GUJARAT POWER CORPORATION LTD.

2015

Environmentally Sustainable and Integrated Energy Strategies for Gujarat

IRADe Integrated Research and Action for Development

Environmentally Sustainable and Integrated Energy Strategies for Gujarat

Prepared by
Integrated Research and Action for Development (IRADe)

Submitted to

Energy and Petrochemicals Department
Government of Gujarat
&
Gujarat Power Corporation Limited, Gandhinagar

सत्यमेव जयते
Government of Gujarat

GUJARAT POWER CORPORATION LTD.

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Preface

A nation needs sustainable energy for development. The planet and its people are already paying the price of relying extensively on non-renewable sources of energy for extended period. That is why the concerns of their impact on the environment have become extremely critical in examining energy requirements. These include concerns about the local environment – air, water and soil pollution – and also for the global environment, i.e., climate change and ozone layer depletion.

This report looks at Gujarat's energy situation, its resources and likely requirements in future and explores the options to meet them. These are considered in the context of energy access to all, energy security and also environmental considerations.

Gujarat's energy sector is the most advanced and progressive in comparison with other states in India. In 2011 was 90% of the households were electrified and 38% had clean cooking fuels whereas these figures were a mere 67% and 28.5%, respectively for all of India. Gujarat's per capita electricity consumption in 2013-14 was 1708 kWh compared to 957 kWh for all India despite the fact that there are very few energy resources in the state. Most villages get electricity round-the-clock. Farmers get electricity at prescribed hours and at stable voltage. It has one of the highest installations of solar power in India.

Gujarat is the second highest coal consuming state in India. This is despite the fact that it has no domestic resources of coal. It handles 66% of the country's imports of petroleum products, 36% of imports of coal and 98% imports of LNG; 77% of POL exports and 100% of coal exports pass through its shores. It's Vibrant Gujarat and other programmes encouraging investment in the state may also lead to growth in energy demand.

It is thus challenging to study the current situation, develop scenarios for the future and make policy recommendations. In this context, IRADe has carried out a detailed analysis of energy demand for industry, agriculture and services sectors with perspectives up to 2035 and also suggested a supply strategy and made recommendations.

Energy projections were made assuming 8% and 10% growth rates of the state GDP; it was also assumed in alternative scenarios that services and industry will lead the growth. It is noted that electricity requirement jumps from the present 68 bkWh to 243 and 324 bkWh in 2035 under the 8% and 10% growth rates with falling elasticity scenarios; the required installed capacity jumps to 3-4 times the present capacity of 21,500 MW. In the long run Gujarat will benefit from service led growth that will curtail demand for a state with meagre fossil fuel reserves and will also provide more jobs.

To address the challenges arising from Gujarat's ambitious development plans, the report strongly recommends energy efficiency measures, aggressive efforts in renewable energy while taking care of grid balancing and also at the same time providing energy access at affordable prices.

We were helped in our endeavour by the senior officials of Gujarat Government and Gujarat Power Corporation Limited, who sponsored the study. We are grateful for the support extended by Mr L. Chuaungo, IAS, Principal Secretary (Power), Energy and Power Department, Government of Gujarat. We thank all stakeholders from Gujarat for their participation in discussions and their guidance and help. We are also grateful to Mr Rajendra Mistry, Chief Project Officer and Mr Kunal Vatsyayan, Sr. Officer Projects, of GPCL and other colleagues for facilitating this project and going to great lengths in helping us get the required data.

This report has been presented to industry stakeholders and to Gujarat government officials. The meeting was chaired by Shri Saurabhbhai Patel, Minister for Energy along Sh. Govindbhai Patel, State Minister for Energy and Sh.G.R. Aloria, IAS, Chief Secretary, Government of Gujarat.

The report was released by Hon'ble Chief Minister of Gujarat, Smt. Anandiben Patel on 19th January 2016 at Gandhi Nagar, Gujarat in the presence of Ms.S. Aparna, IAS, Principal Secretary and Shri Ajay Bhadoo, IAS, Secretary to Hon'ble Chief Minister of Gujarat, Shri.L. Chuaungo, IAS, Principal Secretary (Energy), EPD and Shri S. J. Haider, Secretary, Climate Change department, Government of Gujarat.

