conservation measures was through local / state-based and India-level studies. The main inputs include some actual case studies of industries in Kerala and another study by Energy Management Centre, Kerala.[190] In the document, EMC Kerala indicated sector-wise energy saving potential in electricity use. This potential is taken as the target for electricity intensity reduction in the industry. The estimation of the conservation potential in heat demand is derived from numerous other sector-specific studies and other independent case studies.

It is presumed that achieving proposed base-level interventions would require a policy push. The policy imperatives for effecting this intervention are covered in the subsequent chapter. It is assumed that a revised Industrial Policy (with energy efficiency targets for industrial sectors) will be in place by 2015, with a window time for compliance of about 5 years (i.e., by 2020). Consequently, in the IS1-EC scenario, it is assumed that the reduction potential targets will be met by 2021.

It is also emphasized that the reduction potential targets indicated in this scenario can mainly be achieved through passive interventions by reducing waste energy, energy recovery, equipment level efficiency improvement (efficient lighting, efficient motors), and limited process intervention. Major process improvements, which are capital intensive, have not been considered in this scenario.

The following narrative tries to identify the saving potential of the identified sectors.

Agro and Food Processing

The main industries involved in agro and food processing are: agro malls, dairies, fruit and vegetables processing, spice processing, fish drying and others. Considering the huge diversity in industry products, processes and unit sizes, several case studies were analysed in addition to a documented report of the Energy Management Centre (EMC), Kerala that identified the savings potential in this sector.

One case study from MSME's newsletter, a study of rice mills clusters in Kadali indicated a saving potential of 15 per cent simply through better operational practices like reducing excess air in combustion boiler, hot water recovery, use of variable frequency motor drive, load side power factor management, etc.[191]

The other study on sea food processing cluster in Aroor indicated an energy saving potential of 20 per cent in heat use by passive initiative like use of air curtains, optimization of freezer temperature, better insulation, use of variable frequency

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[190] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.

[191] SIDBI. 2010. "Energy Efficiency Potential and Way forward in Kerala". *Newsletter on MSME Energy Saving Project.* Issue 4 (July–September). http://www.inspirenetwork.org/pdf/4.jul–sep10.pdf.

motor drive, etc. On the other hand, the energy saving potential identified by EMC indicated a saving potential of 20 per cent in electricity in the agricultural sector.[192]

Considering all the above studies, an energy reduction target of 20 per cent in electricity and 15 per cent in heat demand by 2021 was assigned for this sector.

Textile Industry

The textile units in Kerala mainly comprise spinning mills and power looms / handlooms. Large textile units typically produce yarn which is the raw material for weaving and loom industry. The largest textile manufacturer in Kerala, GTN textiles (and its subsidiaries) mainly produces yarn.

Based on TERI's study,[193] some of the specific energy saving process measures identified were: use of new spinning technologies like friction spinning / air jet spinning, high-sped drying machines and use of solar process heating technologies in water heating. Based on the assessment of the report, energy efficient textile technologies have the potential to reduce heat demand by 11 per cent and electricity demand by 10 per cent.

However, the potential for energy conservation as estimated by EMC for large textile units was 25 per cent in electricity use.[194] In line with EMC's energy conservation estimation for textiles, a 2021 energy conservation target of 25 per cent in electricity demand and 11 per cent in heat demand is assigned.

Pulp and Paper

The paper industry is highly energy intensive and is the sixth largest consumer of commercial energy in the country. The main fuel used in the pulp and paper industry is coal. The other fuels used are furnace oil, LSHS, rice and coffee husk.

There is a lot of scope for energy intensity improvements in this sector. According to CII's Investors Manual, the energy intensity of Indian paper industry is significantly less than that of international paper industry with a minimum average saving potential of about 20 and 26 per cent in heat and electricity, respectively.[195] The energy saving potential identified by EMC Kerala for paper and pulp industry was 25 per cent.[196]

For pulp and paper, a 2021 energy conservation target of 25 per cent in electricity demand and 10 per cent in heat demand is assigned.

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[192] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.
[193] TERI. 2006. *National Energy Map for India Technology Vision 2030.*
[194] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.
[195] CII. *Investors Manual for Energy Efficiency.* Indian Renewable Energy Development Agency and Confederation of Indian Industry. Chennai, India. http://ireda.gov.in/writereaddata/IREDA–InvestorManual.pdf.
[196] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.

Petrochemicals

Considering the complexity of petrochemicals manufacturing, it is very difficult to apply best available technology (BAT) or best practice technology (BPT) analysis to the petrochemicals industry. Literature review of energy efficiency sector (IEA[197] and TERI[198]) has also not covered this sector in details. However, the energy saving potential estimated by EMC, Kerala for this sector was 10 per cent in electricity demand.

In line with EMC's estimation, a 2021 energy conservation target of 10 per cent electricity is assigned for this sector.

Chemicals and Fertilizers

The chemicals sector is represented by industry chemicals (caustic soda, organic chemicals), fertilizers, breweries and pharmaceuticals. Travancore-Cochin Chemicals Ltd. is the largest consumer of electricity in this segment followed by FACT Udyogmangal's fertilizer manufacturing plants.

The technology mainly used in caustic soda manufacturing process is membrane cell technology which uses a semi-permeable membrane to separate the anode and cathode compartments with porous chemically active plastic sheets that allow migration of sodium ions where they react with de-mineralized water to produce caustic soda and hydrogen gas. Almost 90 per cent of the total electricity used is utilized in the electrolytic cells. According to TERI's study,[199] the main technology options for caustic soda manufacturing are a move from existing technology to Oxygen Depolarized Cathodes (ODC) technology. The study assumes increasing penetration of ODC technology in India with an energy intensity reduction potential of 17 per cent in electricity for about 9 per cent increase in heat requirements.

The fertilizer sector accounts for 8.0 per cent of total fuels consumed in the manufacturing sector and is one of the major consumers of hydrocarbons. The fertilizer industry in Kerala is mainly based on use of ammonia. Industrial production of ammonia for fertilizers accounts for almost 80 per cent of the total energy used in the fertilizer Industry. The most important step in producing ammonia (NH3) is the production of hydrogen, which is derived either from steam reforming of natural gas or from partial oxidation process. Partial oxidation process consumes 40-50 per cent more energy than steam reforming process but offers the flexibility of using a variety of fuels. Part of the petroleum feedstock is also used to provide heat for reaction. According to CII's report, the estimated energy saving potential for the fertilizer industry is about 10 per cent in electricity.[200] On the other hand, according to EMC Kerala, the energy saving potential in the chemicals and fertilizer Industries is 15 per cent and 10 per cent in electricity, respectively.[201]

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[197] IEA. 2011. *Energy Transition for Industry: India and the Global Context.*
[198] TERI. 2006. *National Energy Map for India Technology Vision 2030.*
[199] Ibid.
[200] CII. *Investors Manual for Energy Efficiency.* Indian Renewable Energy Development Agency and Confederation of Indian Industry. Chennai, India. http://ireda.gov.in/writereaddata/IREDA-InvestorManual.pdf.
[201] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.

Based on the above studies and estimates, a 2021 target of 15 per cent in electricity is assigned.

Rubber

The main rubber products produced in the state are tires, latex and crumb rubber.

The main raw materials for tire industry include rubber bales, chemicals, textiles and steel. The process begins with the mixing of basic rubbers with chemicals, carbon black, antioxidants and other additives. These ingredients are mixed in giant blenders operating under high heat and pressure to produce a homogenized batch of black material which is the raw material for the processing and machining phase, which also uses substantial energy.

Latex is usually manufactured using either 'Talalay' or 'Dunlop' processes. The Talalay process can give softer finish and is used for manufacturing medical products and contraceptives. Both the processes can use natural rubber, synthetic rubber or a mix of both. In the Talalay process, liquid latex formulation is poured into a mould, sealed closed in a vacuum and is flash frozen. The frozen latex is flash heated to "gel" into permanent solid form and is allowed to cool before being removed from the mould. The latex mould is then used as a raw feed for a variety of end products.

Crumb rubber is a high-quality product and usually uses latex as feed material. Production of block rubber from field latex or field coagulum grade involves unit operation such as pre-cleaning, blending, washing, final size reduction, coagulation, dripping, drying, baling as 25 kg blocks, packing, testing and grading.

To assess the potential for energy conservation in this sector, a case study of MSME Newsletter was referred, which estimated that the energy saving potential of crumb rubber manufacturing cluster in Kotayyam was 15 per cent in heat and 10 per cent in electricity, use mainly through optimizing grinding media ratios, optimizing humidity control, heat (and waste heat) recovery from dryers, better water management, etc.[202]

In addition, based on EMC Kerala's assessment, the energy saving potential in rubber industry was identified to be 15 per cent in electricity.[203] On the basis of the two assessments, a 2021 EC target of 15 per cent reduction in heat and electricity is assigned to this sector.

Minerals and Materials

The minerals and materials sector is mainly represented by cement, abrasives, clay and other construction materials.

The main process used in the cement industry is dry process, which can be further categorized into three main categories: (a) 4-stage pre-heater pre-calcinator, (b) 5-

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[202] SIDBI. 2010. "Energy Efficiency Potential and Way forward in Kerala". *Newsletter on MSME Energy Saving Project.* Issue 4 (July–September). http://www.inspirenetwork.org/pdf/4.jul-sep10.pdf.
[203] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.

stage preheater pre-calcinator, and (c) 6-stage pre-heater, twin stream, pre-calcinator, pyrostep cooler.[204] The energy efficiency options for the cement industry are conversion of 4- and 5-stage cement plants to modern 6-stage plants and moving towards producing a higher share of blended cement in the total cement production to reduce clinker cement ratio (clinker production is the most energy-intensive process in the manufacture of cement accounting for almost 80 per cent of total energy use). According to TERI's study,[205] the potential reduction in energy intensity in moving from a 4-stage process to a 6-stage process is about 16 per cent in heat and 35 per cent in electricity.

However, IEA's 2011 report on the Indian industry suggests that there may be very little potential for energy saving in the Indian cement industry; to the tune of about 18 per cent, mostly in heat requirement as the specific electricity consumption of Indian cement industry is among the lowest in the world.[206] On the other hand, EMC Kerala estimates an energy saving potential of 15 per cent in electricity consumption for the cement industry.[207]

In line with other studies, cement industry is considered as a marker for this category. Based on above assessments, a target of 15 per cent energy reduction in both electricity and heat by 2021 is assigned.

Metals and Alloys

The main industries in this sector are castings and forgings, metal processing, etc.

Indian foundry industry is very energy intensive. The energy input to the furnaces and the cost of energy play an important role in determining the cost of production of castings. Major energy consumption in medium and large scale foundry industry is the electrical energy, which is used in an induction and arc furnace. In a typical process, the furnace which melts the raw metal feed is usually fired by petroleum fuels. The molten metal is then transferred to an electrical induction furnace (called the holding furnace), which is used to maintain the required temperature. The melting process in this sector accounts for 86 per cent of total energy used. The molten metal is then poured into predesigned casts and allowed to cool before being removed and processed.

Metal processing involves processing of metal products to desired specifications. Typical applications are rolling mills, sheet metal, etc. Based on case study of MSME Newsletter,[208] the energy saving potential of rerolling manufacturing cluster in Kanjikode was assessed at 20 per cent in heat and 15 per cent in electricity use mainly through simple measures like control of excess air, closing furnace door, maintaining optimum fuel preheat temperatures, optimum furnace loading, use of ceramic insulation, use of variable frequency drives, etc. EMC

[204] TERI. 2006. *National Energy Map for India Technology Vision 2030.*
[205] Ibid..
[206] IEA. 2011. *Energy Transition for Industry.*
[207] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.
[208] SIDBI. 2010. "Energy Efficiency Potential and Way forward in Kerala". *Newsletter on MSME Energy Saving Project.* Issue 4 (July–September). http://www.inspirenetwork.org/pdf/4.jul-sep10.pdf.

Kerala estimates the energy conservation potential in this industry at 10 per cent in electricity use.

Metal processing as a marker for this sector and based on the assessments of local industries, an energy saving target of 20 per cent in heat and 10 per cent in electricity is assigned for this sector.

Engineering and Industrial Goods

This sector mainly comprises manufacturers of automobile products, electrical and electronic equipment, etc and accounts for 2.9 per cent of total industrial electricity requirement and about 1.9 per cent of total heat demand. EMC Kerala estimates a reduction potential of 15 per cent in electricity use.[209] In line with EMC Kerala's estimates, an energy saving target of 10 per cent in electricity by 2021 is assigned for this sector.

Others

For this sector, a 2021 target of 10 per cent in both electricity and heat requirements by 2021 is assigned.

10.3.2 Intervention Scenario 2: Energy Efficiency

Majority of the studies on industry sector energy use typically focus on large-scale industries and assess energy efficiency potential in terms of specific energy consumption based on technology (BAT: Best Available Technology) or process (BPT: Best Process Technology) (IEA[210] and TERI[211]). Even though these studies do provide a basis of comparing efficient technologies with less efficient technologies, the actual evolution of energy intensities of technologies and processes is not captured in sufficient detail. However, process and technology improvements naturally evolve and while some improvements may bring incremental results, some other may bring about sudden step changes. For a long range projection up to 2050, taking BAT or BPT as benchmarks would not be justified considering the pace of technology evolution in the industry sector. It is difficult to imagine that a BAT today would still be a BAT in 2030 or 2040.

In such a scenario, it is assumed that a further reduction in energy intensity will be brought about by incremental and step improvements in sectoral manufacturing processes. The main reference for assuming this technological evolution is *The Energy Report by WWF*.[212]

The WWF study indicates the estimated level of reduction of energy intensity for select sectors. The main strategies identified in the WWF study include increased use of recycled material, increased retrofits and continuing improvements in BAT.

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[209] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.
[210] IEA. 2011. *Energy Transition for Industry.*
[211] TERI. 2006. *National Energy Map for India Technology Vision 2030.*
[212] WWF International. 2011. The Energy Report: 100% Renewable Energy by 2050. Avenue du Mont-Blanc, Switzerland.

The assumed levels of energy intensity reduction in the industries as estimated in the WWF study are reproduced in Table 10.5 below.

Table 10.5: Energy Intensity Reduction Potential in Industry Sector

Industry Sectors	Percentage Reduction		Strategy
	Elec	Heat	
Steel (Raw feed)	49	49	Smelt reduction process improvements, improvements in BAT, increased recycling
Cement	30	50	Reduction in clinker production, use of other material for blending by up to 40%
Paper	45	45	Increased use of recycled paper up to 75%.
Others	2/p.a.	2/p.a.	Process optimization, efficient equipments

Although the energy report also assumes increased recycling of used / unused stocks as raw materials in steel, paper and aluminum sectors, this intervention has not been explicitly factored considering the low per capita consumption of these commodities in India as compared to OECD levels.

However, considering the time lag in technology adoption in developing countries and the age of the industrial units in the state, it is assumed that these improvements in energy efficiency will take effect only from 2025. As the energy intensity reduction potential in Table 10.5 indicates the percentage potential for reduction from 2000 to 2050, the level of reductions assumed for the period 2025 to 2050 for minerals (Cement) and pulp and paper (Paper) sectors are half of the figures estimated in Table 10.5. For other industries, a 2 per cent annual reduction in energy intensity is assumed after 2025. Based on the above assumptions, the estimated energy intensity evolution across sectors scaled from a unit value of 1 in 2025 is as shown in Table 10.6 below.

Table 10.6: Assessed Energy Intensity Reduction Potential for Selected Industry Sectors

Industry Energy Share	EI Scale (Electricity)		EI Scale (Heat)	
	2025	2050	2025	2050
Agro and Food Sector	1	0.5	1	0.5
Textiles	1	0.5	1	0.5
Paper and pulp	1	0.775	1	0.775
Petrochemicals	1	0.5	1	0.5
Chemicals	1	0.5	1	0.5
Rubber	1	0.5	1	0.5
Minerals and Materials	1	0.85	1	0.75
Metals and Alloys	1	0.5	1	0.5
Engineering and Industrial Goods	1	0.5	1	0.5
Others	1	0.5	1	0.5

10.3.3 Intervention Scenario 3: Supply / Carrier Substitution

The main strategy considered in this scenario is the replacement of process heat with solar process heating applications. The PWC study assessing solar process heating potential for industry was referred.[213] The study has assessed process heat requirements across various industry sectors and has identified low-grade process heat requirements (up to 90° C) that can be supplied by commercially available Evacuated Tube Collector (ETC) and Flat Plate Collector (FPC) technologies. The study identifies agro and food processing, textiles, paper and pulp as three major sectors, where low-grade heat requirements, mainly for hot water or steam, can be replaced with solar process heating to the extent of 25 per cent. As textiles and food processing mostly use low-grade heating, a replacement potential of 15 per cent is assumed for these sectors. For paper and pulp, a substitution potential of 10 per cent is assumed. The interventions are assumed to be in place by 2030.

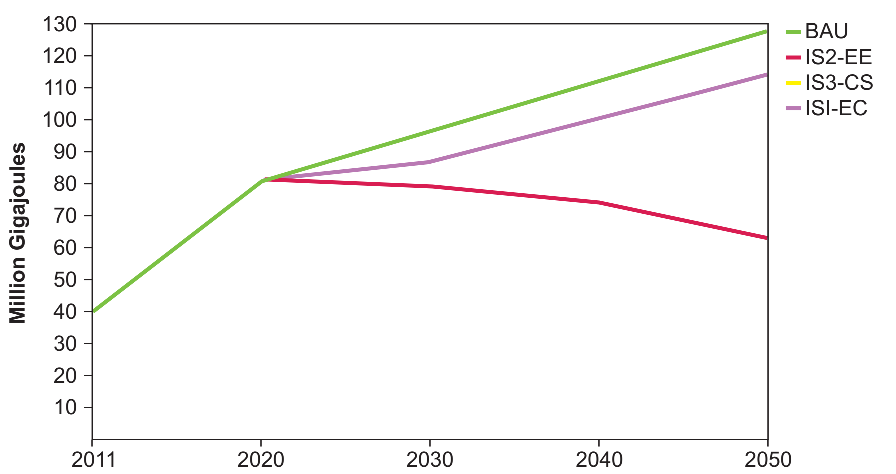
Output

Figure 10.3 and the Table 10.7 below indicate the curtailed demand of the industrial sector

Table 10.7: Energy Demand Reduction through Three Step Interventions in the Industry Sector

Industry Demand Scenarios (PJ)	2011	2020	2030	2040	2050
BAU	48.3	75.5	90	104.8	119.7
IS1-EC	48.3	75.5	78.4	91.1	103.8
IS2-EE	75.8	75.5	71.6	66.9	57.1
IS3-CS	48.3	75.5	71.6	66.8	57

Figure 10.3: Energy Demand Reduction through Three Step Interventions in the Industry Sector



213 PWC. 2011. *Identification of Industrial Sectors Promising for Commercialization of Solar Energy: Commercialisation of Solar Energy in Urban and Industrial Areas.* PricewaterhouseCoopers study on behalf of the Ministry of New and Renewable Energy, Government of India, and Federal Ministry for Environment, Germany. New Delhi, India. http://mnre.gov.in/file-manager/UserFiles/identification_of_insdustrial_sectors_promising_for%20_commercialisation_of_solar_energy_ComSolar.pdf.

10.4 AGRICULTURE: DEMAND INTERVENTION SCENARIOS

Irrigation pump-sets typically work at very low efficiencies of about 20-30 per cent because of non-standardization and improper design. Technically, for a given head and a required discharge, a customized design of pump size, pump type and piping size can actually give an efficiency of 50-60 per cent.[214] However, agricultural pump-sets and system sizing are typically based on local norms, availability and price. In many cases, locally made pumps / motors are used, which are perceived to be more robust and customized, but are less efficient as compared to branded motors.

As the electricity supply to agriculture is mostly subsidized or unmetered, there is no incentive for the farmers to install efficient equipment or use less water. Most of the strategies in addressing energy use in agriculture have focused on pump-set improvement schemes (mostly subsidy based) and water use management schemes (mostly support based).

Tractor use in agriculture is stable. This would suggest that its utilization in end-use activities is difficult to substitute. No major intervention strategy for tractors is assumed. However, the possibility of fuel substitution, diesel with biofuels has been considered as a part of the end result.

Fertilizer application in Kerala has witnessed a decrease in 2011-12 as compared to 2010-11 because of huge increase in fertilizer prices brought about by the policy migration from floating subsidy fixed price regime to fixed subsidy floating price regime. This coupled with already high input costs of seeds, labour seem to suggest a difficult time for agriculture in Kerala. In view of the emerging situation, the Agricultural Development Policy (Draft) 2013 of the government of Kerala has identified many strategies including promotion of site specific nutrient management system, management of input costs, and change in fertilizer mix. However, as the actual implementation will be site specific no quantitative assumptions have been made.

10.4.1 Intervention Scenario 1: Energy Conservation

Agricultural Development Policy (Draft) 2013, government of Kerala has identified micro-irrigation as one of the focus areas. The policy draft section on micro-irrigation includes aspects like reduced conveyance loss, reduced evaporative loss and allowing deep percolation. According to the policy draft, these measures have the potential to bring about energy savings to the tune of 30-40 per cent because of reduced water requirement and pumping. As the actual implementation potential for such a scheme is dependent on cropping choice, it is assumed that energy demand can be reduced by about 30 per cent by adopting micro-irrigation practices. As the implementation of this scheme would require considerable overhauling of institutional infrastructure and also involve capacity building, it is assumed that energy savings from micro-irrigation will kick in only after 2020, with a moderate reduction of 5 per cent by 2025, increasing to 10 per cent by 2030, 20 per cent by 2035 and will attain a saturation of 30 per cent by 2050.

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[214] Sant, Girish and Dixit, Shantanu. 1996. "Agricultural Pumping Efficiency in India: Role of Standards". *Energy for Sustainable Development.* Vol. 3(1) (May): 29–37.

10.4.2 Intervention Scenario 2: Energy Efficiency

According to the report on impact of the Energy Conservation Act, the efficiency of irrigation pump-sets can be enhanced up to 50-52 per cent by adopting BEE star labelled agricultural pump-sets, translating into a saving of about 30-40 per cent.[215] For the Intervention Scenario 2, 100 per cent replacement of all agricultural pump-sets with BEE star label pump-sets (with 35 per cent less energy consumption) is assumed to be in place by 2030.