I would also like to thank Dr. Kirit Parikh and IRADe staff for the tireless efforts to prepare this report in a short time. We hope this report will not only help Gujarat, but also inspire others to think about energy future.

December 30, 2015

Dr Jyoti Parikh
Executive Director, IRADe

Hon'ble Chief Minister of Gujarat Smt. Anandiben Patel releasing the report "Environmentally Sustainable Integrated Energy Strategies for Gujarat", prepared by IRADe on January 19th, 2016 at Gandhi Nagar, Gujarat

Dr. Jyoti Parikh, Hon'ble Chief Minister of Gujarat Smt. Anandiben Patel and Dr. Kirit Parikh at the release function in Gandhi Nagar

Hon'ble Minister for Energy Sh.Saurabh Bhai Patel, Hon'ble State Minister for Energy Sh.Govindbhai Patel and Sh.G.R.Aloria, IAS, Chief Secretary, and Senior Government of Gujarat Officials at the Meeting to discuss the report results at Gandhi Nagar, Gujarat on 21.12.2015

Stakeholder Consultations Meeting on 24.05.2015 at Gandhi Nagar along with State Government and Private Sector Energy and Power Officials

Acknowledgements

IRADe acknowledges the support and help it received from various organisations, departments and officials of the Government of Gujarat. IRADe especially thanks the officials of Energy and Petrochemicals Department-GoG, GPCL, GSECL, GUVNL, GIDR, MGVCL, PGVVN, UGVNL, DGVVL, GMDC, GIDB, GIDC, INDEXTB, GSPC, Socio-Economics Department, GIPCL, GEDA, GIPCL, Adani Power, Torrent Power, Essar Power, Tata Power for providing valuable data, insights and in meeting IRADe staff and sharing their views on the future of power generation and other related issues.

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Shri S.B. Khyalia, Managing Director , MGVCC; Dr. Jayanti S. Ravi, Secretary and Commissioner (Rural Development); Shri Dhananjay Dwivedi, Secretary , DST; Shri S. J. Haider, Secretary , Climate Change department; Smt. Shobhana Desai, Additional Secretary (Petrochemical), Energy & Petrochemicals Department, GoG., Shri H.F. Gandharva, Joint Secretary (Energy) Energy & Petrochemicals Department, GoG.; Shri P.L. Panchal, Dy. Secretary (Co-ordination) Energy & Petrochemicals Department; Shri Anupam Anand, Managing Director , UGVCL; Shri J. K. Vyas, Vice President (Corporate Affairs), GUDC Ltd; Shri Dipen Chauhan, Sr. V.P.(Commercial), Gujarat Gas Limited; Shri U. C. Patel, Chief Engineer (TR) , GETCO; M. B. Jadeja, Ex. Director (Technical), PGVCL; Shri K. H. Chorera, OSD (Power) , Energy & Petrochemicals Department EPD; Smt. Shahmeena Husain, Director Administration, GUVNL; Shri A.B. Jaiswal, EE(Environment), GSECL Co , Vadodara; Shri C.C.Gandhi, Supdt. Engg, UGVCL; Shri. Shewtal Shah, Technical Advisor, Climate Change Department; Mr.Pankaj Kumar, IAS (MD), GMDC, Mr.R.N.Pandey, GM (R&D), GSPC, Mr.Jagdish Shah, GM (IP) I/C and Mr.Hemanshu Bhagat (PE), iNDEXTb (Vibrant Gujarat), Mr.S.P.Desai (CGM &CFO), and Mr.Y.J.Bhatt (AGM-BO), GIPCL, Mr.S.B.Patil (Dep. Dir I/C) and Mr.A.K.Chauhan (SPE), GEDA, Mr.B.P.Pati, IFS (CGM), and Mr.A.L.Thakor (GM-PRD/LPS), GMDC, Mr.K.P.Jangid (GM-Com), GUVNL, Mr.N.BoseBabu (GM-TS&OM), GSPL, Mr.P.K.Vishwanathan (Asso. Prof.), GIDR, Mr.Shiv Chaudhary (GM-Engg), Adani Power, Mr.Chetan Bundela (GM), Torrent Power, Mr.R.M.Bhadang (I/C CFM), Mr.Vijay Jani (CS), Ms.Bela Jani (EE-P&P), GSECL. Dr.Pradeep Kumar Dadhich, Deputy Director IRADe is acknowledged for sharing views and providing guidance on important aspects related to the project. Mr.Mohit Kumar Gupta, Project Associate and Mr.Pushkar Pandey, Research Associate IRADe are duly acknowledged for helping out with survey, data collection, and editing.