10.4.3 Intervention Scenario 3: Supply / Carrier Substitution

The main strategy adopted for this intervention is large scale adoption of solar water pumps for agricultural pumping. Majority of the area in the state is blessed with ground water level less than 10m below ground level (bgl). Based on the report on *Ground Water Level Scenario in India*[216] it can be deduced that 87 per cent of the irrigated area has ground water level 10m bgl. Coincidentally, solar PV pumps available in market with the capacities ranging from 0.5 HP to 2 HP can easily pump water from a depth of 10 to 12m maximum for practical irrigation purpose. This is highly favourable for disseminating solar PV pumps on a large scale in Kerala which is the area yet to be fully explored by the state government.

With expected cost reductions in solar panels and increases in electricity price, it is expected that farmers will increasingly opt for solar water pumping. It is assumed that a concerted push for adoption of solar pumping can help achieve a penetration of 40 per cent by 2030 and 60 per cent by 2050. It is further assumed that branded solar pumps will have efficiencies similar to those of BEE-start rated agricultural pumps.

Output

Figure 10.4 and the Table 10.8 below indicate the curtailed demand of the Agriculture sector

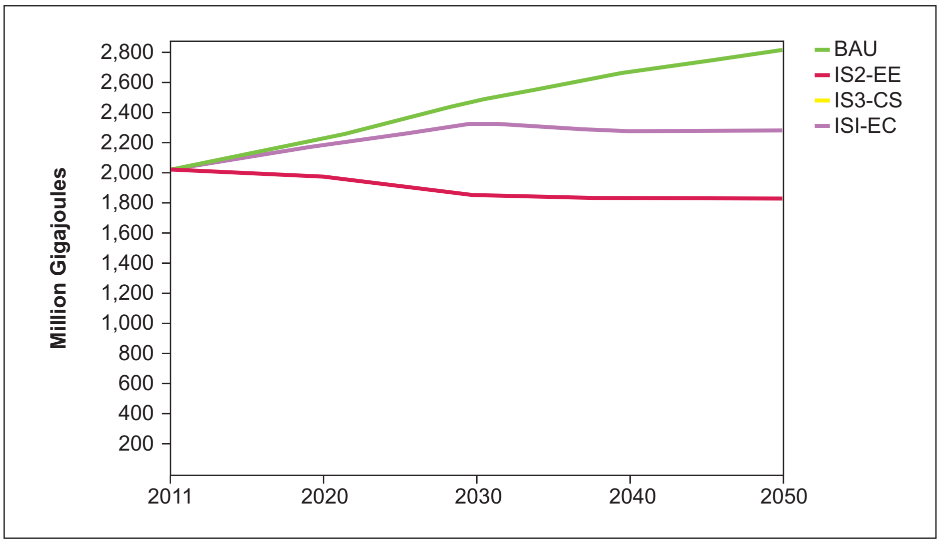
Table 10.8: Energy Demand Reduction through Three Step Interventions in Agriculture

Agricultural Demand Scenarios (PJ)	2011	2020	2030	2040	2050
BAU	2	2.2	2.5	2.7	2.8
IS1-EC	2	2.2	2.3	2.3	2.3
IS2-EE	2	2	1.8	1.8	1.8
IS3-CS	2	2	1.8	1.8	1.8

[215] Winrock. 2011. Impact of Energy Conservation Act in the State of Kerala. Winrock International India, Energy Management Centre. Kerala. http://www.keralaenergy.gov.in/emc_reports/Impact%20of%20Energy%20Conservation%20Act%20in%20the%20State%20of%20Kerala.pdf.

[216] Central Ground Water Board. 2012. Ground Water Level Scenario in India. Ministry of Water Resources, Government of India. http://cgwb.gov.in/documents/GROUND%20WATER%20LEVEL%20SCENARIO_November-12.pdf.

Figure 10.4: Energy Demand Reduction through Three Step Interventions in Agricultural



10.5 PUBLIC LIGHTING, WATER WORKS AND BULK

The main interventions that are proposed in these sectors are changes in lighting technologies, adoption of energy efficient pumps and reduction in water loss. The potential savings achieved are thus a mix of energy conservation, energy efficiency and supply substitution strategies, and have been appropriately covered.

10.5.1 Intervention Scenario 1: Energy Conservation

Energy conservation is mainly seen from the perspective of water losses in pumping. According to data from the Kerala Water Authority, the distribution loss on account of leakage in public water supply has increased from about 20 per cent in 2006-07 to about 30 per cent in 2007-09 and 25 per cent in 2009-10. This high loss in leakage roughly translates into excess energy consumption to the tune of 33 per cent. Starting from 2015, a target based intervention in pumping and line renovation is assumed with a target of 7.5 percentage point reduction every five years to reach a figure of 10 per cent loss by 2025. This translates into an energy saving potential in public works of 10 per cent by 2020 and 17 per cent by 2025 and beyond. A lower level of saving to the tune of 10 per cent by 2020 is assumed for the bulk category on account of savings in water.

According to the report by Winrock, the energy saving potential for street lighting and municipalities and corporations is assessed to be 25 per cent.[217] The energy saving potential for water works is assessed to be 20 per cent with actual achievement by 2020.

10.5.2 Intervention Scenario 2: Energy Efficiency

No specific interventions are assumed for this scenario.

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[217] Winrock. 2011. *Impact of Energy Conservation Act in the State of Kerala.* Winrock International India and Energy Management Centre, Kerala. http://www.keralaenergy.gov.in/emc_reports/Impact%20of%20Energy%20Conservation%20Act%20in%20the%20State%20of%20Kerala.pdf.

10.5.3 Intervention Scenario 3: Supply/Carrier Substitution

The main strategy considered under this intervention is replacement of 20 per cent of conventional street lights with solar street lights by 2025, 30 per cent by 2030 and 50 per cent by 2040 and beyond.

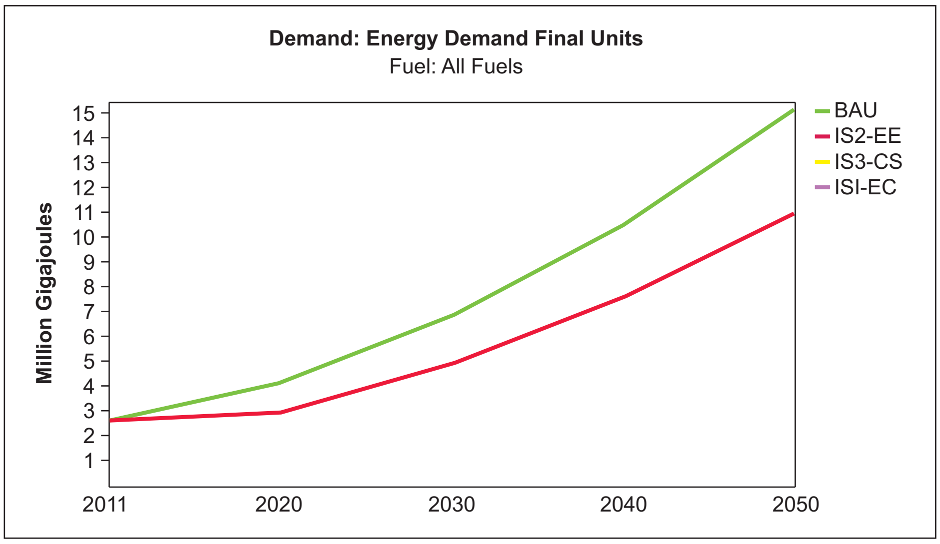
Output

Figure 10.5 and the Table 10.9 below indicate the curtailed demand of the industrial sector

Table 10.9: Energy Demand Reduction through Three Step Interventions in Agriculture

Public and Bulk Demand Scenarios (PJ)	2011	2020	2030	2040	2050
BAU	2.6	4.1	6.8	10.5	15.1
IS1-EC	2.6	3	5	7.6	11
IS2-EE	2.6	3	5	7.6	11
IS3-CS	2.6	3	5	7.6	11

Figure 10.5: Energy Demand Reduction through Three Step Interventions in Public Utilities and Bulk



10.6 TRANSPORT SCENARIO

The BAU scenario seems to confirm what many experts have already consider to be a major problem: rampant growth of personal transport. The trend is evident even without any analysis: the total number of registered vehicles in Kerala was 6.87 million as on 31 March 2012, out of which a share of 77 per cent (5.33 million vehicles) is held by two-wheelers and cars. Considering past growth in the population of registered vehicles, the total registered vehicle population is expected to cross the total household numbers in Kerala by 2015. This would perhaps make Kerala the first state to achieve this distinction.

This kind of growth in personal transport vehicles is a serious cause for concern not only from an energy perspective but also from the perspective of the state's infrastructure, which is not designed to handle this level of growth in personal vehicle population. A run of the mill solution like increasing road infrastructure, widening roads would help the state's economy (and business interests) and may even be necessary in the short run, but such a solution would just postpone the formulation of a real solution.

As many experts have pointed out, the main drivers for this level of growth in personal transport are increasing incomes and dissatisfaction with public transport modes. The growth accruing due to increase in income is natural and may not directly translate into on-road use. (Many households owning personal vehicles also use public transport. Many others owning two vehicles may use only one at a time). However, the increase in personal transport on account of dissatisfaction with existing public transport modes is directly adding to road traffic, energy use and emissions. Even more important, this shift is actually taking away revenues of the public transport system, making it less efficient and consequently less alluring to existing public transport passengers who will also eventually shift to personal vehicles. It is necessary to make an intervention before this vicious cycle reaches a tipping point.

The intervention scenarios covered in this section try to structure a transition away from this BAU growth model. The interventions suggested here are taken as policy inputs and are separately covered in Part IV of the report. Furthermore, one very effective strategy in transport sector intervention could be localization. Even though localization strategies to optimize transaction matrices and supply chains between production points and consumption centres would reduce economic activity (PKm and TKm), it would not mean any reduction in consumption but would simply imply an optimization in resource transfer process.

10.6.1 Intervention Scenario 1: Energy Conservation

The main strategy considered under energy conservation includes a move towards shared transport modes (car pool, bus pools and shared rickshaws), voluntary movement to non-motorized transport, localization, better transport management for freight and minimization of long distance travel, particularly air travel.

One of the main strategies considered for effecting energy conservation is resource pooling. Resource pooling, mainly car pooling is one of the most effective ways of reducing energy intensity and saving money. Car pooling could be an ideal way for commuting to work for service sector professionals working in clustered commercial areas (IT Parks, Industrial Parks, etc). Furthermore, corporates with staff strength of more than 100 can also take initiative to start a bus services or facilitate car pooling through shared admintrative resources. Considering the growth in urbanization and increasing growth of the services sector, even a shift of 1 per cent in the total personal on-road car transport to a car pool and 2 per cent into a pooled bus service by 2025 would have substantial impact on energy consumption. In number terms, this would mean a diversion of about 59,113 cars in 2025, but in traffic density and energy terms this would translate into an effective reduction of approximately 72.5 per cent reduction as compared to a non-intervention situation (assuming a car pool of four and a bus pool of 20 persons). At the state level, this would translate roughly into a 2.5 per cent reduction each in traffic density and energy use. In line with the proposed strategy, a target based achievement of converting 0.5 per cent of car transport into car pool and 1 per cent into bus pool is assumed by 2025. This would mean an effective reduction of 1.5 per cent cars on account of car pool.

Another workable resource pooling strategy could be shared rickshaws/taxi services. Shared rickshaws are actually working very effectively in large urban areas and provide better frequency and a comfortable last mile travel on high density routes, which cannot be otherwise frequently serviced by buses. The focus strategy here is development of such a hub and wheel shared transport infrastructure that connects bus/rail passengers from hub locations to last mile destinations through shared rickshaw/taxi transport. Development of such an infrastructure would be the starting point of large scale modal migration especially from two-wheelers to shared bus and rickshaw transport. It is assumed that 5 per cent of the rickshaw population is converted into a pooled rickshaw service by 2020. This would mean a reduction of 10 per cent in the total distance travelled.

In addition, a moderate level of voluntary shifting from personal motorized transport to non-motorized transport or walking is also assumed. This shift would not necessarily mean a reduction in consumption but would mean a reduction in intensity of use. (Even though in reality, there could be involuntary shifts from motorized transport on account of increasing fuel prices or medium term disruptions in supplies, such changes have not been factored. A shift of 5 per cent of motorized transport (mainly from cars) to non-motorized modes is assumed to be in place by 2030.

It is very difficult to quantify localization potential even though there could be numerous ways in which such localization would work. One simple way would be to use fresh milk instead of relying on pasteurized milk. This simple measure would not only reduce the cost of transport but would also result in consumers getting a fresher stock. Another very effective strategy could be use of locally available building material (laterite, bamboo, wood, clay, etc) for construction. This would not only reduce the material and the added transport costs, but would also result in a more climate friendly building design with reduced energy needs. The strategy of using local material for construction is not new; there are live examples and the proof of the concept is already established in some existing buildings in Kerala. As the real estate sector is a major growth activity hub in Kerala and construction materials comprise a large share of intra-state freight transport, increasingly stringent building norms on sustainable construction practices will bring about a reduction in associated transportation needs. However, in the absence of data, the potential of localization for energy reduction has not been estimated.

Indian trucking industry is very energy intensive and is also very inefficient. The current maximum annual running distance of HCVs is to the tune of 75,000 km as against an annual running distance of 175,000 to 200,000 km by HCVs in advanced countries. Past studies on Indian trucking industry efficiency consistently point out that the reasons for the low kilometerage include bad roads, inefficient loading/unloading practices, bad driving and excessive waiting times at check points and other clearance points. According to the report of JPS Associates on trucking economics, the average running time for short trips (within 500 km) was only 33 per cent of the total trip time as against 20 per cent time spent at check posts and official stops and about 17 per cent time spent in traffic congestion.[218] To a limited extent, the state can smoothen these processes within its border. Most of the energy consumed during these waiting periods and traffic jams is going towards

[218] JPS Associates. 2011. *Study on Economics of Trucking Industry.* JPS Associates (P) Ltd. Report submitted to the Ministry of Shipping, Road Transport and Highways. New Delhi. India.

idling or low speed driving, which is very fuel inefficient. In addition, past studies also emphasize that better driving practices have the potential to reduce energy intensity by about 10 per cent.[219] It is assumed that a combination of better road surfaces, better check posts management and mandatory driving courses for trucking industry can effect a reduction of 15 per cent in fuel consumption. This intervention is assumed to come into effect by 2030.

Air travel is another area which consumes very high energy. In contrast to developed nations, majority of the domestic air travel in India is for business reasons. It is assumed that much of this travel can be avoided by use of modern communication technologies (video-conferencing, skype, conference video calls, etc). Corporates can be requested to the curb all non-essential travel and use alternative communication techniques. However, in the absence of any basis for quantification, a target of 30 per cent is assumed starting 2025.

10.6.2 Intervention Scenario 2: Energy Efficiency

The four main strategies adopted in this intervention scenario are

a) Inter-modal Shift
b) Intra-modal Shift
c) Policy driven migration to higher efficiency vehicles
d) Changes in energy intensities of technologies

The modal shift strategies identified for intervention are inter-modal shift from road to rail or bus and intra-modal shift from cars to buses in case of passengers and four-wheelers to three wheelers in case of freight. The inter-modal shift strategy proposed here does not compromise economic activity as the total traffic (PKm and TKm) are the same as that projected in the reference (BAU) scenario.

a) Inter-modal Shift

The modal shares estimated in the BAU scenario for passenger and freight traffic are reproduced in Table 10.10 below.

Table 10.10: Modal Share in BAU scenario

Modal Share Passenger (BAU) %	2011	2015	2020	2030	2040	2050
Road	92.1	95.2	95.7	95.7	95.2	94.8
Rail	7.4	4.2	3.5	3	2.6	2.3
Air	0.4	0.5	0.7	1.1	2	2.8
Water	0.1	0.1	0.1	0.1	0.1	0.1
Modal Share Freight (BAU) %	**2011**	**2015**	**2020**	**2030**	**2040**	**2050**
Road	83.6	81.6	82.67	84.94	87.75	89.84
Rail	7.99	10.7	10.56	10.02	8.77	7.7
Air	0.02	0	0.01	0	0	0
Water	8.42	7.7	6.76	5.04	3.49	2.46

[219] UNEP. 2011. *Transport: Investing in Energy and Resource Efficiency.* United Nations Environment Programme. UK. http://www.unep.org/transport/lowcarbon/newsletter/pdf/GER_10_Transport.pdf.

Roads dominate both passenger and freight traffic. From an energy and traffic perspective, the most effective strategy in the inter-modal shift would be a move away from less efficient and highly congested road transport to rail or water transport. The main strategy is an aggressive shift in passenger and traffic volumes from roads to railway. Considering the high density of population in coastal areas and existing presence of rail from north to south, it is assumed that such a shift can be made much more easily in Kerala.

The greatest possibility lies in shifting traffic from contract carriages (long distance inter-city/inter-state buses) to rail. The most potent way to effect this modal shift could be to increase the frequency and effectiveness of rail, so that it can run like a fast local between nearby stations. In this context, use of fast suburban trains similar to those used in Mumbai can be very effective in meeting both short distance and long distance traffic demand. However, in this context, even a moderate increase in rail share from 3.2 per cent in 2030 to the present (2011) share of 7.5 per cent would imply an additional passenger handling capacity of 34.5 billion PKm over the 13.8 billion PKm existing capacity in 2030. This level of additional infrastructure requirement necessitates clear understanding of the technical and commercial feasibility of the proposed modal shift. In view of this, no specific intervention quantification is assumed for this modal shift but this modal shift strategy is clearly marked as an intervention that can be studied in detail by the state.

For understanding the level of possible modal shift of freight from road to coastal mode, Deloitte study on coastal Transport was referred.[220] The study assessed the feasibility of diverting traffic to coastal mode. It considered all major and non-major ports and assessed the economic benefit of shifting freight traffic from roads/rail to coastal mode. The study made an end-to-end cost comparison between inland + coastal + Inland) mode vis-à-vis all road and all rail mode for main corridors that included inter-state routes from Gujarat, Rajasthan, Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh, and found that there was an economic case for shifting a part of the inter-state road freight to coastal mode. The assessed divertible traffic from road to coastal transport was estimated at 12.34 and 17.31 million tonnes in 2014-15 and 2019-20, respectively. Assuming an average coastal travel distance of 1,027 nautical miles or 1,900km (the average distance of major ports in the trading states), the total divertible freight traffic in billion TKm was assessed at 23.4 billion TKm and 32.8 billion TKm in 2014-15 and 2019-20 as compared to the projected values of 7.5 and 7.9 billion TKm, respectively. To factor in the possibility of future diversion of cargo, the volume of water cargo was increased to 32.8 billion TKm in 2020 and its share in 2020 (amounting to 22 per cent) was kept constant for the projection period. To reflect the modal shift, the share of roads in freight was reduced. It is to be noted that while pointing out the possibility of diversion, the Deloiitte study also made recommendations on enhancing infrastructure across major ports and non-major ports for facilitating such a diversion. The study recommendations suggested low potential for diversion of passengers from road/rail to coastal and hence no modal shift in passenger traffic to coastal is assumed.

[220] Deloitte. 2011. *Preparation of Strategy Road Map cum Action Plan for Development of Coastal Shipping.*

It is further assumed that increased electrification and increased prices of petroleum fuels (diesel) will make rail more economical for freight traffic movement over time and assume an increase in share of rail from about 10 per cent to 25 per cent by 2050. Understandably, such a shift would necessitate better infrastructure and transport architecture to facilitate last mile delivery systems that work from large hubs and move radically outwards. It is assumed that such an infrastructure will increasingly be provided by all electric vehicles plying on roads.

Based on the above assumptions, the proposed inter-modal shift is shown in Table 10.11 below.

Table 10.11: Proposed Inter-modal Shift

Modal Share Passenger (BAU) %	2011	2015	2020	2030	2040	2050
Road	92.1	95.5	96	70.7	68.7	66.2
Rail	7.4	3.7	3.1	27.8	28.6	30
Air	0.4	0.5	0.7	1.1	2	2.8
Water	0.1	0.3	0.2	0.4	0.7	1
Modal Share Freight (BAU) %	**2011**	**2015**	**2020**	**2030**	**2040**	**2050**
Road	84	81	68	63	58	53
Rail	8	11	10	15	20	25
Air	0	0	0	0	0	0
Water	8	8	22	22	22	22

Assumptions

b) Intra-modal Shift

The second strategy adopted is a shift in intra-modal share in roads from more energy intensive modes (cars and two-wheelers) to buses. The existing and projected passenger and freight share between public (buses) and private modes (cars and two-wheelers) is as shown in Table 10.12 below.

Table 10.12: Road Passenger Intra-modal Share in BAU Scenario

Modal Share Road Passenger %	2011	2020	2030	2040	2050
Buses Long Distance	65.6	67.3	67.4	64.2	57.6
Buses	13.6	11	10	8.8	7.5
Three Wheelers	7.5	6.3	5.1	4.5	3.8
Jeeps	0.1	0.1	0	0	0
Taxi Cars	3.2	2.8	2.7	2.7	2.8
Cars	2.6	3.6	4.4	6.4	12.6
Two Wheelers	7.5	8.9	10.4	13.3	15.7

Assumptions

Ironically, the rapid increase in share of cars and two-wheelers not only adds to the traffic but also adds exponentially to the energy demand as these modes are very energy intensive as compared to public transport modes. The main strategy presumed here is to freeze the share of personal vehicles in total passenger volume in 2030 at 2020 levels. This can be done provided public transport is strengthened, improved and overhauled to absorb the migration.

In line with the delineated strategies, it is assumed that the share of cars in total passenger transport traffic can be brought down to 2020 levels by 2030. For two-wheelers, a more ambitious target of freezing the two-wheeler share to 9 per cent from 2030 as compared to 8.76 in 2011 is assumed. This would mean a moderate increase in activity of two-wheelers as compared to present levels. It is further assumed that the decrease in the share of two-wheelers is transferred to short distance buses (stage carriages) and shared rickshaws, while that of cars is transferred to long-distance buses (contract carriages) and short-distance buses (stage carriages). The share of autorickshaws is assumed to stay at the 2011 levels. Based on the above, the final intra-modal share of passenger vehicles is as shown in Table 10.13 below.

Table 10.13: Proposed Intra-modal Share for Road Passenger Traffic

Modal Share Road Passenger %	2011	2020	2030	2040	2050
Buses Long Distance	65.6	66	64	60	56
Buses	13.6	10	11	14	19
Three -wheelers	7.5	8	8	8	8
Jeeps	0.1	0	0	0	0
Taxi Cars	3.2	3	3	3	3
Cars	2.6	4	4	4	4
Two-wheelers	7.5	9	9	9	9

Assumptions

c) Policy Driven Migration towards More Efficient Vehicles

In the reference scenario, the vehicle technology penetration of new technologies (hybrid, four-stroke, CNG, etc) was curtailed at 20 per cent to reflect the fact that technology changes were happening by market forces without any policy push. However, a focused policy migration towards early adoption of more efficient technologies is identified as a key intervention. Technology adoption is a slow process in developing economies, but government and institutional support in technology transfer, target-based regulation, capacity building and media campaigns have the potential to significantly accelerate technology adoption. It is assumed that this happens in the form of a new transport technology policy that defines technologies of choice and stipulates timeframes for addition of new technologies. For example, the energy intensity of a four-stroke motorcycle is about 62 per cent less than that of a two-stroke motorcycle while the energy intensity of a diesel hybrid bus is 69 per cent less than that of a normal diesel bus. Considering an average vehicular life of 8-15 years, a strong policy stipulation in 2020 supporting efficient technology breeds can affect 100 per cent penetration of new efficient technologies latest by 2035. It is assumed that 100 per cent penetration of efficient technologies happens by 2040. The following table summarizes the values. (This scenario does not assume any change in the penetration of electric vehicles compared to a BAU scenario as the intervention from EVs are considered in the last scenario separately.)

The revised penetration of road vehicle technologies is shown in Table 10.14 below.

Assumptions

Table 10.14: Proposed Efficiency-based Technology Share

Stage Carriages (% Share)	2011	2020	2030	2040	2050
Diesel	100	90	25	0	0
CNG	0	5	10	5	0
Hybrid	0	5	60	90	95
Electricity	0	0	5	5	5
Contract Carriages (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Diesel	100	95	40	0	0
CNG	0	2	5	0	0
Hybrid	0	3	55	100	100
Rickshaws (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Gasoline	100	70	30	0	0
CNG	0	10	10	0	0
Hybrid Gasoline	0	10	40	45	45
Hybrid CNG	0	10	20	50	50
All Electric	0	0	0	5	5
Taxis (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Gasoline	10	5	0	0	0
Diesel	90	70	50	0	0
Hybrid Gasoline	0	5	10	10	10
Hybrid Diesel	0	20	40	90	90
Cars (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Gasoline	65	50	20	0	0
Diesel	35	25	10	0	0
CNG	0	5	10	0	0
Hybrid Gasoline	0	10	45	80	80
Hybrid Diesel	0	10	10	10	10
EV	0	0	5	10	10
Jeeps (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Diesel	100	90	50	0	0
Hybrid Diesel	0	10	50	100	100
Two Wheelers (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Petrol Two-Stroke	80	60	30	0	0
Petrol Four-Stroke	20	35	60	85	80
EV	0	5	10	15	20
HCVs (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Diesel	100	85	50	10	0
Hybrid Diesel	0	15	50	90	100
LCVs (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Diesel	100	95	70	0	0
Hybrid Diesel	0	5	25	90	90
EV	0	0	5	10	10

d) Changes in Energy Intensity of Different Technologies
The BAU scenario already assumes 10 per cent change in energy intensity of existing vehicles and 15 per cent in new technologies over the projection period for road vehicles. However, based on assessment of *The Energy Report,*[221] the potential for reducing energy intensity of air and water travel is to the tune of 50 per cent. The study assumes that the main reduction potential for air traffic could come from improvements in airframe and engine design, gains from air traffic management, etc while that for ship freight would be from propeller and hull maintenance and upgrades, operational improvements, etc. In line with the assumptions of the study, an energy intensity reduction of 40 per cent for air and water modes is assumed over the projection period.

10.6.3 Intervention Scenario 3: Carrier Substitution

The main strategy for this intervention is a mission-mode migration towards electric mobility. Electric vehicles are already a reality. Tesla Motors in the USA has already developed and commercialized luxury electric sedan model (Model S) that has a range of 480 kmph, a top speed of 192 kmph and a fuel efficiency of about 0.15 kWh/km at a speed of 80 Kmph. In energy terms, this translates into an energy intensity that is 20 per cent of the energy intensity of current breed of gasoline based cars. All electric buses are also commercially available today. BYD, a European manufacturer has already rolled out an all electric bus with a capacity of about 60-70 passengers and a fuel efficiency of 1.04 kWh/km, about two times more efficient than an existing diesel bus. China and Japan have already committed to large scale adoption of electric hybrids and full electric vehicles, earmarking billions of dollars into R&D, development and infrastructural support. China already has a significant penetration of electric two-wheelers.

The idea of a mission-mode migration has already been mooted at the central government level with the announcement of the National Electric Mobility Mission Plan (NEMMP) 2020.[222] The NEMMP 2020 acknowledges that the past attempts at electric mobility were not very successful because of high costs, battery technology constraints, consumer mindset and lack of a coherent centralized vision. The projections for demand of all electric and hybrid electric vehicles by 2020 indicate a national-level demand of about 3.5-5 million two-wheelers, 0.2 to 0.4 million other all electric vehicles (cars, three-wheelers, buses) and 1-3-1.4 million demand for electric hybrids. The NEMMP underscores the demand projections with the fact that these projections would come to fruition only with adequate government support for industry.

Considering Kerala's industrial policy focus on non-polluting and value creating industry, Kerala could be one of the best placed states to promote manufacturing of EVs and formulate a state mission for EV penetration. For this scenario, it is assumed that aggressive penetration targets for EVs are met only by 2030 considering the long gestation of technology development and commercialization. The main thrust modes for promoting EVs are two-wheelers, three-wheelers, cars,

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[221] WWF International. 2011. *The Energy Report: 100% Renewable Energy by 2050.* Avenue du Mont-Blanc, Switzerland.
[222] Department of Heavy Industry. 2012. *National Electric Mobility Mission Plan 2020.* Ministry of Heavy Industries & Public Enterprises, Government of India. New Delhi, India. http://dhi.nic.in/NEMMP2020.pdf.

stage carriages, light commercial vehicles. A 50 per cent or greater than 50 per cent share of EVs by 2050 is assumed in the chosen categories.

Assumptions

The following Table 10.15 shows the proposed penetration level of EVs in the technology mix.

Table 10.15: Proposed All Electric Vehicle Penetration

Stage Carriages (% Share)	2011	2020	2030	2040	2050
Diesel	100	90	25	0	0
CNG	0	5	10	0	0
Hybrid	0	5	60	80	50
Electricity	0	0	5	20	50
Rickshaws (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Gasoline	100	70	30	0	0
CNG	0	10	10	0	0
Hybrid Gasoline	0	10	20	35	25
Hybrid CNG	0	10	40	35	25
All Electric	0	0	0	30	50
Cars (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Gasoline	65	50	20	0	0
Diesel	35	25	5	0	0
CNG	0	5	10	0	0
Hybrid Gasoline	0	10	45	60	30
Hybrid Diesel	0	10	10	10	0
EV	0	0	10	30	70
Two Wheelers (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Petrol Two Stroke	80	60	30	0	0
Petrol Four Stroke	20	35	60	60	20
EV	0	5	10	40	80
LCVs (% Share)	**2011**	**2020**	**2030**	**2040**	**2050**
Diesel	100	95	70	25	0
Hybrid Diesel	0	5	25	55	50
EV	0	0	5	20	50

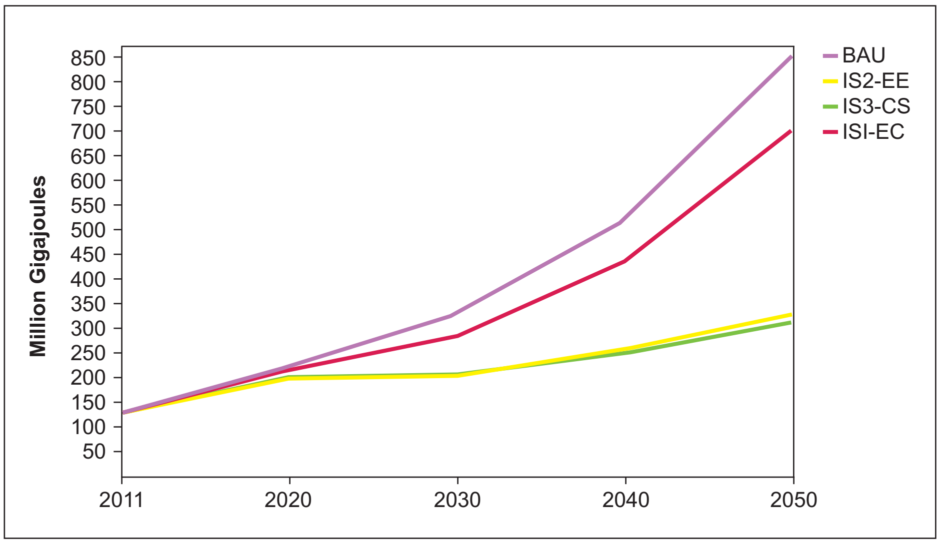
Based on the above interventions, the final curtailed demand for the transport sector is as shown in Table 10.16 and Figure 10.6 below

Output

Table 10.16: Energy Demand Reduction through Three Step Interventions in the Transport Sector

Transport Energy Demand (PJ) - Scenarios	2011	2020	2030	2040	2050
BAU	128.2	225.2	329.3	520.9	853.5
IS1-EC	128.2	224.6	285.7	439.8	705.6
IS2-EE	128.2	204.6	222.8	271.6	339.6
IS3-CS	128.2	204.6	220.6	262.5	317.6

Figure 10.6: Energy Demand Reduction through Three Step Interventions in the Transport Sector



10.7 THE CURTAILED DEMAND SCENARIO FOR THE STATE UP TO 2050: FINAL OUTPUT

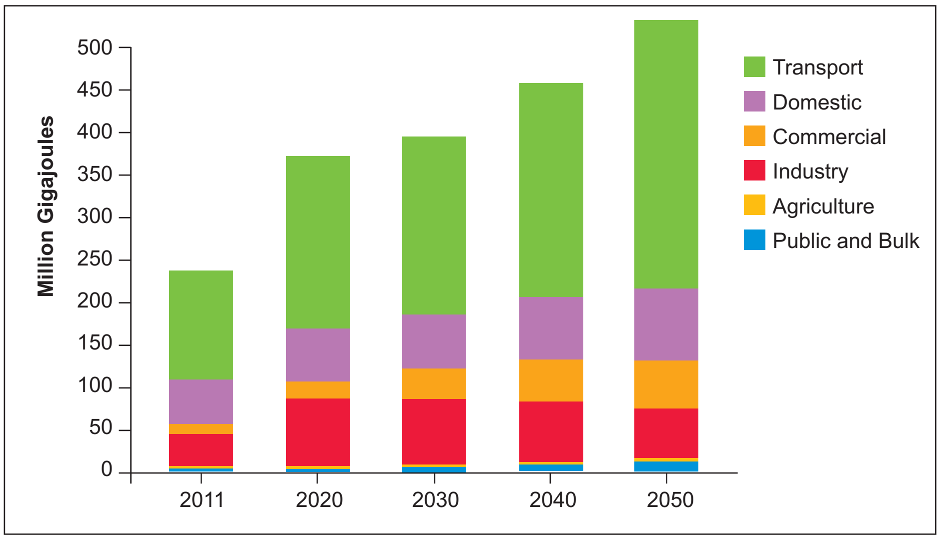
The following Tables 10.17, 10.18, 10.19 and 10.20, and Figures 10.7, 10.8, 10.9 and 10.10 summarize the result of the interventions.

10.7.1 Output 1: Final Curtailed Demand Scenario (Sectoral)

Table 10.17: Final Curtailed Sectoral Demand (PJ)

Curtailed Energy Demand (PJ)	2011	2020	2030	2040	2050
Transport	128.2	204.6	220.6	262.5	317.6
Domestic	54.4	63.4	63.9	73.3	87.7
Commercial	12.2	20.6	36	49.2	54.1
Industry	48.3	75.8	71.6	66.8	57
Agriculture	2	2	1.8	1.8	1.8
Public and Bulk	2.6	3	5	7.6	11
Total	247.7	369.3	399	461.2	529.2

Figure 10.7: Final Curtailed Sectoral Demand

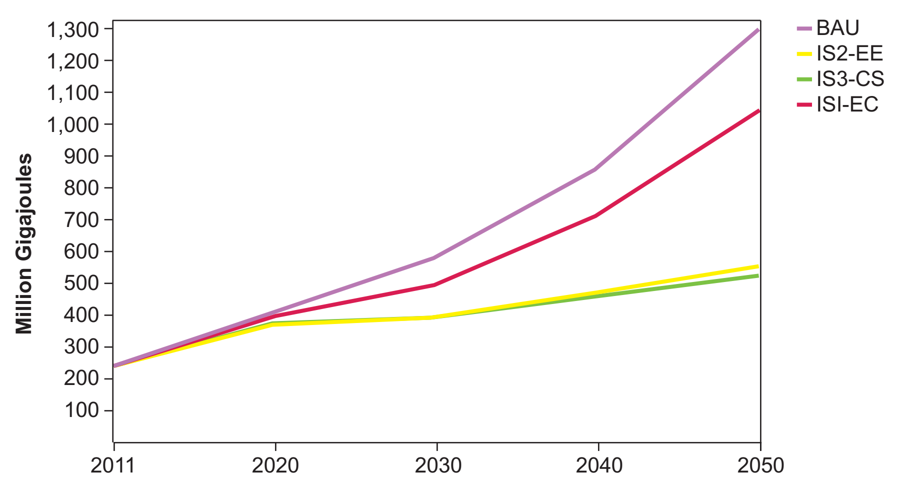


10.7.2 Output 2: Energy Demand Reduction Potential (Scenario Wise)

Table 10.18: Final Energy Reduction Evolution through Three Step Intervention

Total Energy Demand (PJ) - Scenarios	2011	2020	2030	2040	2050
BAU	247.7	400.8	576.2	858.6	1,294.5
IS1-EC	247.7	393.9	490.4	708.6	1,037.3
IS2-EE	247.7	368.3	401.4	473.3	558.5
IS3-CS	247.7	369.3	399	461.2	529.2

Figure 10.8: Final Energy Reduction Evolution through Three Step Intervention

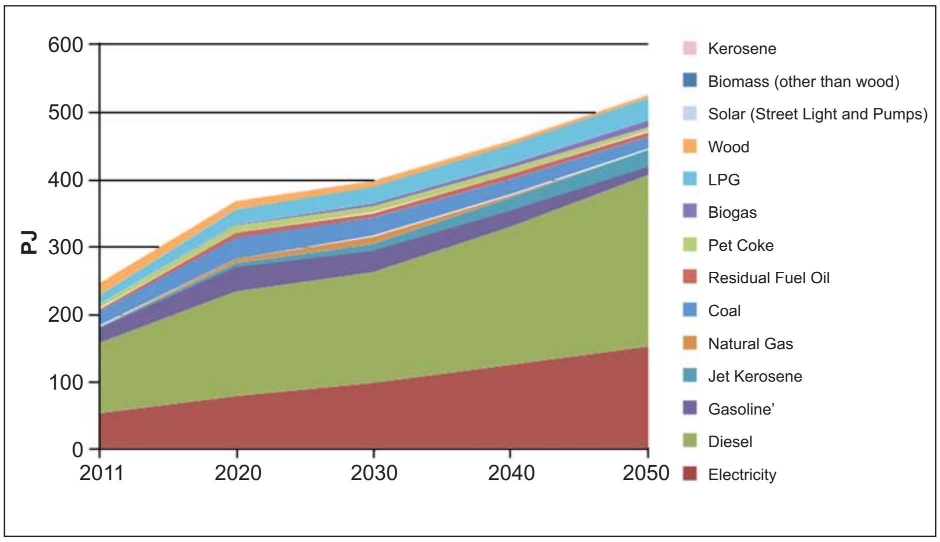


10.7.3 Output 3: Final Curtailed Energy Demand (Energy Supply Sources)

Table 10.19: Final Curtailed Energy Demand by Energy Sources

Energy Demand by Fuels (PJ)	2011	2020	2030	2040	2050
Electricity	54.5	78.9	98.9	126.5	153.2
Diesel	102.8	155.8	163.7	204.4	253.7
Gasoline	22.4	36.7	33.2	25.1	13.5
Jet Kerosene	2.8	6.3	10.4	18.6	25
Natural Gas	0	5	10.2	3.5	0
Coal	21.7	32.2	27.4	23.2	18.6
Residual Fuel Oil	3.6	6.3	7.2	7.4	6.6
Pet Coke	7.2	10.6	9.2	7.9	6.6
Biogas	0.1	1	4.1	7.3	10.7
LPG	13.6	23.6	25.9	29.2	33.4
Wood	18.9	12.5	8.2	6.3	5.1
Solar (Street Lights and Pumps)	0	0.12	0.46	1.43	2.19
Biomass (other than wood)	0.02	0	0	0	0
Kerosene	0.17	0.18	0.26	0.36	0.52
Total	**247.7**	**369.3**	**399**	**461.2**	**529.2**

Figure 10.9: Final Curtailed Energy Demand by Energy Sources



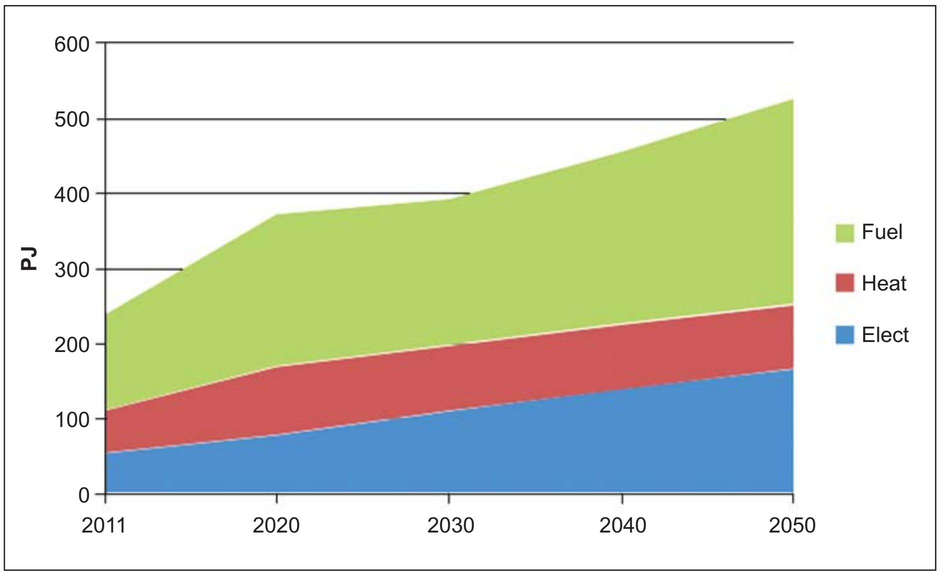
10.7.4 Output 4: Final Curtailed Energy Demand (Energy Carriers)

The proposed interventions indicate a reduction of more than 50 per cent in energy demand. But even the curtailed demand represents an increase of about 2.2 times in energy demand. In this background, the possibility of meeting the required demand would mean assured availability of energy supply sources. And this assurance can only come from renewable resources. The next chapter tries to assess the feasibility of meeting the required energy demand through renewable resources.

Table 10.20: Final Curtailed Energy Demand by Energy Carriers

Energy Demand	Unit	2011	2020	2030	2040	2050
Electricity	BU	15.1	21.9	27.5	35.1	42.5
Heat	PJ	65.3	86.38	82.24	81.67	81.51
Fuel	mtoe	3.05	4.87	5.19	6.0	6.97

Figure 10.10: Electricity, Heat and Fuel Demand in PJ for the Curtailed Scenario



11. TOWARDS 100% RE: OVERVIEW OF SUPPLY POTENTIAL

Summary

After the estimation of curtailed demand in the Chapter 9, this chapter tries to summarize and tweak the renewable supply options and their possible availability within the time horizon of the study. The main objective of this chapter is to estimate energy availability from RE over the projection timeframe.

11.1 OVERVIEW OF SUPPLY OPTIONS

The following narrative summarizes the result of the RE potential assessment based on technology.

11.1.1 Wind Power

The total wind potential estimated in the study indicates a total onshore potential of 7,353 MW and an offshore potential of 41,447 MW. The potential figures for onshore include potential area with a wind power density (WPD) of over 150 W/m^2. The assessment also includes potential of three land use categories: non-irrigated farmland, no farmland (wasteland and grassland) and plantations. This categorization of land use is consistent with actual practice in other states with wind installations, where wind turbines co-exist with farming. In Part II, the actual land requirement was also assessed based on a footprint model of development. A footprint model implies that turbine occupies a limited area to the extent of its foundation and sub-station, leaving the remaining land for other productive uses (see the section on wind in Part II for more details).

Table 11.1 below summarizes the results.

Table 11.1: Estimated Grid-tied Wind Power Potential at 80m

Onshore Wind	WPD > 150		200 < WPD < 250		WPD>250	
Potential	Area (km^2)	MW	Area (km^2)	MW	Area (km^2)	MW
Farmland	443.3	3,103.1	269	1,883	48	336
No Farmland	93.5	654.5	61.3	429	2.6	18.2
Plantation	513.7	3,595.9	202	1,414	55	385
Total	**1,050.5**	**7,353.5**	**532.3**	**3726**	**105.6**	**739**
Offshore Wind	**WPD > 200**		**250 <WPD< 300**		**WPD > 300**	
Potential	**Area (km^2)**	**MW**	**Area (km^2)**	**MW**	**Area (km^2)**	**MW**
Offshore (80m)	5,921	4,1447	1370	9,590	551	3,875

The total land diversion assessed for 100 per cent of this potential would mean an actual land diversion of about 0.38 per cent of the total land. While this is a small figure, 100 per cent utilization is not anticipated. The criteria employed to allocate percentage utilization is based on the wind resource quality. The total potential is distributed in two bins: medium-grade potential (WPD 200-250) and high-grade potential (WPD>250). This works out to be 3,726 and 739 MW, respectively and it is assumed that this potential can be fully harnessed within the projection period. Furthermore, considering future development of technologies and penetration of turbines designed for low-wind regimes, it is assumed that even low grade potential would be available beyond 2040 and an additional 1,000 MW of this low grade wind potential can be achieved by 2050.

In offshore, a similar analysis based on resource quality indicates a medium-grade potential of 9,590 MW and high-grade potential of 3,875 MW. Even though high-grade potential can be fully harnessed, an actual deployable potential of only about 1,800 MW (about 45 per cent) is assumed by 2050. This utilization is assumed to factor in considerable complexities in actual offshore development and competing demands from other sectors (fisheries, freight traffic, etc). Based on the above assessments, a constant level of deployment is assumed. The available capacity and energy availability from wind based on these assumptions is shown in Table 11.2 below.