IRADe Project Team

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Abbreviations

CAGR	COMPOUNDED ANNUAL GROWTH RATE
CC	COMBINED CYCLE
CDM	CLEAN DEVELOPMENT MECHANISM
CNG	COMPRESSED NATURAL GAS
CWET	CENTRE FOR WIND ENERGY TECHNOLOGY
DAU	DYNAMICS AS USUAL
DMIC	DELHI-MUMBAI INDUSTRIAL CORRIDOR
ECBC	ENERGY CONSERVATION BUILDING CODE
EPS	ELECTRIC POWER SURVEY
GEDA	GUJARAT ENERGY DEVELOPMENT AGENCY
GERC	GUJARAT ELECTRICITY REGULATORY COMMISSION
GETCO	GUJARAT ENERGY TRANSMISSION CORPORATION
GHG	GREEN HOUSE GAS
GIDB	GUJARAT INDUSTRIAL DEVELOPMENT BOARD
GIDR	GUJARAT INSTITUTE FOR DEVELOPMENT RESEARCH
GIPCL	GUJARAT INDUSTRIAL POWER CORPORATION LIMITED
GoG	GOVERNMENT OF GUJARAT
GoI	GOVERNMENT OF INDIA
GPCL	GUJARAT POWER CORPORATION LIMITED
GSDP	GROSS STATE DOMESTIC PRODUCT
GSEB	GUJARAT STATE ELECTRICITY BOARD
GSECL	GUJARAT STATE ELECTRICITY CORPORATION LIMITED
GSPC	GUJARAT STATE PETROLEUM CORPORATION LIMITED
GUVNL	GUJARAT URJA VIKAS NIGAM LIMITED
HHS	HOT HEAVY STOCK
HSDO	HIGH SPEED DIESEL OIL
IGCC	INTEGRATED GASIFICATION COMBINED CYCLE
INDEXTB	INDUSTRIAL EXTENSION BUREAU
IRADe	INTEGRATED RESEARCH AND ACTION FOR DEVELOPMENT
JGY	JYOTIGRAM YOJANA
km	KILOMETRE
LNG/LPG	LIQUIFIED NATURAL GAS/ LIQUIFIED PETROLEUM GAS
LSHS	LOW SULPHUR HEAVY STOCK
MCM	MILLION CUBIC METRES
MNRE	MINISTRY OF NEW AND RENEWABLE ENERGY
MoSPI	MINISTRY OF STATISTICS AND PROGRAMME IMPLEMENTATION
MoU	MEMORANDUM OF UNDERSTANDING
MSO	MOTOR SPIRIT OIL
mtoe	MILLION TONNES OF OIL EQUIVALENT
MU	MILLION UNITS
MW	MEGA WATT
NAPCC	NATIONAL ACTION PLAN ON CLIMATE CHANGE
OC	OPEN CYCLE
PAT	PERFORM, ACHIEVE AND TRADE
PLF	PLANT LOAD FACTOR
PNG	PIPED NATURAL GAS
POL	PETROLEUM, OIL AND LUBRICANTS
PPA	POWER PURCHASE AGREEMENT

PV	PHOTOVOLTAIC
RE	RENEWABLE ENERGY
REC	RENEWABLE ENERGY CERTIFICATES
RES	RENEWABLE ENERGY SOURCES
RPO	RENEWABLE PORTFOLIO OBLIGATION
SEZ	SPECIAL ECONOMIC ZONES
SPV	SOLAR PHOTO VOLTAIC

Contents

The study was sponsored by Gujarat Power Corporation Limited (GPCL), an organisation under the Energy and Petrochemicals Department of Government of Gujarat.