Table 11.2: Assessed Energy Availability from Wind Power

Wind Power	CUF	2011	2020	2030	2040	2050
Wind Onshore	22%	35	2,981	3,223	4,465	5,465
Wind Offshore	25%	0		300	900	1,800
Energy availability (BU)	NA	0.06	3.82	6.87	10.58	14.47

11.1.2 Solar Power

The following table summarizes the potential for solar power. It is assumed that grid-tied solar PV potential of 4,273 MW in wasteland and 2,543 MW in grassland area is feasible as the land use considered in the analysis can be made available. However, development of full potential would take time. It is assessed that 100 per cent utilization of grid-tied PV capacities can only happen by 2030. No deployment of large scale solar CSP plants is assumed. (see section on Solar Energy Assessment in Part II).

Considering the momentum of present PV development in the state, it is assessed that the projected decentralized PV potential of 31,145 MW can be harnessed. However, considering capital constraints and variation in roof availability factors over time, only 50 per cent development of this potential is assumed by 2050. Table 11.3 summarizes the estimated potential.

Table 11.3: Estimated Grid-tied and Off-grif Solar PV Potential

A	Grid-tied solar PV potential	Potential	Units
1	Wasteland	4,273	MW
2	Grassland	2,543	MW
3	Floating PV	3,850	MW
C	**Decentralized Solar PV Potential in Kerala**	**Potential**	**Units**
1	Households	13,079	MW
2	Institution / commercial buildings	18,066	MW

Based on the above considerations the total power and energy availability over the years is shown in Table 11.4 below.

Table 11.4: Assessed Energy Availability from Solar Power

Solar PV	CUF	2011	2020	2030	2040	2050
Land based Grid tied PV (MW)	16%	0	300	1,000	2,500	4,500
Grid-tied Floating PV (MW)	16%	0	200	500	1,000	2,300
Off Grid PV (MW)	16%	0	1,000	4,000	8,000	15,000
Energy availability (BU)	NA	0	2.1	7.71	16.13	30.55

11.1.3 Biomass Power

The potential for bioenergy has been estimated based on assessed biomass resource availability over the projection period. As the bioenergy estimates have already provided projected value of biomass resources, it is assumed that these values are reflective of actual utilizable potential. The results of bioenergy estimation and the energy availability are summarized in Table 11.5 for reference.

Table 11.5: Estimated Bio-energy Potential

Biomass Energy	2011	2020	2030	2040	2050
Biomass Electricity (MU)	0.31	0.44	0.56	0.66	0.79
Biomass Heat (PJ)	20.8	23.4	25.45	27.62	30.8
Bio-fuels (mtoe)	0	0	6.8	13.6	15.5

Note: For details on biomass, please refer to Chapter 6 (Part II) on Sustainable Bio-energy Assessment.

11.1.4 Hydro Power

Based on the assessment in Part II, the prospective value of future hydro potential is about 540 MW of small hydro. This is in addition to about 140 MW installed SHP capacity today. It is assumed that all of this capacity can be made available from 2030 onwards. In addition, existing large hydro is also considered as a renewable energy supply source considering that built hydro has no environmental externalities. Table 11.6 below summarizes the assessed energy availability from hydro power.

Table 11.6: Assessed Energy Availability from Large and Small Hydro

Small Hydro	CUF	2011	2020	2030	2040	2050
SHP (MW)	50%	154	270	540	540	540
Hydro (MW)	65%	1998	1998	1998	1998	1998
Hydro Generation (BU)		12.05	12.6	13.7	13.7	13.7

11.1.5 Wave Power

The assessed potential for wave power is 420 MW (assuming only 10 per cent of the total wave power potential of the state is available for utilization). It is assumed that this potential can be utilized in stages to achieve 100 per cent utilization by 2050. Table 11.7 shows the assessed energy availability from wave power.

Table 11.7: Assessed Energy Availability from Wave Power

Wave Energy	CUF	2011	2020	2030	2040	2050
Wave Potential (MW)	10%	0	50	150	250	420
Energy Generation (BU)		0	0.04	0.13	0.22	0.37

11.2 SUMMARY OF RENEWABLE SUPPLY OPTIONS: OUTPUT

Table 11.8 consolidates the energy supply projections for the state.

Table 11.8: Assessed Total Energy Availability

RE Supply Potential	2011	2020	2030	2040	2050
Electricity (BU)	12.42	18.94	29.09	41.39	59.97
Heat (PJ)	20.8	23.4	25.45	27.62	30.8
Fuels (mtoe)	0	0	6.8	13.6	15.5

RE electricity supply sources include onshore and offshore wind, grid-tied centralized and decentralized PV, large and small hydro, biomass and wave power. The main heating fuels considered in the supply potential figures include wood (rubber wood and forest timber) and biogas based on organic MSW, tapioca wastes and animal wastes. The main fuel sources include biofuels derived from coconut fronds, tapioca, cashew-nut apple, and algal oil.

12. THE 100% RE SCENARIO

Summary

The main objective of this chapter is to assess the possibility of meeting 100 per cent of energy demand through RE resources by 2050. Table 12.1 summarizes the RE supply potential with curtailed demand across carriers.

Table 12.1: Energy Demand Requirements and Supply Potential

Demand Requirements (Curtailed Demand)	2011	2020	2030	2040	2050
Electricity (BU)	15.1	21.9	27.5	35.1	42.5
Heat (PJ)	65.3	86.38	82.24	81.67	81.51
Fuels (mtoe)	3.05	4.87	5.19	6.0	6.97
RE Supply Potential	**2011**	**2020**	**2030**	**2040**	**2050**
Electricity (BU)	12.42	18.94	29.09	41.39	59.97
Heat (PJ)	20.8	23.4	25.45	27.62	30.8
Fuels (mtoe)	0	0	6.8	13.6	15.5

12.1 MATCHING SUPPLY AND DEMAND

Even though Table 12.1 gives a broad picture of the availability and the demand, other considerations like suitability, source matching and fuel matching play a major role in determining if available sources can meet the demand requirements in a holistic manner. The following sections try to assess this suitability across different energy carriers.

12.1.1 Electricity

Table 12.1 above indicates the electricity supply requirements corresponding to the curtailed demand scenario. However, the electricity supply requirements in Table 12.1 do not consider T&D losses which would inflate the supply side requirements.

T&D losses have been up to 2050 by extrapolating the T&D losses projections made by CEA in the 18th EPS report.[223] Based on the results, the estimated T&D losses and the actual supply requirements for electricity are calculated in the Table 12.2 below.

Table 12.2: Total Electricity Requirements after Including T&D Losses

Supply Potential	2011	2020	2030	2040	2050
Electricity Demand (BU)	15.1	21.9	27.5	35.1	42.5
T&D losses (%)	19	14.8	12.13	10.15	8.55
Supply Requirement (%)	18.6	26.32	31.29	39.06	46.47

[223] CEA. 2011. *Report on Eighteenth Electric Power Survey of India.*

Table 12.3 below indicates source-wise energy availability for electricity as estimated in the last section.

Table 12.3: Electrical Energy Availability from RE Sources

RE Supply Availability	Unit	2011	2020	2030	2040	2050
Large Hydro	BU	11.38	11.38	11.38	11.38	11.38
Small Hydro	BU	0.67	1.2	2.4	2.4	2.4
Biomass	BU	0.31	0.44	0.56	0.66	0.79
Wind	BU	0.06	3.82	6.87	10.58	14.47
Solar	BU	0	2.10	7.71	16.12	30.55
Wave	BU	0	0.04	0.13	0.22	0.37
Total Electricity	**BU**	**12.84**	**18.94**	**29.09**	**41.39**	**59.97**

Considering the source-wise energy availability shown in the Table 12.3, it can be seen that wind and solar will have to play a major role in the future energy scenario as the availability of existing technologies as large hydro is not assumed to increase. One major energy supply option for the state considered in the scenario also includes state-owned thermal plant capacity of 235 MW. Contribution from central generating stations and IPPs are not considered.

However, to make sure that the proposed scenario can tackle the large integration of wind and solar, following constraints are considered:

1. The first constraint is to ensure that the cumulative penetration of wind and solar does not exceed a figure of 30 per cent at the state level before 2020. Interestingly, this assigned constraint is more on account of weak inter-state and inter-regional linkages, operational practices (inflexibility of conventional and hydro generation because of commercial mechanisms) and lack of short-term open access than on account of technical characteristics of RE.

However, going forward, the possibility of increased penetration of supply-driven RE over time is factored in. Some of the factors that would make it possible are briefly discussed below:

- Future availability of strong inter-state and inter-regional linkages: Many studies on large-scale renewable integration have singled out a strong evacuation backbone as the most important prerequisite for RE integration. Denmark is able to handle an instantaneous penetration of 100 per cent RE (wind) primarily because of the strong interlinks and interregional corridor capacity that allows it to export the surplus much more easily to a much larger Nordic pool. In this context, the planned high capacity interconnection of southern grid with the national grid by 2017 (could be delayed to 2020), would be one step forward. Proposals like creation of green corridors,[224] which are specifically planned for RE evacuation are sure to engender more debate on requirements and desirability of RE generation. In addition, subsequent transmission capacity additions in the future beyond 2030 will automatically plan for large-scale RE evacuation as RE would by then play a major role.

224 Power Grid Corporation of India. 2012. *Report on Green Energy Corridors: Transmission Plan for Envisaged Renewable Energy Capacity.* Power Grid Corporation of India Limited. Vol. 1 (July 2012). http://indiaenvironmentportal.org.in/files/file/Report-Green%20Energy%20corridor.pdf.

Availability of strong interregional links and interstate capacity would allow the state to evacuate power in times of excess generation and also import power (from the cheapest source) at times of slack. More importantly, such interconnections would absorb the variability much more easily and ease load management problems.

- ***Forecasting of RE sources:*** Variability of RE is seen as the biggest stumbling block by load dispatchers and system operators. One way to mitigate this is to schedule RE. CERC has already prepared the regulatory groundwork for implementing this mechanism and it is a matter of time before RE forecasting becomes a reality. A real time access to RE generation would allow the dispatchers to integrate maximum possible RE in the grid.

- ***Better operational management:*** The proposed solutions of strong inter-regional corridor capacity and forecasting may be adequate in the short term. However, when system size becomes a constraint, the most critical requirement will be a change in the operational philosophy. Variability in generation will have to be essentially managed by varying regional or national thermal and storage-based hydro power plant generation to the extent possible. Understandably, this would require significant changes in existing commercial mechanism and in the way conventional plants, mainly thermal and hydro, are run currently.

- ***Dynamic communication capability:*** On the technology side, such a change would require advanced and dynamic communication capability coupled with design changes that will increase the dynamic response capabilities of prime movers and generators. A case in point is Control Centre of Renewable Energies (CECRE), Spain, which is a dedicated RE control centre. The centre is responsible for managing all wind farms of over 10 MW. The centre is integrated into the main power control centre of Spain and acts as an intermediary between the grid operators and RE generators. The main function of CECRE is to integrate maximum RE production into the electricity system whilst maintaining quality levels and guaranteeing supply security. It receives real time information (every 12 seconds) from 23 control centres of generating companies and assesses it to determine the possibility of integrating the available wind generation into the system without compromising system security and operational performance. The analysis of CECRE is conveyed to the main national control centre, which modulates the generation from other sources.

- ***Availability of new storage technologies:*** Development and adoption of new storage technologies would effectively blow away the distinction between supply-driven sources and demand-driven sources. There could be storage solutions that are neither expensive nor technologically complex. One case in point is the storage technology developed by Highview Power (www.highview-power.com). The utility scale system is based on cryogenic energy storage that uses existing available technology used in air separation plants. It uses liquefied air or nitrogen as energy storage, which is converted into heat through standard thermodynamic operations. A pilot has shown good results and the technology is available at low cost compared to other technologies and is also indicated to be about 50-80 per cent efficient. A lot of research is going on in exploring other solutions. But availability of such storage systems will allow even 100 per cent penetration.

- ***Learning curve in managing RE:*** There is no standard limit of RE penetration. Even though a 100 per cent RE electricity would be difficult to manage given the present status of technology, 100 per cent RE based electricity can be achieved in future. In this context, conventional technologies may have a large role to play in optimal system management because the present system operation, system protection and reliability indices are built on the basis of the performance of conventional technologies. However, going further, new insights, technological innovations and operational experience of high RE penetration will allow system operators to gradually manage higher and higher penetration of renewables. The final limit of RE penetration will entirely depend on how well the system operators are able to match the system with the demand pattern, within the defined parameters.

In view of the above considerations, beyond 2020 and up to 2040, a maximum penetration of 10 per cent on the regional level (southern grid) is considered as the upper limit of integration for supply driven sources (wind, solar and wave). Beyond 2040, a 10 per cent penetration limit is assessed in terms of the national grid. This assumption presupposes a that there would be no major corridor constraints in evacuating the assigned RE power within the regional (up to 2040) and the national boundary and that a large pan-India transmission infrastructure that is capable of routing power effectively and efficiently, is already in place.

System demand (demand of Southern and National Grid) has been derived from extrapolating CEA's 18th EPS[225] demand projections for India and the southern region. The electricity requirement is given at all India level as well as at regional level. Electricity requirement has been estimated on the basis of sector-wise electricity consumption and T&D losses. Here, energy requirement (i.e., consumption plus losses) has been projected for the period beyond 2021-22. The energy requirement data given by CEA show an almost linear trend. Following equations have been used for projection of energy requirement.

All India energy requirement = 615546+95032* time and

Southern region energy requirement = 166519+25078* time

Where, t denotes time and takes values from 1 to 45 [1 = 2006, 2 = 2007,........, 45 = 2050]

Table 12.4: Derivation of National and Regional Electricity Demand

Electricity Demand (BU)	2011	2020	2030	2040	2050
All India	829.6	1,660.8	2,611.2	3,561.5	4,511.9
Southern Region	224.3	442.7	693.2	943.9	1,194.7

2. Allocation of demand driven sources first: The only demand driven sources under consideration are large hydro, existing thermal power (235 MW) and biomass gasification and combustion technologies. Understandably, as the share of biomass power is very low (less than 0.5 per cent), the allocation logic first allocates all hydro (large and small), followed by thermal and biomass. Priority allocation of demand driven sources is done because in any case, these sources would have to run continuously to meet the ever increasing demand. Furthermore, like demand driven

[225] CEA. 2011. *Report on Eighteenth Electric Power Survey of India.*

sources, hydro generation also has zero variable cost and thus would be ideal as a flexible base load plant. Biomass potential is very low and it is assumed that built plants will have to run to achieve commercial returns from the project. However, no new conventional thermal capacity addition is envisaged over the projection period. Furthermore, assuming a 40-year life of a thermal project, existing thermal capacity is assumed to get decommissioned in 2040, beyond which thermal is considered to be not available and is not allocated.

The unmet demand after allocating all demand driven sources is then matched with available wind, solar and wave potential. The ideal situation would be to distribute the energy share equally across technologies as their generation patterns are partially complementary; however, depending on energy availability, technology with the lowest supply potential is first allocated fully followed by other supply driven technology. If there is energy deficit even after allocating all supply driven RE sources, then the deficit is assumed to be met by purchases or trading, and is considered non-renewable.

Based on the logic described above, the allocation for meeting electricity demand is shown in Table 12.5 below.

Table 12.5: Electricity: Supply Allocation of Generating Sources

Curtailed Demand Requirements – Electricity						
	Unit	2011	2020	2030	2040	2050
Total Electricity	BU	18.6	26.32	31.29	39.06	46.47
Supply Availability- Electricity						
First Allocation Sources						
Hydro	BU	12.05	12.6	13.7	13.7	13.7
Thermal	BU	1.44	1.44	1.44	1.44	0
Biomass	BU	0.31	0.4	0.6	0.7	0.8
Unmet Demand	BU	4.8	11.88	15.55	23.22	31.97
Wind Energy	BU	0.6	3.82	6.87	10.58	14.47
Solar Energy	BU	0	2.1	7.71	12.42	17.13
Wave Energy	BU	0	0.04	0.13	0.22	0.37
Deficit	BU	4.2	5.92	0.84	0	0
Other Non Renewable	BU	4.2	5.92	0.84	0	0
RE Penetration (State)	%	3.2	22.6	47	59.7	69
RE Penetration(Region)	%	0.2	1.3	2.1	2.5	2.7
RE Penetration (National)	%	0.07	0.4	0.6	0.7	0.7
Renewable Capacity Requirements						
Onshore Wind	MW	35	2,981	3,223	4,465	5,580
Offshore wind	MW	0		300	900	1,700
Land Based grid-tied solar	MW	0	300	1,000	1,000	1,000
Floating grid-tied solar	MW	0	200	500	500	500
Decentralized solar	MW	0	1,000	4,000	7,500	10,800
Wave	MW	0	50	150	250	420

Continued…

Table 12.5: ...continued

RE Energy Availability						
RE Supply Availability	Unit	2,011	2,020	2,030	2,040	2,050
Large Hydro	BU	11.38	11.38	11.38	11.38	11.38
Small Hydro	BU	0.67	1.2	2.4	2.4	2.4
Biomass	BU	0.31	0.4	0.6	0.7	0.8
Wind	BU	0.06	3.82	6.87	10.58	14.47
Solar	BU	0	2.1	7.71	16.12	30.55
Wave	BU	0	0.04	0.13	0.22	0.37
Total Electricity	**BU**	**12.84**	**18.94**	**29.09**	**41.39**	**59.97**

Conventionally, operational procedures for matching demand with supply involve detailed technology suitability assessment related to dispatch amenability, technical flexibility, costs, etc to decide on priority of generation allocation. In the conventional format, where demand driven sources dominate, supply sources are dispatched and not allocated. However, in the present context, the focus is on energy supply and availability and not on operational feasibility and hence annual energy availability based allocation is done.

However, at the same time, it is assessed that even operationally, a state-level penetration of 69 per cent demand driven sources (wind, solar and wave) would be manageable in 2050 because of the system evolution discussed above. Beyond 2030, integration of the estimated RE capacity presupposes adequacy of strong inter-regional links and effective regulatory mechanisms in place. But this presupposition is based on a strong possibility of future developments which have been covered earlier in this section (national grid, forecasting storage technologies, etc).

One important observation is that 100 per cent electricity from renewables is in the context of the annual power requirements. In actual practice, seasonal and diurnal variations will have to be managed through interstate settlements or open access. For example, solar generation will be low in peak monsoons and even with an increase in wind and wave power generation in that season Kerala will have to rely on importing power from the regional/national grid. However, in summer months or slack monsoon season actual solar and wind generation could be more than the state level demand and in this case, the surplus can be exported to other states.

12.1.2 Fuel Demand

Table 12.6 summarizes the fuel demand and its availability

Table 12.6: Demand Requirement and Supply Potential of Transport Fuels

Demand Requirement (mtoe)	2011	2020	2030	2040	2050
Diesel	2.5	3.73	3.91	4.88	6.05
Gasoline	0.5	0.87	0.79	0.6	0.32
Jet Kerosene	0.1	0.15	0.25	0.44	0.59
Natural Gas	0	0.12	0.24	0.08	0
Total	**3.1**	**4.87**	**5.19**	**6**	**6.96**

Continued...

Table 12.6: ...continued

Supply Availability (mtoe)		2020	2030	2040	2050
Bio-crude (Coconut fronds)	0	0	0.34	0.32	0.29
Bio-ethanol (Tapioca)	0	0	1.54	1.54	1.54
Algal Oil (Brackish Water)	0	0	0.15	0.22	0.30
Algal Oil (Sea Water)	0	0	4.78	11.47	13.38
Total	**0**	**0**	**6.81**	**13.55**	**15.51**

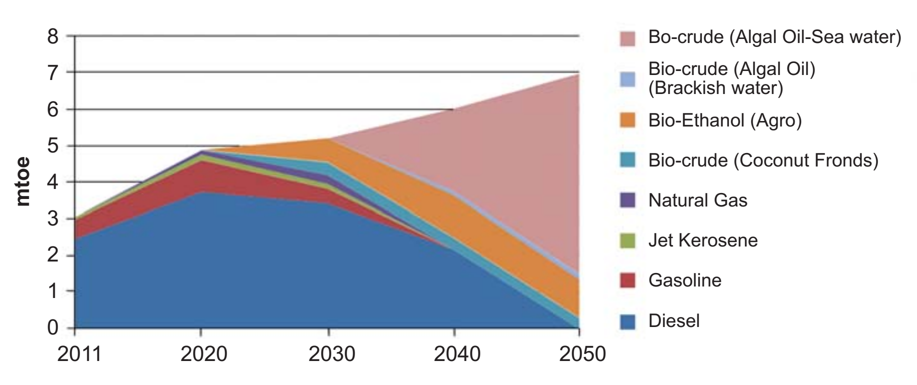
According to Table 12.6, the transport fuel demand can be easily met through biofuels. The mainstay of the new fuel supplies are algal oils derived from cultures grown either in brackish water or in sea water. The potential of these sources is large enough to meet all of transport demands. However, the availability of new technologies especially algal oil based fuels may have technology access issues in the short run. Other biomass to liquid technologies, mainly based on sustainably generated agricultural wastes may be near-commercialization, but have issues with the quality of processed fuel. In view of the same, significant interventions are assumed to kick in only in 2030. The fuel substitution mainly assumes delayed technology availability but accelerated uptake of brackish water and sea water based algae technology in 2030 with a significant uptake of this technology only after 2040. In line with the assessment of the energy report,[226] it is assumed that these new generation bio-fuels would be able to substitute all types of transport fuels by 2050.

Based on the above assessment, the final fuel supply share is as shown in the Table 12.7 and the Figure 12.1 below.

Table 12.7: Assessed Final Fuel Supply Share (mtoe)

Fuel Supplies (mtoe)	2011	2020	2030	2040	2050
Diesel	2.46	3.73	3.42	2.17	0.00
Gasoline	0.53	0.87	0.40	0.00	0.00
Jet Kerosene	0.07	0.15	0.13	0	0
Natural Gas	0.00	0.12	0.24	0	0
Bio-Crude (Coconut fronds)	0	0	0.35	0.32	0.30
Bio Ethanol (Agro)	0	0	0.65	1.15	1.05
Bio-crude (Algal Oil) (Brackish Water)	0	0	0.00	0.11	0.15
Bio-crude (Algal Oil -Sea Water)	0	0		2.25	5.46

Figure 12.1: Final Supply Share of Transport Fuels



12.1.3 Heat Demand

The main demand for heat is from cooking and industry. Table 12.8 summarizes the demand and the supply availability over time.

Table 12.8: Demand Requirement and Supply Potential of Heat Fuels

Curtailed Domestic Heat Demand (PJ)	2011	2020	2030	2040	2050
LPG	11.6	19.1	17.1	14.4	11.1
Biogas	0.1	1	4.1	7.3	10.7
Wood	16.6	8.4	3.5	1.4	0.7
Kerosene	0.1	0.1	0.1	0	0
Total	**28.4**	**28.6**	**24.8**	**23.1**	**22.5**
Curtailed Commercial Heat Demand (PJ)		**2020**	**2030**	**2040**	**2050**
LPG	2.1	4.5	8.8	14.8	22.3
Kerosene	0	0.1	0.2	0.3	0.5
Total	**2.1**	**4.6**	**9**	**15.1**	**22.8**
Curtailed Industrial Heat demand (PJ)		**2020**	**2030**	**2040**	**2050**
Coal	21.7	32.2	27.4	23.2	18.6
Petroleum Coke	7.2	10.6	9.2	7.9	6.6
Residual Fuel Oil	3.6	6.3	7.2	7.4	6.6
Wood	2.3	4.1	4.7	4.9	4.4
Total	**34.8**	**53.2**	**48.5**	**43.4**	**36.2**
Supply Potential (PJ)		**2020**	**2030**	**2040**	**2050**
Biogas	14.59	16.4	17.2	17.9	18.6
Wood	6.2	7	8.2	9.7	12.2
Total	**20.79**	**23.4**	**25.5**	**27.6**	**30.8**

From Table 12.8 above, it becomes apparent that the heat demand for the curtailed demand scenario cannot be met through biomass combustion and biogas alone. The fuel requirements for cooking in the domestic and commercial sectors would still imply dependence on LPG even by 2040 and 2050. Even though some of the LPG use can be substituted by biofuels, especially in the small-scale commercial sector, the requirement of upgrading existing distribution and storage infrastructure for liquid fuels and considerations related to their suitability of use within indoor spaces for cooking applications precluded any quantification of substitution. Consequently, the unmet heating demand for domestic and commercial sector was assumed to be met by LPG up to 2050 and beyond. On the other hand, wood based heat availability from estimated supply sources was found to be adequate meet the wood based heat demand as well as the kerosene demand.

In the case of industrial process heating fuels, demand for wood was met through estimated wood resources by 2040. On the other hand, industrial processes were studied to understand the possibility of substituting other industrial fuels with liquid biofuels. The use of coal and fuel oil in industrial processes was mainly to fire boilers and meet other auxiliary heat requirements through direct combustion route. However, it was found that pet coke was unique for most of the industrial processes, where it was not only used as heat source but also as a chemical reducing agent for raw materials. Based on the consultations with experts and the study of

[226] WWF International. 2011. *The Energy Report: 100% Renewable Energy by 2050.* Avenue du Mont-Blanc, Switzerland.

available literature, it was assessed that 100 per cent substitution of coal and fuel oil with biofuels was practically possible. However, no ready substitution was available in pet coke applications.

Based on the previous section, the availability of surplus fuels was assessed at 9.73 and 8.56 mtoe in 2040 and 2050, respectively. Assuming a heat equivalent ration of 41.8 PJ/mtoe, the total heat supply potential for surplus biofuels was estimated well in excess of the required demand or industrial heating through coal and fuel oil. Table 12.9 below shows the estimated heat supply potential of surplus biofuels.

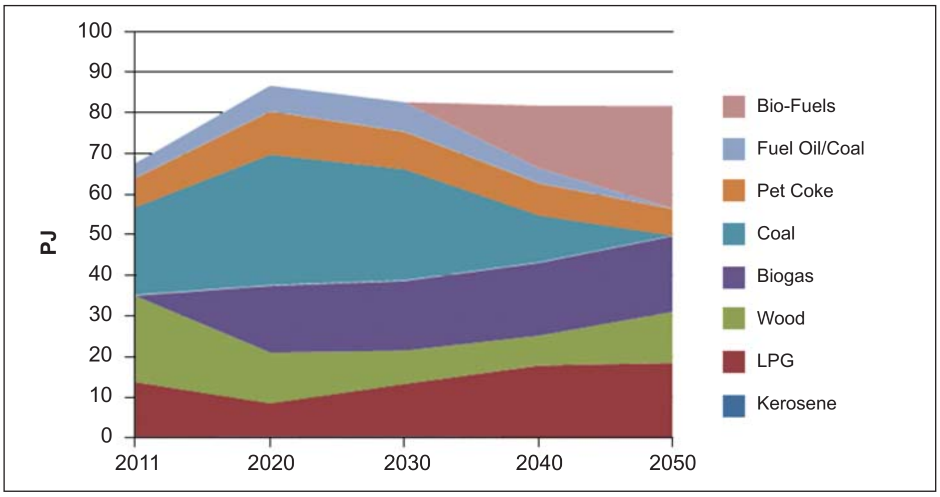
Table 12.9: Total Heat Supply Potential of Surplus Biofuels

Surplus Bio-fuels (mtoe)	2011	2020	2030	2040	2050
Bio-Ethanol (Agro)	0	0	0.89	0.39	0.49
Bio-crude (Algal Oil) (Brackish Water)	0	0	0.15	0.11	0.15
Bio-crude (Algal Oil -Sea Water)	0	0	4.78	9.22	7.93
Total	**0**	**0**	**5.82**	**9.73**	**8.56**
Total Equivalent Heat Availability (PJ)	**0**	**0**	**243**	**407**	**358**

Table 12.10: Assessed Final Supply Share of Heating Fuels

Final Supply Scenario – Heat (PJ)					
Cooking Demand (PJ)	2011	2020	2030	2040	2050
Kerosene	0.1	0.18	0.26	0	0
LPG	13.7	8.38	13.1	17.92	18.6
Wood	18.9	8.4	3.5	2.42	8.12
Biogas	0.1	16.4	17.15	17.92	18.6
Total	**32.8**	**33.4**	**34.0**	**38.3**	**45.3**
Industrial Heat Demand (PJ)	**2011**	**2020**	**2030**	**2040**	**2050**
Coal	21.7	32.2	27.4	11.6	0
Pet Coke	7.2	10.6	9.2	7.9	6.6
Fuel Oil/Coal	3.6	6.3	7.2	3.7	0
Wood	2.3	4.13	4.69	4.89	4.43
Bio-Fuels	0	0	0	15.3	25.2
Total Industrial Heat	**34.8**	**53.2**	**48.5**	**43.4**	**36.2**

Figure 12.2: Final Supply Share of Heating Fuels



Based on the above assumptions, the final supply scenario for cooking and industrial heat is derived in Table 12.10. Figure 12.2 maps the supply technology evolution over the years.

12.2 FINAL SCENARIO: SUMMARY AND BRIEF CONCLUSION

Table 12.11: Final Supply Scenario by Energy Supply Sources

Final Energy Supply Scenario (PJ)	2011	2020	2030	2040	2050	% Share
Kerosene	0.1	0.18	0.26	0	0	0
LPG	13.6	8.38	13.1	17.92	18.6	3.45
Coal	21.7	32.2	27.4	11.6	0	0
Pet Coke	7.2	10.6	9.2	7.9	6.6	1.22
Fuel Oil	3.6	6.3	7.2	3.7	0	0
Diesel	102.8	156.1	143.2	90.84	0	0
Gasoline	22.4	36.37	16.72	0	0	0
Jet Kerosene	2.8	6.27	5.434	0	0	0
Natural Gas	0	5	10.03	0	0	0
Thermal based Electricity	5.18	5.18	5.18	5.04	0	0
Other Non-renewable (Electricity)	15.12	21.31	3.02	0	0	0
Biogas	0.1	16.4	17.15	17.92	18.6	3.45
Wood	18.9	12.53	8.19	7.31	12.55	2.33
Biofuels for Heat	0	0	0	15.3	25.2	4.67
Bio-crude (Coconut Fronds)	0	0	14.42	13.29	12.4	2.3
Bio-Ethanol (Agro)	0	0	27.17	48.07	43.89	8.13
Bio-crude (Algal Oil) (Brackish Water)	0	0	0	4.598	6.27	1.16
Bio-crude (Algal Oil - Sea Water)	0	0	0	94.05	228.2	42.29
Hydro	43.38	45.36	49.32	49.32	49.32	9.07
Biomass	0	1.44	2.16	2.52	2.88	0.53
Wave	0	0.144	0.468	0.792	1.332	0.25
Wind onshore	0.2	13.74	22.36	30.98	37.92	7.03
Wind offshore	0	0	2.4	7.1	14.2	2.63
Land based grid-tied solar PV	0	1.5	5	5	5	0.93
Floating grid-tied solar	0	1	2.5	2.5	2.5	0.47
Decentralized solar (rooftop PV)	0	5	20.2	37.8	54.5	10.1
Total Supply	**257.08**	**385.00**	**412.08**	**473.55**	**539.96**	**100**

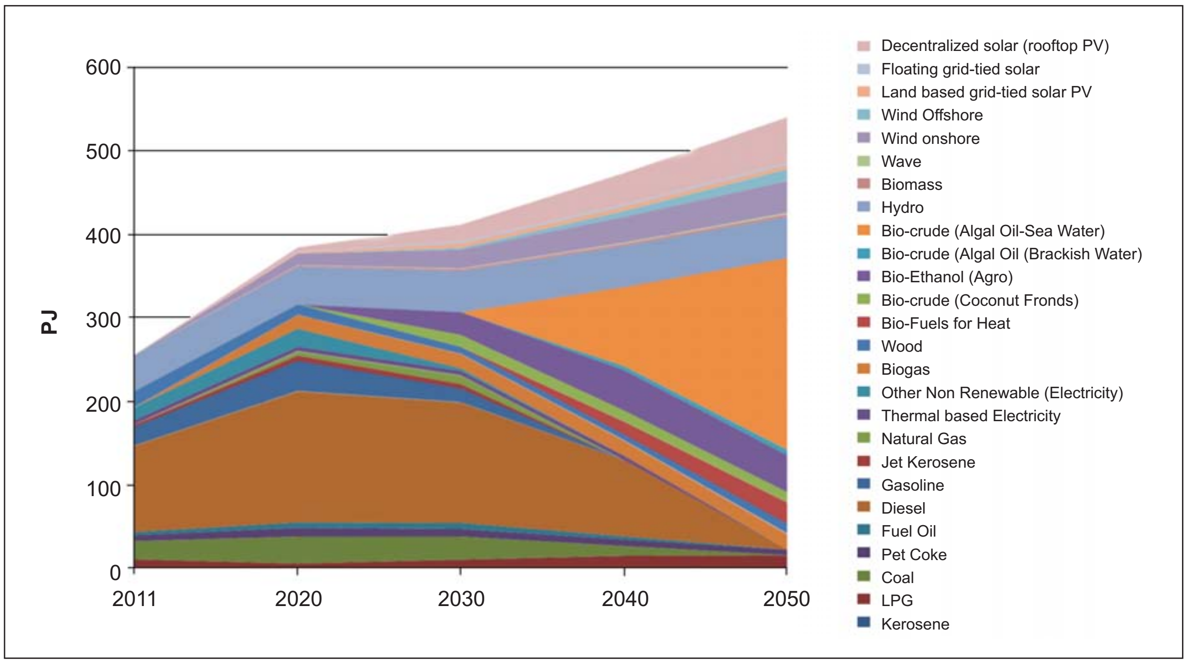


Figure 12.3: Final Energy Supply Scenario by Energy Supply Sources

Based on the demand matching that is done in the previous sections, the final results of the state energy scenario indicate that the state can meet just over 95 per cent (95.33 per cent) of its energy demand from renewable sources. Table 12.11 and Figure 12.3 below summarize the final results.

These results validate the findings of *The Energy Report,* which also indicated a similar scale of reduction in fossil fuels and corresponding increase in renewables. As emphasized in the global report, achievement of a 100 per cent RE scenario is possible without compromising on growth.

It is not hard to see the implications of this. This means that there are alternatives to a BAU growth and these alternatives are not unachievable. A majority of them would just require efforts to understand the need (for such a transition) and a resolve to make the change.

PART IV

STRATEGIC INTERVENTIONS FOR TRANSITION

13. POLICY CONSIDERATIONS FOR THE TRANSITION

The developed energy scenario is an indication of what can be achieved. However, it is obvious that naturally evolving market transformations (better technologies, lower cost) alone would not be sufficient to effect this change. While the actual transformation will have to come about at the individual level, this cannot happen without a top-down mandate on the need to move away from a BAU evolution. This top-down mandate is possible only through a comprehensive policy statement that integrates cross-sectoral linkages followed by sectoral regulations that assign target based compliance.

The following narrative tries to identify these policy imperatives across sectors.

13.1. TRANSPORT SECTOR

Policy Objectives

- Increased shared resource use
- Modal shifts to efficient transport modes
- Enacting fuel efficiency norms
- Shift to electric vehicles

Policy Targets

- Conversion of 0.5 per cent of car population in car pools and 1 per cent in bus pool by 2025
- Conversion of 5 per cent of rickshaw/taxi population in a pooled service by 2020
- Conversion of 5 per cent of car travel to non-motorized mode by 2030
- 15 per cent fuel consumption in trucking industry by 2030 through saving on trip-time and resorting to better driving practices
- Reduction of 30 per cent of air travel by 2025 through use of alternative communication technologies
- Increasing freight share of coastal transport to 20 per cent by 2020 and rail share to 25 per cent by 2050
- Freezing passenger road traffic share of personal transport vehicles at 2020 levels (4 per cent for cars, 9 per cent for two-wheelers).
- Achieving 100 per cent shift to efficient technologies by 2050
- Achieving at least 50 per cent share of electric transport in feasible modes by 2050

The main take away from the study is the finding that the transportation sector has the largest energy share when compared to other sectors. In fact, the base year share estimated in the study indicates a share of slightly over 50 per cent. This high level of energy use is clearly indicative of a rapid migration from public transport modes to personal transport modes (two-wheelers and four-wheelers comprise over 80 per cent of the registered vehicle population). Unfortunately, this large-scale migration from public transportation to private transport seems to be the beginning of a vicious cycle that keeps on weakening the public transport systems at the cost of strengthening the private transport systems. It is imperative to realize this and make policy interventions that work on mandating targets.

In line with the main intervention strategies identified in the transportation section, the following policy choices are identified:

Policy Measures on Resource Pooling: Resource pooling (car pools/bus pools/shared taxis/rickshaws) has a very high potential for reducing traffic congestion and energy use. Considering increasing use of cars for commutation to the place of work, a car pool of 4 persons has the potential to reduce three cars from the road. Conversion of personal car travel to a single bus pool of 20 would have the potential to reduce 20 cars off the road. With increasing urbanization, the daily traffic movements are getting more concentrated and there is a large scope for effecting this shift.

The proposed policy should mandate a compulsory car pool or bus pool (car commuters) for all government offices with strength of more than 100 persons. This would necessitate collecting information on transit modes and transport points for the entire office going population. Wherever possible administrative resources (clerical staff of administrative department) of nearby government offices should coordinate and manage establishment of these services. In parallel with this measure, except for senior officers, nominal charges should be levied for parking personal cars within the office premises.

Corporates should also be encouraged to follow these strategies through shared administrative services. IT parks typically house many multinational companies at one location and there is a huge scope for integrating transport needs. In addition, these corporates should be encouraged to levy parking charges for personal cars for people who do not use pooled services in a serviced route. Understandably, collecting data and putting infrastructure in place would be difficult initially, but once the system is operationalized, it will require very little effort to maintain it.

The first step in implementing this would be setting up or assigning of a designated transport unit for the state, which works exclusive as a transport traffic and energy management consultant of the state. The time-based targets for such reductions should be decided after conducting surveys in select government offices, corporate offices and IT parks. Based on the assessed traffic surveys, which also collect the travel needs of the office goers, the surveyed organizations should be encouraged to achieve these targets within a limited time frame. These organizations should be provided support from a state designated agency, which works as an official transport consultant for the state. The success of the results of these interventions in the surveyed units should be taken as a basis for targets for each sector and state-based compliance mechanism should be formulated.

The efforts to convert to resource pooling should be considered as part of a state-level compliance mechanism and for corporates, also as part of CSR.

Another intervention from this policy should be a move to shared rickshaws/shared taxis as fast moving transport modes for short distance travel within largely urban areas. Majority of the rickshaws serve urban population and hence such a move seems to be feasible. However, detailed surveys of road traffic and daily movements in selected urban areas can help identify specific areas where such services would work. Once such high traffic routes are identified, migration of existing vehicle population would be voluntary as the realizable revenues increase. In cities like Mumbai and Ahmadabad, where such shared transport is available, the movement to these routes from taxi and rickshaw unions has been voluntary. And the cost of transport is also only marginally more than that of a public transport.

All these measures should be supported by disincentives for personal transport. These disincentives can work in a top-down level as higher taxes for personal vehicles to a bottom-up level like congestion charges for identified routes.

Policy Measures on Better Freight Management: The main focus of these measures should be on enhancing traffic management and inculcating the knowledge of best driving practices in the freight industry. At an all India level, freight productivity is affected significantly by waiting time at check posts and other official stops and traffic congestion points. Within a limited scope, the state can ease this congestion by smoothening management of check posts (faster turnaround time by quicker collection and essential checks) and better traffic management on major freight corridors. Another major area could be to train the drivers to use more fuel efficient and safe driving practices. The state can, after a discussion with trucking industry, ask for 100 per cent driver training through approved courses by professional agencies over a 10 year period. Such large scale dissemination would lower the cost of trainings and would also incentivize the trucking industry to participate. The government can also provide a small budgetary support towards meeting part of the fees. This course can be further extended to other passenger public transport systems.

Policy Measures on Travel Avoidance: Modern communication technologies are fast obviating the need for frequent travel. While personal air transport is more inflexible, business travel is an area that can offer a huge potential for travel reduction. In the presence of options like video conferencing and cloud computing, the need for such a travel can, in many cases, be considered superfluous. In many cases, such travel happens more because corporates don't bother to evaluate alternatives. Some of the strategies for corporates could be to reduce travel to the minimum, reduce the size of travel team, and make increasing use of new communication technologies and projecting them as their main communication techniques at the project development stage itself. This strategy has more than obvious benefits. It not only reduces costs but also saves on productivity and gives a better 'quality of life' to the employees. The most effective way to implement this would be by sensitizing the corporate sector to the benefit and the need for such a transition. Like many other seminars and sensitization programmes, targeted corporate sensitization could be an effective tool to bring this about.

Policy Measures for Effecting Transport Modal Shifts: Existing plans of high-speed train corridor and a coastal corridor for passenger movement are a big step towards altering the modal traffic share in the state. However, even though this will have impact on long distance transport, short distance transport, which comprises large share of the transport traffic (commuting to work, inter-city travelling), will be largely untouched. The main policy measures to influence short distance travelling patterns can only come through better short distance public travel facilities. As mentioned in the report, much of the shift to personal transport is on account of dissatisfaction with public transport. Private buses in the state are seen as safety hazards. In addition, rude behaviour of bus operators and bad driving practices are also resulting in increasing alienation of public sentiment. One of the measures to reverse this increasing alienation is to deploy more state-owned buses in the initial phases in select routes. Another measure could be strengthening small scale transport systems (mini-taxis and taxis) that can ferry passengers on short distance routes through shared use. This strengthening of 'last mile' transport systems can be done by reducing entry barriers (reducing vehicle taxes, road taxes, and easing licensing norms, etc).

Feasibility Study for Local Train Network: The railways is already planning investments in signalling systems and track improvements on state rail routes, which will help integrate local train systems with existing services. However, a comprehensive study on operational intricacies (route availability, two-track systems, communication, additional electrification requirements, etc) in addition to financial impacts (revenue realization, traffic forecast study, possibility of passenger/freight shift) has to be undertaken to assess the actual possibility of implementing such a system

Policy Measures on Fuel Efficiency Norms: Even today, technologies are available which are more efficient than technologies in use. Simple hybrid vehicles (which regenerate energy from braking) can be as much as 20-40 per cent less energy intensive as compared to existing technologies. The energy intensity of a four-stroke motorcycle is about 62 per cent less than that of a two-stroke motorcycle, while the energy intensity of a diesel hybrid bus is 69 per cent less than that of a normal diesel bus. However, it is obvious that implementing such norms would not result in immediate benefits. A policy stipulation today can bring about 100 per cent of targeted change (a shift to the high efficiency models) only about 15-20 years from now assuming maximum possible life of 12 years and slow adoption of new technologies initially). To the extent possible, the state can involve the centre in suggesting a policy on fuel efficiency norms which can be implemented in phases in the state. Understandable, fuel price evolution would also be a major factor that would influence an automatic shift to high efficiency vehicles.

The best way to implement fuel efficiency norms is to first identify the preferred technologies for the state, record their actual performance in terms of key parameters and set the performance parameters of these models as standards that are to be achieved by some future year (2025). Future measurements for fuel efficiency achievements can then be simply based on the vehicle technology in use and a small levy can be collected from vehicle owners of old technologies. This will kick start the process of technology adoption. Subsequent penetration of new technologies will then be voluntary as increasing fuel costs would bring down the payback period for new technologies.

Policy Measures on Electric Vehicles: The spatial spread of the population and the predominance of independent houses make Kerala very amenable to electric transport. An electric vehicle is a factor more efficient than existing ICE or even hybrid vehicles. Tesla Motors in USA has already developed and commercialized luxury electric sedan model (Model S) that has a range of 480 kmph, a top speed of 192 kmph and a fuel efficiency of about 0.15 kWh/km (0.245 kWh/miles) at a speed of 80 kmph. In energy terms, this translates into an energy intensity that is 20 per cent of the energy intensity of the current breed of gasoline based cars. All electric buses are also commercially available today. BYD, a European manufacturer has already rolled out an all electric bus with a capacity of about 60-70 passengers and fuel efficiency of 1.04 kWh/km; about two times more efficient than an existing diesel bus.

A shift to EV in this sense would have two advantages: one, electricity as a source itself is clean and less energy intensive than transport fuels considering energy investment from raw material extraction stage to final end use. Second, the source for electric vehicles would be low cost as compared to diesel vehicles (approximately Rs 0.45/km for Tesla car assuming electricity cost of Rs. 3 per unit). And even at a system level, the cost to the utility for supply would also be low as the vehicle charging would be mostly happening at night (in times of low load).