1. Background

Integrated long term planning for Power and Energy to sustain reliable supply is essential for sustainable long-term socio-economic growth. This energy policy document addresses various challenges envisaged for the state of Gujarat, assesses energy requirement for next 2 decades and suggests policies formulated with an integrated approach. The major objectives envisaged for the project are:

- To forecast the requirements of power and energy in Gujarat for various sectors (industry, agriculture and services) over the next 20 years in tandem with economic development.
- To suggest an integrated Energy Strategy for the state, addressing supply options, environmental impacts and energy efficiency that ensure access to energy for every household and to suggest policy to implement the strategy.

2. Challenges

A robust energy strategy is essential for Gujarat to continue to develop with double-digit growth rate. Integrated long term planning for power and energy to sustain reliable supply is critical for sustainable socio-economic growth. This energy strategy will address the following challenges that are likely to come up:

- Rapid industrialisation all over the state. Vibrant Gujarat Model and its impact on the structure of the economy
- Rapid urbanisation
- Buoyant agriculture that requires electricity
- Constrained energy resources like coal for energy generation; issues related to gas supplies
- Environmental concerns arising from use of fossil fuels
- Changing structure of energy and power demand due to shift in economy
- Increasing population and economic improvement leading to higher demand

3. Economy

Gujarat's GDP has been registering a growth of around 10% during the past decade. Figure1 shows the trend of the State GDP while Figure2 shows the shares of sectors in the State GDP. Shares of primary, secondary and tertiary sectors have been reported at 11.10%, 39.2% and 49.7%, respectively in the total State GDP in 2012-13 at 2004-05 prices. There is a marked shift in the economy of the state from being agriculture oriented to being industry and services oriented.

Traditionally service sector included low cost services, small traders and small and medium scale activities including transportation. Since the last 2 decades, there has been a big boom of banking, financial and tourism services. However, in the current decade and forthcoming future, a big boost is expected from IT, Knowledge industries and on-line retail and booking activities. Thus the range of service sector has expanded in terms of scope and value. Indeed, the developed countries have service sector share exceeding industry sector and account for more than 50% share of GDP.

Figure-1 Gujarat state GDP (in Million INR) at 2004-05 constant prices

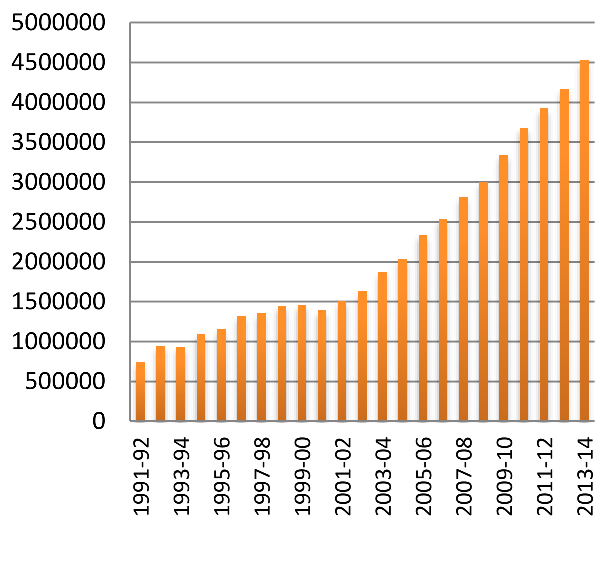
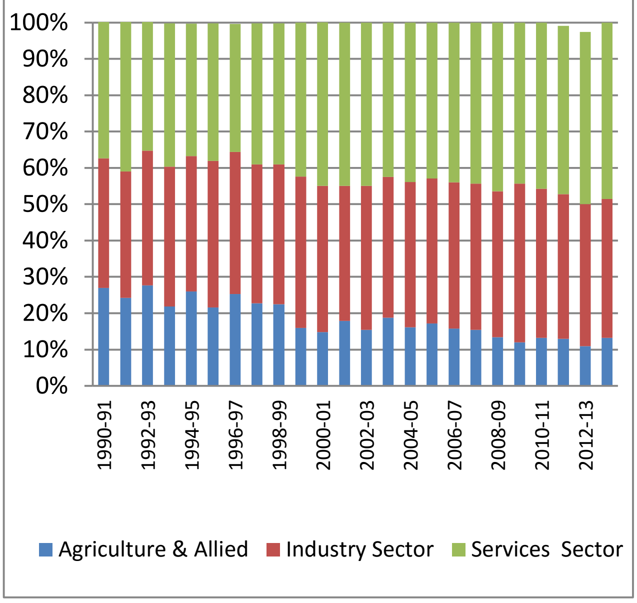