The best way to implement this is to incentivize a shift to EVs by reducing taxes, spreading awareness and mainly by making sure that EV technologies are available at the retail level and have adequate servicing facilities. Implementing the last measure would mean creation of a parallel infrastructure but this can be done if the state is able to persuade EV manufacturers to set shop in the state. A strong EV manufacturing base would also be in line with the preference of the state's industrial policy to high tech and engineering industries. Once technologies are available, have servicing infrastructure and are used, further penetration will be voluntary and automatic. As mentioned, the best strategy could be to support development of the fledgling EV industry in the state.

13.2 BUILDINGS AND REAL ESTATE

Policy Objectives

- Move towards green buildings /sustainable architecture in commercial and domestic sector
- Increased use of locally available building materials

Policy Targets

- 15 per cent and 5 per cent penetration of low energy building (all electric buildings with 60 per cent less energy consumption)in urban and rural areas by 2050.
- 70 per cent share of green buildings/energy efficient retrofit building in the commercial sector by 2050
- 30 per cent energy savings in residential spaces by 2030 through new architectural practices, adoption of green building and retrofits

Buildings perhaps have the second largest potential to save costs and reduce energy. As compared to transport, the energy use in built structures is mainly on account of electricity. However, in terms of the total energy invested, all forms of energy are used in a building lifecycle: transport fuels, industrial heating energy and electricity. In Kerala, building and real sector is growing at a very high rate.

However, it has to be realized that this level of activity has to be sustainable. There is an increasing shortage of construction materials. The prices of construction materials are also increasing a very high rate because of decreased availability and increasing transportation distances. On top of that high labour costs also add substantially to the final built costs. In the face of depleting resources and increasing use of energy for alternative material (artificial sand, etc), it is worth considering if these levels of growth can be sustained. The most effective move for this sector can be to move towards sustainable agricultural practices that use local materials as far as possible. Alternative architecture based on use of bamboo, soft and hard wood, local clay, etc is already being practiced. These practices have tremendous potential to reduce the energy invested in a building and also to reduce the energy requirement of a built structure. On the other end of the spectrum are green buildings, which use integrated planning and modern material to maximize resource use and minimize energy requirements of the built enclosure. Both of these alternatives are mentioned in the Housing Policy and the Green Building Policy of the state.

The way forward is to start work on implementing these policy objectives. Commercial and institutional buildings have the maximum potential to effect this change. Based on the policy, a green building regulation that stipulates long-term targets for large real estate companies could be a very effective step. All large real estate companies can be mandated to comply with floor-area based percentage target of meeting green buildings/sustainable buildings in newly constructed buildings. For example, a real estate firm that constructs 1,000,00ft^2 of floor area in the first year could be mandated to have 2 per cent (2,000ft^2) as target for green building/sustainable building. The advantage of this top down target setting is that the cost of such buildings will be borne by eventual owners, who would be persuaded by real estate companies to opt for this. In addition, compulsory environmental and building certification norms for commercial buildings starting in (2020) would help bring compliance from the supply side. This would necessitate setting up of separate building standards that not only include feature of green buildings but also the features of sustainable architecture, which holds a great promise for Kerala.

For the housing sector, sensitization of alternative building practices like use of locally available material has to be done with the help of organizations like COSTFORD, Nirmithi Kendra, etc. This sensitization has to be of very large scale and can be supported by the state through separate budgetary allocation. This programme aimed at targeted groups could also include site visits to actual built structures. Subsequently, the government can incentivize such construction practices by allowing a reduction in housing tax, local body taxes, electricity and water connection charges, etc. Subsequently, adoption of all electric buildings that integrate small-scale generation sources (building integrated PV, biogas, etc) can also be incentivized by offering lower taxes and attractive feed in tariff rates.

13.3 ENERGY AND POWER

Policy Objectives

- Integration of super efficient appliances
- Integration of all available sources of renewables
- Reverse shifts to use of biogas and wood for cooking in rural and urban areas

Policy Targets

- Minimum 30 per cent self generation target for commercial establishments through solar PV

- 100 per cent penetration of super-efficient appliances in the household sector by 2040 (urban) and 2050 (rural)
- Achieving 20,000 MW solar PV deployment target by 2050 (grid tied and off-grid)
- Achieving 10,000 MW wind target by 2050
- Achieving 700 MW of small hydro capacity by 2030
- Achieving 1,000 MW of wave energy capacity by 2050

The main strategy for power sector is the move towards supper efficient appliances. Energy Management Centre, Kerala is already doing admirable work in the field of energy conservation and energy management. KSEB is also efficiently run, considering the comparatively low T&D losses. The state has also made a decisive move towards solar power.

In this background the major scope for the power sector is a targeted move towards energy efficiency (migration to super efficient equipments as compared to star rated equipments) and increased push for higher integration of all renewables including small hydro, wind, solar and wave.

Policy Measures for Supporting Super Efficient Equipments (SEA)

A move towards super efficient appliances has already been mooted at the central level with BEE announcing the Super Efficient Equipment Program (SEEP). Adoption of this programme at the state level could be the first step followed by a regulation mandating SEEP penetration in new commercial buildings.

Considering difficulties in ensuring compliance on SEA use, the best way to effect the change could be to make SEAs available in the state. This can be followed by large scale dissemination and awareness campaigns that could help in gradual acceptance of SEAs. Subsequent measures could be taxing non-efficient products to reduce the price disparity between SEA and non-SEA products. Another workable strategy could be to promote development of SEA manufacturing industry in the state. This would not only reduce the cost but would also be in line with the vision of the industry policy of the state, which shows a preference for development of this sector.

Policy Measures for Supporting Renewables

The main policy measures for supporting RE include stipulations related to land use (preferential land allotment), grid planning, grid operations and stakeholder management.

- **Renewable Energy Vision Plan:** The state is sitting on large renewable resources in wind (onshore and offshore) and solar (grid-tied and off-grid) but the choice of choosing renewables over alternative technologies has to be made by the state. A transition to solar is already in place but there is a necessity to include wind resources also. The state has to decide on the desirability of integrating more renewables and work out a renewable energy vision.
- **Land Allocation:** Renewable resources are very site specific. In this sense they should be given preferential allotment of land/sea (or a first right of refusal) that is deemed to be resource rich. In the case of offshore energy, the major high grade potential exists off the coast of Thrissur. Resource potential of the identified zone could be carried out followed by declaration of a selected

area (about 800 km^2) as reserved for wind power development. Similarly, land areas suitable for wind development, south of Palaghat, Walayar pass should be preferentially reserved for wind power development. The land associated with grid-tied solar potential could also be reserved for future development.

- **SPO Targets for Commercial for Solar Energy:** This provision is already mooted in the draft solar policy of the state. The next obvious step would be to mandate targets as early as possible. The main strategy for formulating substitution intervention in the commercial sector could converge on solar power generation at distributed level. Commercial establishments like malls, large office buildings, hospitals, hotels may have ample space which can be made available for rooftop PV generation. The Kerala Solar Energy Policy (Draft) 2013 also indicates large scale deployment of rooftop PV and heat collector systems for large establishments.

  Considering the seasonal variation in solar power generation, providing appropriate incentives (FIT) or implementing net metering may help in achieving a target of meeting 10 per cent yearly demand for large establishments from solar. This target can be increased by 1 per cent every year up to 2030 to achieve a yearly target of 20 per cent. Imminent drop in solar energy costs coupled with better energy management, building integrated energy architecture, enhanced efficiencies and better storage solutions would facilitate a self-generation potential of up to 30 per cent by 2050.

- **Biofuels for Transport:** In the energy scenario, algal based biofuels are the mainstay of the transport transformation. Even though algal based fuels are under experimental stage, they hold enough promise for countries like US and China and many others, who have poured millions of dollars in R&D related to these sources. The synthesized fuel from algal cultures (both sea and ground water based) suggests that the potential is indeed harnessable and more important, almost limitless.

  The effect of these algal cultures on the host environment is also not found to be significant. In fact naturally grown algae are food for many small aquatic organisms, which are the part of a local food chain. This would suggest that experiments with algal based technology could be one potent way to bring about fuel security. But the experiment has to start as soon as possible to verify bio-vitality of energy yielding cultures and their long term effect on host environment.

  One way to go about this is to develop a biofuels division which can initially study the potential and the technology access issues by visiting actual experiment and manufacturing sites. Based on the report of this division, the state can then decide on the pilot size, scale, location and subsequent development potential.

Grid Planning

The existing grid expansion plans usually do not integrate future RE development potential. This results in significant generation losses and revenue losses as has happened in Tamil Nadu. If the state is to develop a RE plan, the best way of support could be advanced grid planning for the planned capacities. This would not only reduce the construction time but would also help the state in managing the generated power more optimally.

State Advocacy at the National Level

Conduct a detailed grid study to assess power system stability and load flow at inter-state and inter-regional level: A detailed study is required to assess the actual effects of planned renewable penetration on power system safety and protection aspects not only for the state but also for the southern region and finally for the national grid. The study can also assess the proposed plan from the perspective of inter-state and inter-regional corridor capacity to evacuate power and to flag requirements of new inter-regional or inter-state transmission lines. This study can only be done by involving expert system consultants and national-level agencies like CEA and RLDCs, who are involved in planning and operations. The state can put up a strong demand for such a study with the central agencies to estimate the grid augmentation requirement at the state, regional and national levels. At the state level the state can create an apex transmission planning body comprising members from KSEB, wind developers, solar power developers, independent consultants, SLDC (State Load Dispatch Centers) and CTU representatives to create long-term plans and decide on budgetary provisions for new intra-state and inter-state transmission capacity.

Demand Early Commissioning of the Inter-regional Link to Facilitate Operationalization of the National Grid

The proposed renewable energy penetration assumed in the state energy scenario effectively means that even though Kerala will be self sufficient, the actual power flows will vary across the seasons with large increase in interstate and interregional transfer volumes. This would necessitate the availability of a strong interstate and inter-regional corridor. In such a scenario, the availability of an inter-regional corridor to evacuate power to the western and northern regions will be necessary. The state will have to highlight the criticality of an inter-regional link and its timely completion at appropriate forums including the plan panel and CEA to ensure early commissioning of such corridors.

Advocate Creation of an Ancillary Market to Enable Intra-day and Spot Trading of Power

Formulation of enabling regulatory provisions to facilitate creation of short-term and spot power markets would provide maximum benefit to the state by allowing it to trade surplus power at higher costs and buy deficit power at lower costs. The state can take the lead in approaching the central electricity regulator or Ministry of Power (MoP) to enact enabling provisions for facilitating creation of such ancillary markets.

Changes in Grid Operational Philosophy: The state has to overhaul the existing operational management practices to allow accommodation of high RE in the grid. The conventional operational philosophy cannot accommodate RE simply because it is modelled around the predictable system behaviour of conventional sources and the new philosophy has to essentially be centered on the need for accommodating renewables as and when they come. The state can avail services of reputable national/international consultants to look at this aspect. Detailed consultative exercises with operations experts in European utilities and grid planners can help in developing the guiding precepts for the new operational management philosophy.

Development of Small Hydro

There is small uptake in investment in the SHP sector by private investors despite the declaration of new SHP policy. Some of the measures, which may be hindering uptake are the provisions related to BOOT time (30 years from the date of allocation, whereas 5-6 years go in construction) and the stipulation for multiple approvals, which are time consuming. The best way to move forward in the short term could be to allow more time under BOOT for the investor and enacting a single window clearance mechanism for investors. In addition, to allay risk perceptions, the state can make the DPRs of the proposed SHP plant public and allow time for local opinion to come in through grama sabha. The projects can be allocated after a consensus acceptance at the grama sabha level.

Assessing Feasibility of New Technologies

According to various official reports, the state is also planning adoption of new technologies like floating PV panels, tidal energy systems, and wave energy systems. It will be in the interest of the state to assess the feasibility of these technologies by expediting pilot installations of these technologies. Preliminary estimates based on existing studies also indicate a coastal wave energy potential of 4200 MW across the entire coastline. However, it is important to assess the actual feasibility by installing pilot projects at identified locations.

13.4 INDUSTRY

Policy Objectives

- Support for achieving sectoral energy conservation targets
- Government support in encouraging adoption of BAT and BPT in Industries

Policy Targets

- Achieving sector defined energy conservation targets by 2020
- Supporting up to 50 per cent reduction in energy intensity of identified industry sectors by 2050 through technology support and encouragement for adopting BAT (best available technologies)
- Up to 15 per cent switch to solar process heating in select sectors by 2030

The main strategy considered under this sector is allocation of an Industry sector specific target on energy conservation. The best way to achieve it could be to devise a state level PAT (perform, achieve and trade) scheme for industries within a single sector. However, provisions should also be made to include conservation efforts in heat demand. Implementing this would require substantial resources for capacity building, monitoring and dispute resolution but these resources can be harnessed through joint manpower and financial pooling of industry bodies, EMC, state industries department and state industries Development Corporation. Another way to implement this could be create designated sector based ESCOs that provide guidelines on implementation.

Second measure could be supporting existing and new Greenfield industries in adopting BAT over time. This would require government involvement in aspects related to technology assessment, technology transfer, and capacity building. One way to do this could be to bring in external industry consultants and ESCO representatives on industries approval committee, which would be approving all new Greenfield projects. For existing industries, a move to process improvements can be supported by indirect subsidy in the form of revenue foregone (discount in electricity/water rates, etc).

13.5 AGRICULTURE

Policy Objectives

- Phasing out of diesel pumps
- Adoption of micro-irrigation practices
- Switch to solar water pumping or energy efficient pumps

Policy Targets

- 20 per cent reduction in energy savings through micro irrigation by 2030
- 35 per cent reduction in energy use for irrigation pumps with 100 per cent shift to efficient pumps/solar water pumps by 2030
- 60 per cent penetration of solar water pumps by 2050

The agricultural policy includes promotion of micro-irrigation as one of the strategies for agricultural development in the state. In the face of declining water tables and increasing difficulties in accessing once perennial small surface water sources, micro-irrigation could be the centre-piece of conservationist approach that is strongly needed to save agriculture in Kerala.

In addition, from an energy perspective, move towards efficient pump sets and solar water pumping has to supported through subsidies to the farmer. In the past, many sate utilities have in fact made an economic case out of providing direct subsidy (up to 90 per cent) for a switch to efficient pumps. This was done as the energy savings on the already subsidized electricity more than paid for itself by allowing the utility to increase its revenue from non-subsidized categories. Solar water pumps are already under a subsidy scheme but they can be further subsidized and preferentially promoted in locations where they are feasible (from the perspective of water level and sowing season).

13.6 PUBLIC UTILITIES (LIGHTING AND WATER WORKS)

Policy Objectives

- Reducing water wastage in water transmission
- Optimizing energy conservation in street lighting

Policy Targets

- Over 15 per cent reduction in energy use in public water works by reducing transmission losses by 2025
- 20 per cent reduction in energy use in street lighting by 2020
- 50 per cent penetration of solar street lighting by 2040

Many studies have consistently pointed out the huge saving potential in this sector. Based on identified strategies, an immediate policy measure could be to reduce transmission loss (currently at about 25 per cent) to 5 per cent. It will be increasingly difficult to sustain these levels of losses as piped water supplies increase and an early intervention can have long term benefits.

14. STATE INVESTMENT CONSIDERATIONS FOR THE TRANSITION

One of the most critical metric for facilitating the 100 per cent RE energy scenario is the cost associated with the proposed transition strategies. In line with inputs from stakeholders, the objective is to assess the level of direct investments required from the state in new infrastructure development and other capital investments required to facilitate the transition.

It is assumed that the envisaged role of the government/state is to be an initiator, incubator and a facilitator and it will play a role only in investments deemed essential; investments which may not have immediate economic benefit or would be considered risky and hence would not be taken up by private sector under normal circumstances. The focus is on infrastructure and large capital investments in equipment. It is assumed that for most of the other strategies where state sector investment is not earmarked, the bulk of investments will come from the private sector which will find business opportunities in these strategies under the new business environment created by policy and regulatory forcings.

The methodology for determining investment implications for the state involves determination of CAPEX (Capital Expenditure) and Net OPEX (Operational Expenditure) for these investments. Net OPEX costs are considered to be the final recurring costs after considering actual operational expenditure, revenue realization potential and savings accrued, if any.

CAPEX is estimated based on available literature/empirical data. **Net OPEX cost calculation** (operational costs in addition to baseline OPEX costs) is dependent on the technical implications of the intervention. For example, in strategies which result in energy savings, Net OPEX costs are considered to be negative and exactly equal to the achieved savings. In strategies where new infrastructure necessitates additional maintenance and operations expenditure, net OPEX costs are the difference between actual operational costs and revenue realization potential.

Based on these assumptions, the sector-wise investment assessments are estimated below.

14.1 TRANSPORT SECTOR: INVESTMENT IMPLICATIONS

The main intervention strategies considered in the transport sector include resource pooling, better traffic management, modal shift to coastal freight transport, intra-modal shift to public transport (mainly buses) and increased penetration of electric vehicles. For most of the strategies, necessary policy and regulatory support can develop a facilitating environment for private investments. However, two specific intervention strategies that may require initial investment from the state sector would be

a) Investments in infrastructure development for cargo handling in non major ports for facilitating inter-state cargo to shift from road to coastal mode
b) Investments in new road public transport systems (mainly buses) to manage additional transport requirements.

Investments in Infrastructure Development for Cargo Handling in Non-major Ports: The proposed quantified targets of freight modal shift to coastal shipping from road, derived from Deloitte study[227] also identify potential ports (major and non major) that will have to be developed for cargo handling to make the shift possible. For example, for the port of Azhikkal, the study identifies investment requirements related to land acquisition, surveys, site development, development of cargo berths, buildings, amenities, dredging, storage yards, material handling equipments, etc and estimates the total cost at Rs 75 Cr (Rs 750 million). In all, the identified total investment requirements across Azhikkal, Beypore, Kollam, and Alappuzha to be about Rs 146 Cr (Rs 1456 Million). All of this investment has to be made by the state before 2020 to facilitate the proposed freight shift by 2020.

As the benefit of these investments accrue to the private sector, it is assumed that OPEX for the ports will be managed through a mutually agreeable levy collection managed in public private mode in such a way that there will be no cost implications to the state. It is assumed that collections from freight handling rates and other levies would take care of operational expenses.

Based on these considerations, the cumulative state investment requirements spread across ten-year periods are shown in Table 14.1 below.

Table 14.1: State Investment Requirements for Port's Infrastructure

Up gradation of all ports for cargo handling (Rs Cr)	2011- 20	2020-30	2030-40	2040-50
CAPEX	146			
NET OPEX	0	0	0	0
Net Outflow	**146**	**0**	**0**	**0**

Investment in New Buses and Road Based Public Transport Infrastructure: Additional state level investment in public transport infrastructure, especially buses and mini buses for local and long distance travel can facilitate the reversal of the trend of the increasing preference for personal transport. The proposed intra-modal intervention of shifting cars and two wheelers share in road transport to public transport and maintaining car and two wheeler share at 4 per cent and 9 per cent, respectively translates into additional passenger load of 38 billion p-km to public transport (Long distance buses, short distance buses and auto rickshaws) in 2030. This share increases to 78 billion PKm in 2040

[227] Deloitte. 2011. Preparation of Strategy Road Map cum Action Plan for Development of Coastal Shipping in Kerala. Submitted to the Directorate of Ports, Government of Kerala. Deloitte Touche Tohmatsu India Private Limited. http://www.keralaports.gov.in/images/Final%20Report%20-%20Kerala%20Coastal%20Shipping%20-%20v%204.0%2020%20Jun%202011.pdf.

and 180 billion PKm in 2050. While investments for auto rickshaws/taxis can come out of private sector, the state will have to take a leading role in making investment in new state transport buses.

The estimated passenger shift to public transport translates into an additional requirement of about 6,800 buses in 2030 and increases to about 23,430 new buses in 2040 and 57,600 new buses in 2050. This is not a very large addition as compared to the base year fleet of 74000 buses. Assuming present cost of about Rs 16.5 lakh (Rs 1.65 million) for a single 50 seater bus,[228] the total investment requirement in terms of present costs works out to be Rs 1,123 Cr (Rs 112.3 million), Rs 3,873 Cr (Rs 387.3 million) and Rs 9,500 Cr (Rs 950 million) in 2030, 2040 and 2050, respectively. The cumulative investment requirement for procuring new buses are estimated for every ten-year period. Even if the state can strengthen its public transport infrastructure from existing share of about 8 per cent to 30 per cent, new state sector investment requirements would work out to be about 336 Cr for the period 2020-30, Rs 1,162 Cr for the period 2030-40 and Rs 2,850 Cr for the period 2040-2050 .

Based on data available from the website of Kerala road transport Kerala State Road Transport Corporation, the average annual distance travelled per bus assuming 330 days of full service operations in 2012 was about 82,860 km. Assuming a fuel efficiency of 4.5 km/l and a fuel cost of Rs 65/lit, the total fuel cost per bus is estimated at Rs 11.96 lakh/year.

In line with the World Bank study on analyzing operational cost break-up of public buses in India, it is assumed that fuel costs represent 50 per cent of total operational costs (excluding depreciation).[229] This translates into an operational cost of Rs 23.92 lakh/year/bus.

On the other hand, based on data available from Kerala state road Transport Corporation's website, average earnings per km are reported as Rs 30.7 /km in 2012. Considering an average annual run of 82860 km per bus, the total earnings from a bus are estimated to be Rs 25.42 Lakh/year/bus.

The calculations indicate a slender operational profit of Rs 1.06 Lakh per bus/per year. Based on the above calculations, Table 14.2 summarizes the investment requirement from the state in public transport.

Table 14.2: State Investment Requirements for Public Transport Infrastructure

Investment in new buses and public transport (Rs Cr)	2011-2020	2020-2030	2030-2040	2040-2050
CAPEX		336	1160	2850
OPEX		*607*	*2088*	*5130*
REVENUE REALIZATION		*645*	*2217*	*5448*
NET OPEX		-38	-129	-318
NET OUTFLOW		**298**	**1031**	**2532**

228 Starline 50, Eicher 11.2AB HHR. http://tabindia.weebly.com/eicher-full-buses-price-list.html.

229 World Bank. XI. *Cost Estimation: Introduction to Public Transport Planning and Reform.* Public Private Infrastructure Advisory Facility and The World Bank. http://siteresources.worldbank.org/EXTURBANTRANSPORT/Resources/341448-1269891107889/6914036-1278599591319/7230414-1278599610386/costs.pdf.