Figure-2 Sectoral shares of SGDP in Gujarat



Source: Socio-Economic review 2014-15, Government of Gujarat and Vibrant Gujarat, 2015 brochure

4. Energy Scene

Energy consumption in Gujarat is predominantly based on fossil fuels (petrol, diesel, kerosene, LPG, coal, lignite, natural gas) and electricity, which are the main commercial fuels. A detailed analysis of these fuels is taken up with respect to present consumption patterns, future requirements and policies to meet these requirements.

a. Electricity

Gujarat generates the bulk of electricity it needs within the state; it also gets a share of electricity from Central Sector plants. This share has increased from 12% (@ 580MW) in 1990 to 21% (@ 3,890 MW) in 2014. Thus development of the Central Sector is of some relevance to Gujarat.

The state's overall installed capacity of power generation has increased from 4,823MW in 1990 to 18,510 MW in 2014 showing a compound annual growth rate (CAGR) of 5.15% over the past 2 decades. Over1990-2014 the CAGR of the installed capacity of the state government run power plants has been 1.54%, of the autonomous public sector state government companies 17.60%; the private independent power producers' plants (IPP) have shown a robust growth of 11.55% and the Central Sector power plants have grown at 7.85% annually. In recent years, the maximum growth has been registered by the public sector state government sector followed by private sector.

It is interesting to note that the private sector share has risen from 10% (495 MW) in 1990 to 41% (7,607 MW) in 2014. The private sector continues to grow at a faster pace with a growth rate exceeding 15% since 2002. The active participation of the private sector is indicative of the good functioning of the sector with appropriate pricing policy and collection of bills. A look at the fuel-wise capacity generation in the state shows that fossil fuel still has the major share (93%) whereas hydro and nuclear comprise only 7% of the total power generation. There is a huge dependence on conventional fuels for power generation and hence the environmental impact (land, air and water pollution) of these plants is also large.

Even though Gujarat has no coal resource of its own, it is the main fuel for power generation.

Coal price and availability will continue to remain of great importance to Gujarat.

Electricity Generation

The power supply of Gujarat has improved in the last few years. Year 2012 showed nearly zero per cent deficit. Since then Gujarat has been a power sufficient state. The generation of electricity has increased from 22,834 Million Units (MU) in 1990 to 86,221 MU in 2014, a fourfold jump. The private sector power generation has jumped 19 fold.

Electricity Consumption

The total electricity consumption in Gujarat shows an average growth of 5.81% during the past two decades. Consumption increased from 17,875 MU in 1988 to 68,628 MU in 2014. The per capita electricity consumption increased from 363 kWh/year in 1988-89 to 1,708 kWh in 2013-14, which is nearly twice the national average of around 957 kWh.

Rapid urbanisation, industrialisation, improved electricity supply and improving economic conditions have led to this rise in the consumption rate over the decades. The Vibrant Gujarat initiative, the Delhi Mumbai Industrial Corridor (DMIC), development of Petroleum, Chemicals and Petrochemical Investment Region (PCPIR), Special Economic Zones (SEZ) and other industries will further shoot up electricity consumption in the coming years. With rising per capita incomes and increasing electrical assets in both rural and urban households the power sector will play an important role in the future.