14.2 BUILDINGS AND REAL ESTATE: INVESTMENT IMPLICATIONS

The main public sector investment requirements in this sector mainly centre on retrofitting of existing government buildings. According to Census 2011, the total number of commercial buildings in Kerala including shops/offices, schools/colleges, hotels, hospitals/heath care centres, factory sheds and places of worship is about 2,126,000. These buildings are spread across various categories like shops/offices, school/colleges, work shed/factory, Hospital/Dispensary, Hotels, places of worship etc.

For each of these categories, standard floor area availability is assumed in line with the assumptions stated in rooftop PV potential assessment concluded in Part 2. Depending on the type of institution, the share of state owned buildings in each category is either assigned a value 5 per cent or 10 per cent. Assuming single storied structures, the total floor area available in public sector buildings for retrofit is estimated.

To assess the costs of retrofits in terms of floor area, the NRDC study[230] on retrofitting of Godrej Bhavan Building in South Mumbai was referred. According to empirical data available in the study, the total retrofit investments including investments in energy efficient equipment (lighting, refrigeration, fans, etc), accessory fittings (improved louvers, glass films, etc) and water harvesting was about Rs 2,473/m^2 of floor area.

Assuming retrofit costs of Rs 2,500/m^2 and the assumptions stated above, the total state sector investment in buildings sector is calculated in Table 14.3 below.

Table 14.3: Assessment of State Sector Investment Requirements in Public Buildings

Categories of Institutional/ commercial buildings in Kerala	Shop / Office (Nos)	School/ College etc. (Nos)	Hotel, Lodge, Guest Houses, etc (Nos)	Hospital/ Dispensary etc (Nos)	Factory/ Workshop/ Work shed etc. (Nos)	Place of worship (Nos)	Total
Total Number of commercial Institutional Buildings with concrete roofs	964,441	75,480	52,509	31,589	165,901	105,562	1,395,482
Area available m^2 assuming a single storied structure	30	1500	450	750	1500	450	NA
Total Floor area available (m^2)	28,933,230	113,220,000	23,629,050	23,691,750	248,851,500	47,502,900	485,828,430
Assumed public sector ownership assumed	5%	10%	5%	5%	5%	10%	NA
Total commercial floor area under public sector	1,446,661.5	11,322,000	1,181,452.5	1,184,588	12,442,575	4,750,290	32,327,567
Total cost at present retro-fitting rate of Rs 2,500/m^2	361.66538	2830.5	295.363125	296.1469	3,110.6438	1,187.57	8,081.89

[230] NRDC. 2013. *Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai*. Natural Resources Defense Council, and Administrative Staff College of India.
http://www.nrdc.org/international/india/files/energy-retrofit-godrej-bhavan-CS.pdf

In line with the interventions worked out for the commercial sector, a gradually increasing penetration of green buildings or retro-fitted buildings is assumed; from 5 per cent in 2025 to 10 per cent in 2030, 30 per cent in 2040 and 70 per cent in 2050.

To compare the implications of investment over the baseline scenario, only CAPEX and savings are captured. The savings reported in the NRDC study indicated[231] that electricity use reduced from 271 kWh/m^2 to 238 kWh/m^2; a reduction of 33 kWh/m^2. Assuming similar level of reduction and a commercial electricity supply rate of Rs 5, the cumulative savings in the period 2020-2030 would be about Rs 200 Cr (assuming conversion of 7.5 per cent of targeted floor area).

Based on the above level of interventions, the state level investment requirements are as shown in Table 14.4.

Table 14.4: State Level Investment Requirements in Buildings

Cost of Energy efficient retrofitting and water harvesting in public sector buildings (Rs Cr)	2011-2020	2020-2030	2030-2040	2040-2050
CAPEX	0	808	2,425	5,657
SAVINGS		*200*	*1,060*	*2,660*
NET OPEX		-200	-1060	-2,660
NET OUTFLOW	**0**	**608**	**1,365**	**2,997**

14.3 ENERGY AND POWER: INVESTMENT IMPLICATIONS

The final energy scenario envisages aggressive RE deployment by the state. In this context, the best learning experience for the state planners is to develop state-owned pilot projects of new technologies to demonstrate the state's willingness to support RE. A pilot of 10 MW is assumed for all new untested technologies like offshore wind, grid-tied PV, floating PV, and wave power. For biofuels, a sea algae based 0.1 million ton algal bio-diesel pilot plant is considered.

The capital costs and operational costs for the technologies were derived from available national and international literature. Table 14.5 summarizes the assumed capital costs and the references.

Table 14.5: CAPEX and OPEX Assumptions for RE Technologies

CAPEX of Technologies	Unit	Value	Reference
Offshore wind power	Rs Cr/MW	14.95	2.5 times onshore capital cost as per NREL* Onshore capital costs of CERC†
Grid-tied PV	Rs Cr/MW	8	CERC†
Floating PV	Rs Cr/MW	16	Assumed as twice that on-ground projects
Wave Power	Rs Cr/MW	6.67	URS Study
Bio-diesel (derived from sea based algae)	Rs/lit	55.56	Best case projection (PBR Aggressive) at capital cost of $4.2/Gallons NREL§

Continued…

231 Ibid

Table 14.5: …continued

OPEX of Technologies	Unit	Value	Reference
Offshore wind power	% CAPEX	7.50%	Based on empirical data
Grid-tied PV	Rs Cr/MW	0.12	Based on empirical data
Floating PV	Rs Cr/MW	0.25	Assumed 2 times land based costs
Wave Power	Rs Cr/MW	5%	Assumed
Bio-diesel (derived from sea based algae)	Rs/lit	29	Best case projection (PBR Aggressive) at prod cost of $ 2.2 / Gallons NREL§

* Tegen, S. et al. 2013. 2011 Costs of Wind Energy Review. National Renewable Energy Laboratory, Technical Report NREL/TP-5000-56266 (March). http://www.nrel.gov/docs/fy13osti/56266.pdf.

† Central Electricity Regulatory Commission. 2012. Petition No. 243/SM/2012 (Suo moto) – Determination of Generic Levellised Generation Tariff for the FY2013-14 under Regulation 8 of the (Terms and Conditions for Tariff Determination from Renewable Energy Sources) Regulations, 2012. http://www.cercind.gov.in/2012/orders/243_SM_2012%20dated%2025.10.pdf.

‡ URS. 2009. Wave Power Feasibility Study Report: City and county of San Francisco, URS. San Francisco, CA. http://sfwater.org/modules/showdocument.aspx?documentid=1624.

§ Aden, Andy and Davis, Ryan. 2011. Davis Algal Biofuel Pathway Baseline Costs. National Renewable Energy Laboratories (7 April).

The revenue realization from the power generating pilots is estimated assuming a supply tariff of Rs 3.5 kWh. For biofuels, a retail price of Rs 60/lit is assumed for estimating revenues realized from bio-diesel sales.

Based on these assumptions, the final CAPEX, OPEX requirements and estimated revenue generation are shown in Table 14.6.

Table 14.6: State Level Investment Requirements for Developing RE Pilots

State investments in renewable energy based pilot projects (Rs Cr)	2011-2020	2020-2030	2030-2040	2040-2050
CAPEX	306.7	803.6		
OPEX		69.4	3,591	3,591
Revenue Realization	*49*	*114*	*6,205*	*6,205*
Net OPEX	-49	-44.6	-2,686	-2,686
Net Outflow	**257.7**	**759**	**-2,686**	**-2,686**

14.4 INDUSTRY SECTOR

A majority of the industries in the state are owned by Private sector, except for a handful of few large industries that are owned by the state.

It is to be noted that one distinctive feature of the proposed energy efficiency or energy conservation measures in the industry sector is the self-paying nature of EC and EE interventions. In all the reviewed case studies and literature available related to costs of passive measures like heat/electricity conservation, better insulation, and even equipment level replacements, variable frequency drives, super efficient motors, etc, the payback period was seldom more than 6 years.[232] In some cases, it was less than six months.[233]

In this sense, investments in EC and EE for public sector manufacturing units would not imply a one way outflow of state funds. Additionally, all the major state owned industries have their own management and in that sense they are independent from government control and decisions related to industry unit level EE/EC interventions will be evaluated and approved internally and will be financed through the company's own reserves. In addition, most of the proposed interventions would make economic sense as the initial investments will be recoverable through savings.

In this sense, it is assumed that there would be no direct implication on the state in terms of a separate budgetary outflow.

14.5 AGRICULTURE SECTOR

The main interventions proposed for this sector include adoption of micro-irrigation, phasing out of Diesel Pumps, and use of BEE labelled water pumps (electricity based initially and solar energy based subsequently). All of the proposed interventions will require an early policy push for facilitating adoption of the proposed measures. However, one area where state investments can make an impact is providing financial support to switch from existing low-efficiency pump-sets to energy efficient pump-sets. In fact, in states where supply to agriculture is heavily subsidized or is free, 100 per cent financial support for acquiring BEE star labelled pumps has also been financially justified in some cases with the cost burden being shared by the pump manufacturer and the government.[234]

In Kerala, actual switchover from existing pump-sets would require financial support in addition to a policy push. Based on recent study by netscribes,[235] the average cost of a locally manufactured pump-set is about Rs 18000 while that of a branded pump-set is Rs 26000. In contrast, the costs of a 3 hp solar pump-set are upwards of Rs 3 lakh but it is expected that these costs will come down significantly over time and it is assumed that they will achieve cost parity by 2030.

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[232] Limaye, Dilip R. et al. 2009. *Kerala State Energy Conservation Fund (KSECF) Financing Schemes.* USAID Asia. Report prepared for Energy Management Centre, Department of Power, Kerala.
http://www.keralaenergy.gov.in/emc_Downloads/KERALA%20STATE%20ENERGY%20CONSERVATION%20FUND%20(KSECF)%20FINANCING%20SCHEMES.pdf.
SIDBI. 2010. "Energy Efficiency Potential and Way forward in Kerala". *Newsletter on MSME Energy Saving Project.* Issue 4 (July-September).
http://www.inspirenetwork.org/pdf/4.jul-sep10.pdf.
[233] CII. *Investors Manual for Energy Efficiency.* Indian Renewable Energy Development Agency and Confederation of Indian Industry. Chennai, India.
http://ireda.gov.in/writereaddata/IREDA-InvestorManual.pdf.
[234] IEI. 2010. *Efficient Well-based Irrigation in India: Compilation of Experiences with Implementing Irrigation Efficiency.* The International Energy Initiative and Prayas. Pune, India.
[235] Netscribe. 2012. *Market Research of Agriculture Pump-sets Industry of India.* Shakti Sustainable Energy Foundation and Netscribes (12 June).
http://www.shaktifoundation.in/cms/uploadedImages/agriculture%20pump%20study_report%20final_12th%20june.pdf.

In this background, the best way to financially support a move to star labeled pumps would be to provide an amount more than the cost differential for voluntary replacements of locally manufactured pump-sets. Over next one to two decades, as the existing pump-sets wear out and are replaced, such an incentive supported with policy (making star labels mandatory, preferential charges to star labeled pump owners, etc) will facilitate very high level of replacements. By 2030 and beyond, as solar pump-set become cost competitive, they also can be supported on similar subsidy support scheme.

Kerala has an existing pump-set population of 4.3 lakh pump-sets. No increase in number of pump-sets is assumed as the electricity demand for irrigation has been steady for past some years. Considering a subsidy of Rs 10,000 in terms of present costs per pump-set, the total subsidy disbursement assuming a constant pump-set population would be Rs 430 Cr by 2030 for ensuring 100 per cent replacement.

The OPEX requirement on the other hand would not have any implication for the state as benefits of savings will be passed to farmers.

Table 14.7: State Level Investment Requirements for Agriculture

State investments in energy efficient electricity or solar power based pump-sets (Rs Cr)	2011-2020	2020-2030	2030-2040	2040-2050
CAPEX	215	215		
Net OPEX		0		
Net Outflow	**215**	**215**		

14.6 PUBLIC WORKS AND BULK SUPPLY

The main intervention strategies considered in this sector are reducing water pumping losses, adopting energy efficiency and energy conservation measures in public lighting and water supply and increased use of solar street lighting.

Reduction in water pumping losses would mostly require strong regulation, better maintenance/refurbishment and moderate spares up gradation. While these measures would have cost implications they would be minor and are hence are not considered as infrastructure investments by the state. The key EE and EC interventions in public water works and public lighting would also incur costs. However considering the distributed nature of activities in these areas, these costs are also not considered as part of core infrastructure investments.

The major infrastructural investments in this sector would be related to replacement of 20 per cent, 30 per cent and 50 per cent existing street light fixtures with solar street by 2020, 2030 and 2050, respectively. Solar street lights are either CFL based or LED based. A standard LED based street light fitting having efficiency of 60-100 lumens/watt, 4m height and 10 m span is taken as the representative solar street light model. The per-unit cost based on street light cost derived from Solar City Plan Document of Agra is assumed as Rs 12,000.[236]

[236] Ministry of New and Renewable Energy. *Development of Agra Solar City: Final Master Plan.* Ministry of New and Renewable Energy, Government of India, and ICLEI South Asia. New Delhi. India. http://mnre.gov.in/file-manager/UserFiles/agra_solar_city_master_plan.pdf.

A standard conventional street light fixture using 70 W HPSV (High Pressure Sodium Vapour) lamp consumes about 254 kWh/year. Considering the total public lighting energy requirement of 249.54 MU in 2030 (based on energy demand after EC and EE interventions), and replacement target of 20 per cent (in energy terms), a displacement of about 1.96 lakh (0.196 million) conventional street lights will be required by 2020. To deliver equivalent lumens in the replacement locations, a lower span of 10 m would necessitate two solar street lights in place of one conventional fixture. Based on this assumption, Rs 470 Cr investment will be required by 2020. Assuming the existing central subsidy support of 50 per cent to be available, the actual cost to the state would be Rs 235 Cr. Similarly, additional investments required in the period 2020-30 and 2030-40 to meet 30 per cent and 50 per cent target would be Rs 351 Cr and Rs 919 Cr, respectively.

On the other hand, the savings accruing to the public utilities from the replacements are estimated assuming an electricity tariff of Rs 3.5/kWh.

Table 14.8 summarizes the investment requirement.

Table 14.8: State Level Investment Requirements for Solar Street Lighting

State investments in street lighting (Rs Cr)	2011-2020	2020-2030	2030-2040	2040-2050
CAPEX	235	351	919	
SAVINGS	87.1	130	340	436
Net OPEX	-87.1	-130	-340	-436
Net Outflow	**147.9**	**221**	**579**	**-436**

SUMMARY OF STATE SECTOR INVESTMENTS

Table 14.9 and Figure 14.1 summarize the total state sector investment requirement for all the interventions.

Figure 14.1: Summary of State Investment Requirements

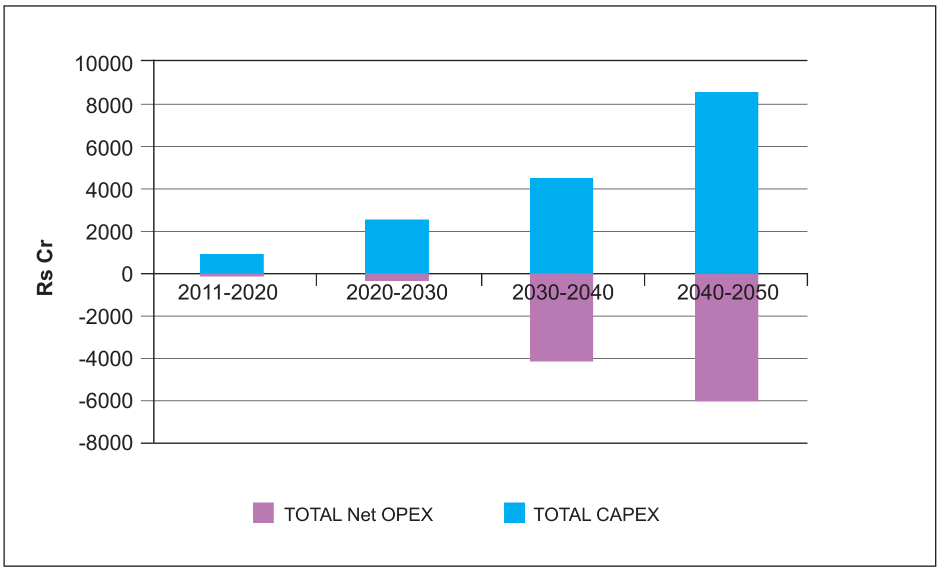


Table 14.9: Summary of State Sector Investment Requirements for the Transition

CAPEX	2011-2020	2020-2030	2030-2040	2040-2050
Up gradation of all ports for cargo handling	146			
Investment in new buses and public transport		336	1,160	2,850
Cost of Energy efficient retrofitting and water harvesting in public sector buildings		808	2,425	5,657
State investments in renewable energy based pilot projects	306.7	803.6		
State investments in energy efficient electricity or solar power based pump-sets	215	215		
State investments in street lighting	235	351	919	
TOTAL CAPEX	902.7	2513.6	4504	8507
Net OPEX				
Investment in new buses and public transport		-38	-129	-318
Cost of Energy efficient retrofitting and water harvesting in public sector buildings		-200	-1060	-2660
State investments in renewable energy based pilot projects	-49	-44.6	-2686	-2686
State investments in street lighting	-87.1	-130	-340	-436
TOTAL Net OPEX	-136.1	-412.6	-4215	-6100
Net Outflow	**766.6**	**2,101**	**289**	**2,407**

Interestingly, the above scenario envisages average annual outflow to grow from about Rs 78 Cr in 2013-2020 period to about Rs 240 Cr in 2040-2050 period. This level of increase corresponds to a CAGR of about 3 per cent, which is significantly less than the 7.3 per cent GSDP (Gross State Domestic Product) growth rate assumed for the state. In this sense, the proposed annual budgetary provisions are not expected to have any major impact on the state.

It has to be noted that the cost estimates in Table 171 are based on present costs and actual cost trajectories of services, equipment and commodities may follow a different path altering the final investment requirements. However, any deviation in the figures would mostly be one sided as the costs of action would far outweigh the costs of inaction because the prices of conventional services, commodities and equipments will increase over time. For example, revenue realization estimation of RE electricity sales assumes a supply cost of Rs 3.5/kWh, which may exhibit a steep increase as conventional power prices go up. Similarly, future constraints in oil supply may escalate conventional fuel prices, allowing higher price realization for locally produced bio-diesel resulting in significant additional revenues that may make the net outflow negative.

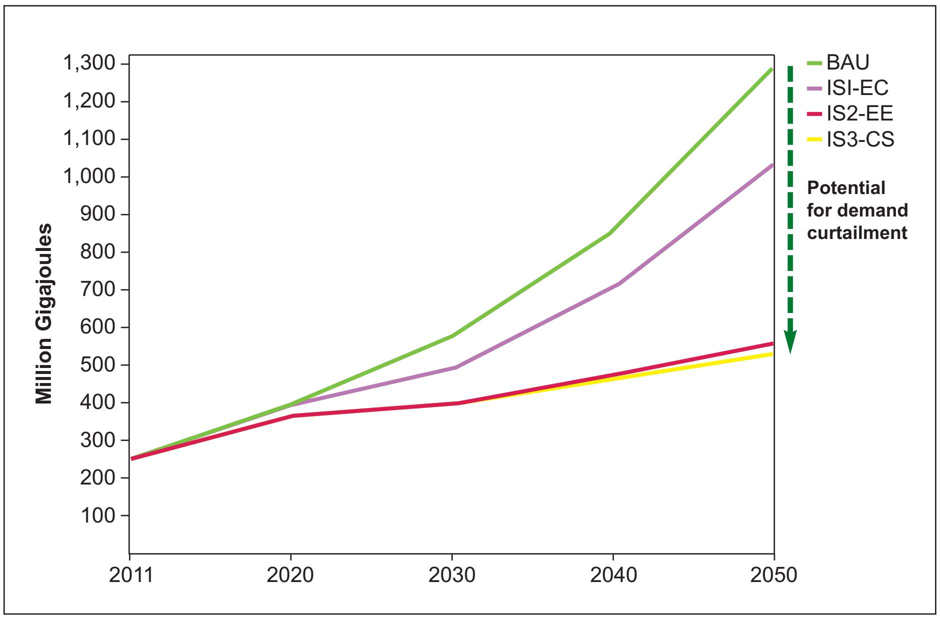
In this sense, the costs estimates are conservative and can be considered as an upper limit of the state sector investment requirements for facilitating the identified interventions.

15. CONCLUSION

A 100 per cent RE future is not a chimera. Technically, at the state level, 95 per cent of the energy requirements can be met from renewable sources by 2050.

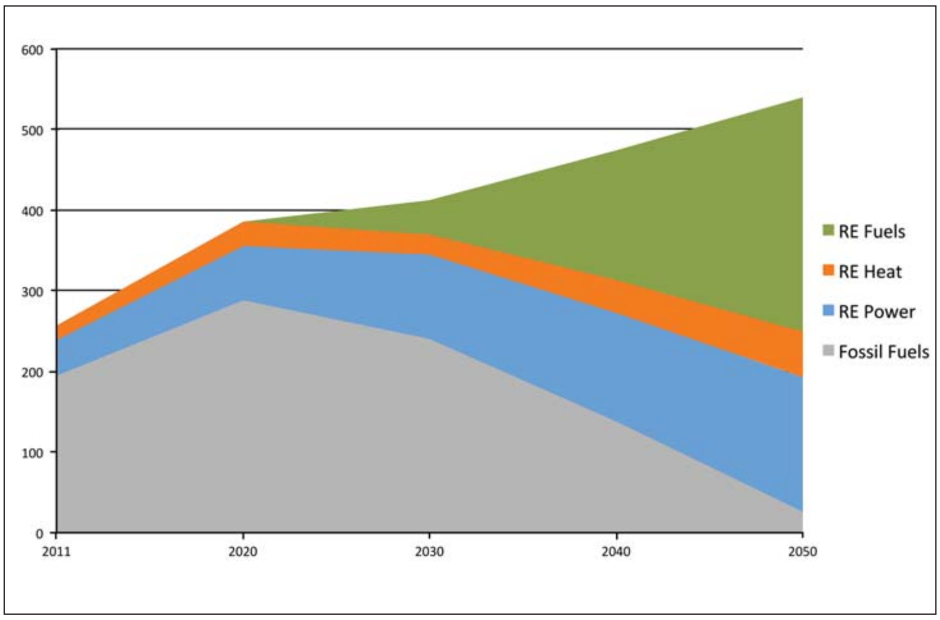
One of the key technical finding is the assessment of demand curtailment potential. Aggressive demand side interventions in energy conservation, energy efficiency and carrier substitution have the potential to reduce energy demand by about 60 per cent (see Figure 15.1).

Figure 15.1: Potential of Demand Curtailment



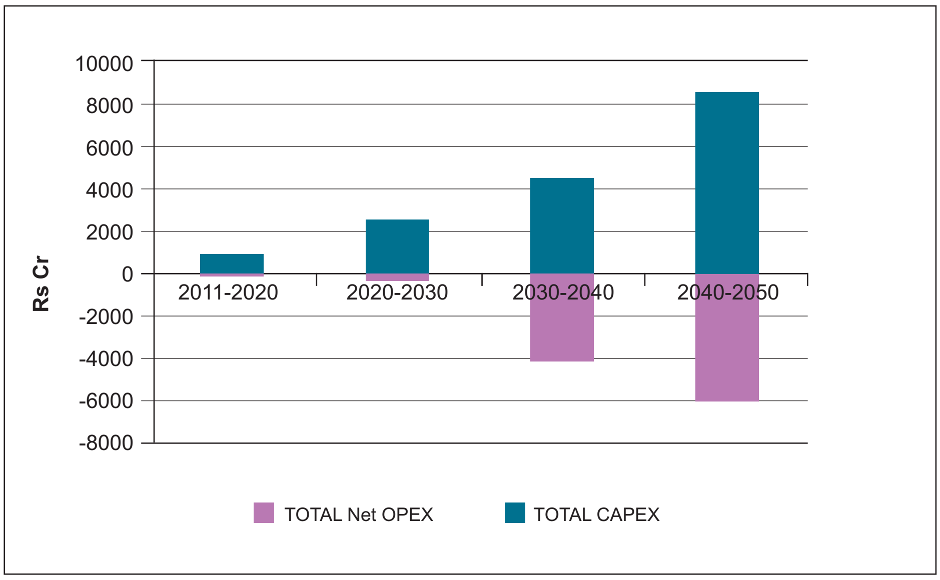
There is enough RE potential in the state to technically power all of its energy demand with renewable sources. Complete phase out of fossil fuels is not deemed possible mainly because of specific fossil fuel end use in some heating and process requirements. For example, part of LPG requirement in the domestic / commercial sector and coke requirement in the industry sector are deemed to be irreplaceable because of the way and the form in which these fuels are used. Despite this, over 95 per cent of the demand can be met internally by harnessing RE resources available within the state. (See Figure 15.2)

Figure 15.2: Final Supply Share of Fuels (PJ)



The public sector investment requirements for facilitating transition to a 100 per cent RE scenario appear to be miniscule as compared to the state's gross domestic product. Even a conservative estimate of state investment requirements in risky and difficult infrastructure ventures suggests significant possibilities of investment returns through accrued savings or new avenues of revenue realization. (See Figure 15.3)

Figure 15.3: State Investment Requirements



Although public sector investments would be a fraction of private sector investments, it can be assumed that future private sector investments will be essentially business investments that will make economic sense under new forcings brought about by evolving policy and regulatory regimes.

The key challenges to achieving the 100 per cent RE scenario are the following

- State's willingness to move from a BAU mode of thinking to a future-oriented mode of thinking. This would necessitate that the leaders and the state administrators share a common overarching vision for transitioning the state to a 100 per cent RE scenario. A starting point for this could be development of a comprehensive energy vision for the state.
- Combining effective long-term policies with iron-clad regulations to ensure that the proposed interim targets are met.
- Timely deployment of identified RE technologies and associated support infrastructure to ensure that 100 per cent targets are met by 2050. The state has to start planning for pilot projects and set up research and development facilities in high potential RE target areas like offshore wind and biofuels.
- Building necessary institutional capabilities for handling and executing the transition. This would necessitate substantial capital and manpower resource investments in capacity building, training, new recruitments, consultancy assignments and awareness programmes.

The key conclusions of the study are

- A BAU growth cannot be sustained indefinitely even with all fossil and renewable sources unless we are able to decouple economic growth (GDP) from energy resource use.
- Evolution and breakthroughs in system operations, material engineering and equipment technologies are continuously going to open up new possibilities in demand curtailment. Technology evolution may reach a stage where the rate of decrease in energy intensity may overtake the rate of increase in demand.
- There are operational challenges in utilizing RE technologies, but these challenges can be overcome by future developments in the energy sector (high capacity corridors, generation forecasting, grid-scale storage, etc).
- Apart from technology, political will and a shared vision are the most critical prerequisites for development of 100 per cent RE scenario.

APPENDIX 1

FORECASTING OF MAJOR VARIABLES

Different regressors are used for performing regressions to forecast the future demand for motor vehicles and railways passenger kilometre and freight kilometre. The regressors are gross state domestic product (GSDP), gross state domestic product from agriculture and industry (GSDP(A) + GSDP (I)), gross state domestic product from agriculture, population of Kerala, urban population of Kerala, and per capita income. However, the regressors had to be forecasted in order to forecast future demand for motor vehicles and railways passenger km and freight km. The Techniques used in forecasting the regressors are discussed below one by one.

FORECASTING GSDP

Data for GSDP at 2004-05 prices have been obtained for the years 2004-05 to 2011-12 from department of economics and statistics, government of Kerala.[237] However, data from 2000-01 to 2003-04 have been obtained from a planning commission document.[238] Data from 2000-01 to 2003-04 are at current price and not in 2004-05 prices. To convert these data in 2004-05 price, use of WPI index (financial year) has been made.[239] Thus, a GSDP data set in 2004-05 prices since 2000-01 to 2011-12 have been obtained.

A year-on-year growth rate of GSDP from 2001-02 to 2011-12 has been obtained. In this process, growth rates of few years appeared to be outliers. These are excluded from the data set to find out the average of year – on – year growth rate. The average of year – on – year growth rate from the year 2001-02 to 2011-12 is found to be approximately 7.3 per cent which has been adopted as the growth rate of GSDP of Kerala up to 2050. Using this method, Kerala's GSDP in 2004-05 prices appears to be Rs 30,565.42 billion in 2050 as against Rs 1,918.67 billion in 2011.

FORECASTING GSDP FROM AGRICULTURE AND INDUSTRY

Data on gross state domestic product in 2004-05 prices from agriculture and industry have been obtained from department of economics and statistics, government of Kerala.[240] These data have been used to separately find out percentage share of GSDP from agriculture (GSDP(A)) in Kerala's GSDP and percentage share of GSDP from industry(GSDP(I)) in Kerala's GSDP for the years

[237] Department of Economics and Statistics, Government of Kerala – GSDP at constant prices (at factor cost by industry of origin) with base year 2004–2005.
[238] Planning Commission. "Gross State Domestic Product (GSDP) at Current Prices (as on 15–03–2012)" http://planningcommission.nic.in/data/datatable/0904/tab_104.pdf.
[239] Office of the Economic Advisors to the Government of India, Ministry of Commerce and Industry, WPI data, 1993–94 series.
[240] Department of Economics and Statistics, Government of Kerala – GSDP at constant prices (At factor cost by industry of origin) with base year 2004–2005.

2004-05 to 2011-12. Then separate linear trends have been fitted to data on percentage share of GSDP(A) in the total GSDP and percentage share of GSDP(I) in the total GSDP for the years 2004-05 to 2011-12. Then these trend equations have been used separately to find out percentage share of GSDP(A) in total GSDP and percentage share of GSDP(I) in total GSDP for the years 2000-01 to 2003-04. Thus, the percentage share of GSDP(A) in total GSDP and percentage share of GSDP(I) in total GSDP for years 2000-01 to 2011-12 is estimated.

In the next step, yearly percentage share of GSDP(A) in total GSDP has been multiplied with the total GSDP of the corresponding year. This gives year wise GSDP(A) for years 2000-01 to 2011-12. Similarly, yearly percentage share of GSDP(I) in total GSDP has been multiplied with the total GSDP of the corresponding year. This gives us year wise GSDP(I) for years 2000-01 to 2011-12. Then year wise GSDP(A) for years 2000-01 to 2011-12 has been added to year wise GSDP(I) for years 2000-01 to 2011-12 to find out year wise GSDP from agriculture and industry (GSDP(A)+GSDP(I)) from 2000-01 to 2011-12.

The CAGR of GSDP from agriculture and industry from 2000-01 to 2011-12 is obtained as 3.98 per cent and this CAGR has been used to predict (GSDP(A)+GSDP(I)) from 2012-13 up to 2049-50. The (GSDP(A)+GSDP(I)) turns out to be Rs 2,748.54 billion in 2049-50 as compared to Rs 624.23 billion in 2011-12.

FORECASTING OF GSDP(A)

Data on gross state domestic product in 2004-05 prices from agriculture have been obtained from department of economics and statistics, government of Kerala.[241] These data have been used to find out percentage share of GSDP(A) in Kerala's GSDP for the years 2004-05 to 2011-12. Then linear trend have been fitted to percentage share of GSDP(A) in total GSDP for the years 2004-05 to 2011-12. Then this trend equation has been used to find out percentage share of GSDP(A) in total GSDP for the years 2000-01 to 2003-04. Thus, percentage share of GSDP(A) in total GSDP for years 2000-01 to 2011-12 is obtained.

In the next step, yearly percentage share of GSDP(A) in total GSDP has been multiplied with the total GSDP of the corresponding year. This gives year wise GSDP(A) for years 2000-01 to 2011-12.

The CAGR of decadal GSDP(A) from 2001-02 to 2011-12 is obtained as 0.29 per cent and this CAGR has been used to predict GSDP(A) from 2012-13 up to 2049-50. The GSDP(A) for the year 2049-50 is Rs 214.07 billion as compared to GSDP(A) of Rs 194.04 billion for the year 2010-11.

FORECASTING POPULATION OF KERALA

Data on Kerala's population from 1961 to 1981 have been collected from Economic Review, 2003[242] of Kerala. Data on Kerala's population in 1991, 2001 and 2011 have

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[241] Department of Economics and Statistics, Government of Kerala – GSDP at constant prices (At factor cost by industry of origin) with base year 2004–2005.
[242] State Planning Board. 2004. *Economic Review 2003.* Thiruvananthapuram, Kerala. Chapter 3.

been obtained from census of India.[243]

In order to find out year wise population of Kerala from 2001 to 2011, 4.86 per cent growth rate of population between 2001 and 2011 has been distributed equally among all years between 2001 and 2011. Thus, annual growth rate of population between 2001 and 2011 is found to be 0.486 per cent and every year's population between 2001 and 2011 is escalated by 0.486 per cent to find out population of the next year.

In the next step decadal increase of Kerala's population from 1961 to 2011 has been obtained. Then the percentage decrease in increase of decadal population is obtained from 1981 to 2011. The following table summarizes decadal increase in population and percentage decrease in increase of decadal population in the past years.

Table A1.1: Decadal Increase in Population and Percentage Decrease in Increase of Population from 1961 to 2011

Year	Decadal population	Decadal increase in population	% Decrease in increase of decadal population
1961	16,900,000	–	–
1971	21,350,000	4,450,000	–
1981	25,450,000	4,100,000	8
1991	29,097,481	3,647,481	11
2001	31,841,374	2,743,893	25
2011	33,387,677	1,546,303	44

In order to find out percentage decrease in increase of decadal population from year 2021 to 2051, a polynomial curve of order 2 has been fitted to the data on percentage decrease in increase of decadal population from year 1981 to 2011. Using the polynomial function, percentage decrease in increase of decadal population from year 2021 to 2051 has been obtained. Then percentage decrease in increase of decadal population for years 2021 to 2051 has been used to find out decadal increase/decrease in population from 2021 to 2051. Then decadal increase/decrease in population has been added to the last census year population to find out decadal population up to 2051. The table below shows decadal population and decadal increase in population for years 2011 to 2051. A negative sign before decadal increase in population indicates that population has gone down.

Table A1.2: Decadal Population and Decadal Increase in Population from 2011 to 2051

Year	Decadal population	Decadal increase in population
2011	33,387,677	–
2021	33,834,559	446881
2031	33,805,511	-29047
2041	33,732,980	-72531
2051	33,514,879	-218101

For an example, increase in decadal population of Kerala from 2011 to 2021 is 446881 and the population in Kerala in 2021 is 33834559 which is addition of 33387677 and 446881.

[243] Census of India. 2012. *Census of India 2011. Size, Growth Rate and Distribution of Population.* Ministry of Home Affairs, Government of India. New Delhi, India.

Following the above procedure, population for the years 2021, 2031, 2041 and 2051 have been obtained. In the next step population of every year has been derived. For this, CAGR of population growth in every 10 years has been obtained from 2010-11 to 2049-50. The following table depicts CAGR for population growth over the years 2010-11 to 2050-51.

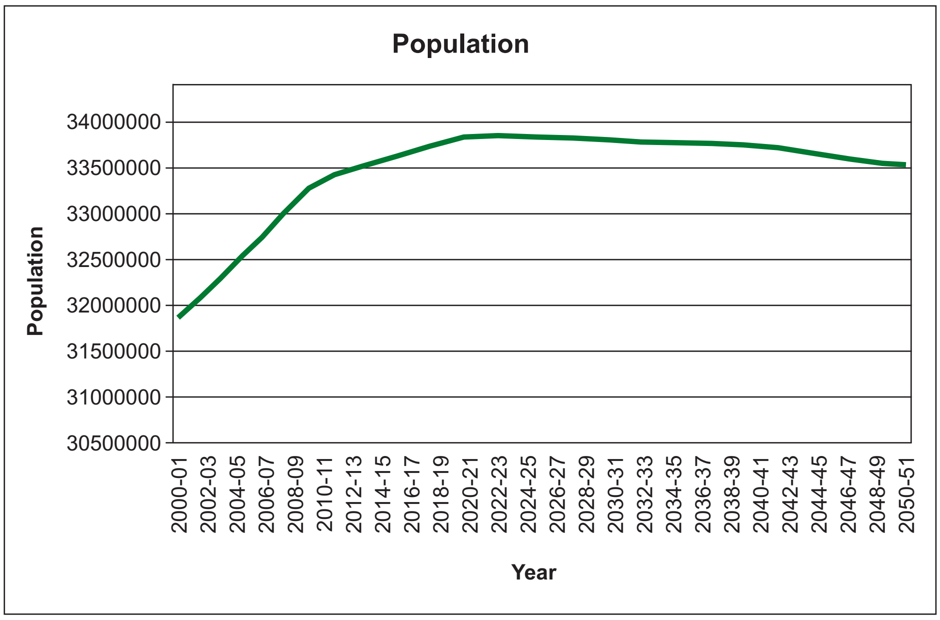
Table A1.3: CAGR for Population Growth over the Years 2010-11 to 2050-51

Year	Decadal population	CAGR (%)
2011	33,387,677	–
2021	33,834,559	0.133
2031	33,805,511	-0.000086
2041	33,732,980	-0.000214
2051	33,514,879	-0.000648

Thus, CAGR for population growth in the decade 2011 to 2021 is 0.133 per cent and this CAGR has been used to forecast yearly population in the decade 2011 to 2021.The CAGR in the decade 2021 to 2031 is found to be -0.000086 per cent and this CAGR has been used to forecast yearly population in the decade 2021 to 2031. In the same manner, -0.000214 per cent CAGR for decades 2031 to 2041 and -0.000648 per cent CAGR for decades 2041 to 2051 have been applied to find out year wise population in the respective decades.

Following the above procedure, population of Kerala for all years between 2011-12 and 2050-51 is obtained. The population in the year 2050-2051 appears to be 33514879 as compared to population of 33387677 in the year 2010-2011. One important feature of population projection has been decrease in population after 2020-2021 and this trend continues up to 2050-51. A diagrammatic representation of yearly population of every year from 2000-01 to 2001-02 is depicted below.

Figure A1.1: Yearly Population of Kerala



FORECASTING URBAN POPULATION OF KERALA

Data on urban population for 2000-01 and for 2010-11 has been obtained from *Economic Review 2011*.[244] Then CAGR has been obtained from urban population data of 2000-01 and 2010-11. The CAGR appears to be 6.78 per cent. Using this CAGR urban population for every year between 2000-01 and 2010-11 is obtained. Also urban population for the year 2011-12 has been obtained using the same CAGR.

In the next step, percentage of urban population in total population of Kerala has been obtained. Percentage of urban population in total population has increased from 26 per cent in 2000-01 to 51 per cent in 2011-12 which is almost two fold increase in urbanization. However, a conservative view of forecasting urbanization of Kerala has been adopted. Thus, yearly increase of 1 per cent in urbanization has been assumed to smooth out the process of urbanization through 2050-51. In this process, 90 per cent of total population seems to be living in urban areas in 2050-51 as compared to 51 per cent living in urban areas in 2011-12.

FORECASTING PER CAPITA INCOME OF KERALA

Year wise per capita income from 2000-01 to 2049-50 of Kerala has been obtained by dividing year wise GSDP of Kerala by population of Kerala of the respective year. Kerala's per capita income is appearing to be Rs 62 thousand in 2011-12 as compared to Rs 911 thousand in 2049-50. However, such a high growth in per capita income may be attributed to the fact that Kerala's population is decreasing after 2020-21 while GSDP is growing at the rate 7.3 per cent over the years.

[244] State Planning Board. 2012. *Economic Review 2011.* Thiruvananthapuram, Kerala. Chapter 2.

APPENDIX 2

DOMESTIC APPLIANCES

Regression of number of households per thousand households on monthly per capita expenditure (MPCE) has been done. For convenience of analysis, domestic appliances have been categorized into tube lights and bulbs, fans, TV, refrigerator, space conditioning, washing machine and others have been collected from National Sample Survey Organization (NSSO) data for years 1999-00, 2004-05 and 2009-10.[245] Data on monthly per capita expenditure have been collected from NSSO data for the years 2000 to 2005 and for the year 2010.

Data for years 1999-00, 2004-05 and 2009-10 have been used to find out separate CAGRs for number of households per thousand households between 1999-00 and 2004-05 and between 2004-05 and 2009-10. The following table shows CAGR for different domestic appliances for urban and rural areas.

Table A2.2: CAGR of Number of Households per Thousand Households for Using Different Domestic Appliances

	Urban areas		Rural areas	
Appliances	1999-2000 to 2004-05	2004-05 to 2009-10	1999-2000 to 2004-05	2004-05 to 2009-10
Fans	2.89	2.17	5.78	5.40
TV	3.63	3.59	7.80	9.40
Refrigerator	6.67	4.49	8.55	9.13
Space conditioning	21.98	22.67	21.67	16.27
Washing machine	10.38	6.72	14.87	8.45
Others	16.87	9.04	32.55	11.91

This CAGR is then used to find out number of households per thousand households for years 2001 to 2004 and 2006 to 2009.

Separate data on average monthly per capita expenditure (in Rs) from 2000 to 2005 and for the year 2010 have been collected for rural and urban areas from NSSO database. Based on data from 2000 to 2005, a CAGR of 13.33 per cent for urban areas and 12.6 per cent for rural areas have been obtained which is used to find out average monthly per capita expenditure for urban and rural areas respectively from 2006 to 2009.

In order to predict the average monthly per capita expenditure (in Rs) from 2011 to 2050, 9.97 per cent CAGR of average monthly per capita expenditure (in Rs) in urban areas for the years 2000 to 2010 and 9.13 per cent CAGR of average monthly per capita expenditure (in Rs) in rural areas for the years 2000 to 2010 have been used.

[245] National Sample Survey Data of various rounds

Regression results for different appliances for rural and urban areas are discussed in the following section. In case of regression with intercept, most of the regressions seem to have positive intercept. This means even when MPCE is nil, there are households who enjoy benefits of domestic appliances like fans, TV, refrigerator, washing machine etc. which sounds unreasonable. Thus, regression through origin has been found suitable for all regressions.

Urban Areas: Number of households per thousand households using different domestic appliances in urban areas has been regressed on average monthly per capita expenditure. Regression results for different domestic appliances are discussed below.

Fans on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having fans and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having fans = 0.5088 × MPCE
t-statistic (15.69)
p-value (0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having fans.

TV on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having TV and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having TV = 0.4269 × MPCE
t-statistic (18.76)
p-value (0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having TV.

Refrigerator on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having refrigerator and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having refrigerator = 0.2465 × MPCE
t-statistic (24.25)
p-value (0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having refrigerator.

Space Conditioning on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having space conditioner and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having space conditioner = 0.0234 × MPCE

t-statistic	(10.60)
p-value	(0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having space conditioner.

Washing Machine on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having washing machine and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having washing machine = 0.1128 × MPCE

t-statistic	(33.71)
p-value	(0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having washing machine.

Others on MPCE: Historical data from 2000 to 2010 on number of households per thousand households using other appliances and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households using other appliances = 0.1959 × MPCE

t-statistic	(24.40)
p-value	(0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households using other appliances.

Rural Areas: Number of households per thousand households using different domestic appliances in rural areas has been regressed on average monthly per capita expenditure. Regression results for different domestic appliances are discussed below.

Fans on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having fans and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having fans = 0.5425 × MPCE
t-statistic (26.52)
p-value (0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having fans.

TV on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having TV and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having TV = 0.4436 × MPCE
t-statistic (73.40)
p-value (0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having TV.

Refrigerator on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having refrigerator and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having refrigerator = 0.1856 × MPCE
t-statistic (66.60)
p-value (0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having refrigerator.

Space Conditioning on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having space conditioner and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having space conditioner = 0.0079 × MPCE

t-statistic	(15.38)
p-value	(0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having space conditioner.

Washing Machine on MPCE: Historical data from 2000 to 2010 on number of households per thousand households having washing machine and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households having washing machine = 0.0594 × MPCE

t-statistic	(34.22)
p-value	(0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households having washing machine.

Others on MPCE: Historical data from 2000 to 2010 on number of households per thousand households using other appliances and historical data from 2000 to 2010 on MPCE have been used for the regression. A simple linear regression model without intercept has been fitted to the available data. The estimated regression equation is as follows

Number of households per thousand households using other appliances = 0.2289 × MPCE

t-statistic	(13.47)
p-value	(0.000)

The independent variable MPCE is statistically significant as evident from the values of t-statistic and p-value. Because R^2 reported by excel is not appropriate for regression without intercept, the same has not been reported here. The equation has been used to predict the number of households per thousand households using other appliances.

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WWF-India is the largest conservation organisation in the country dealing with nature conservation, environment protection and development-related issues. Established as the Charitable Trust in 1969, it has an experience of over four decades in the field. Its mission is to stop the degradation of the planet's natural environment, which it addresses through its work in biodiversity conservation and reduction of humanity's ecological footprint.

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