Sector-wise share of electricity consumption in Gujarat

In 2013-14 the share of electricity consumption in various sectors for Gujarat was as follows:

- Industry had the highest share with 43%
- Agriculture sector followed with 22%
- Domestic sector was 16%
- Other sectors 13%
- Commercial sector 2.5%
- Public water works, public lighting and railway traction constituted the balance 4%

While electricity consumption has doubled in a few sectors like domestic, commercial and water works over the past few decades, industrial consumption has tripled, showing a trend towards industrialisation.

Benefits of un-bundling of the electricity sector in Gujarat

Gujarat is one of the few states in the country that has successfully unbundled its electricity sector. This has resulted in increase in profit for all the group companies, improved service delivery and customer satisfaction, increase in revenue generation and revenue collection and reduction in transmission and distribution (T&D) losses with 100% metering and billing of all consumers.

b. Fossil Fuels

Consumption of fossil fuels in Gujarat has been analysed for various primary and secondary fuels. Major fuels analysed are LPG, naphtha, motor spirit/petrol, kerosene, high speed diesel oil (HSDO), light diesel oil, furnace oil, low sulphur heavy stock (LSHS)/hot heavy stock (HHS) and natural gas. Interesting facts have emerged while assessing the consumption patterns of individual fuels. Several internal and external factors play a role in fuel consumption even at the state level. While some fuels have shown a smooth growth trend like LPG and petrol, some fuels, like naphtha, have shown very abrupt changes in consumption patterns as consumers react to changing relative prices and switch fuels. Also, commissioning of a large industrial unit, such as a fertiliser plant, can substantially boost naphtha or gas consumption as a feedstock.

5. Overall Consumption

The overall energy consumption in the state has increased from 10 to 36 million tonne of oil equivalent (mtoe) over the last 25 years. It has been growing at a CAGR of 5.19% during this period; in the last 10 years it grew at 6.71% but at only 2.17%in the last 5 years. The sudden jump between 2007 and 2009 is mainly attributed to the consumption of naphtha as a fuel in power generation and as feedstock in fertiliser and petrochemicals. Figure3 shows the shares of various fuels consumed in Gujarat. As can be seen there are marked differences in consumption over a period of time in the shares of naphtha, LSHS/HHS and kerosene. Figure4 shows the trends in the consumption of all the fuels in mtoe.

It is seen that the share of electricity is around 48% in the state's energy mix and is increasing. The share of transport fuels, petrol plus diesel, fluctuated between 12.9 % and 15.6%. The share of naphtha increased from 5.42% in 1991 to nearly 18% in 2013. The share of kerosene came down from 5.42% in 1992 to 1.57% in 2013, reflecting the success of Jyotigram Yojana and the spread of LPG and piped natural gas. Jyotigram Yojana is an initiative of the state government to deliver 24-hour power supply to rural areas.

6. Energy Resources of the State

Energy resources such as coal, oil gas and lignite in India belong to the Central government. While the state in which the resource lies gets a royalty, it can be mined only with the permission of the Centre; its allocation is also done by the Centre. While Gujarat has hydrocarbon reserves like lignite, crude oil and natural gas, its major fuel source for generating power which is coal is nil. Gujarat, therefore, has to depend largely on renewable resources if it wants to reduce its energy dependence on other states or imports.

The strategic location of Gujarat places it amongst the top states as far as potential for renewable energy (RE) resources is concerned. As of FY 2013-14 the total RE potential in the state is 36,956 MW (excluding solar) out of which wind potential is 35,071 MW, small hydro 110 MW, biomass power is 1333 MW, cogeneration 350 MW and waste to energy (WTE) is 112 MW. The overall reserves and potential energy resources for Gujarat are presented in Table1.

Figure- 3 Annual share of fuels in Gujarat (mtoe)

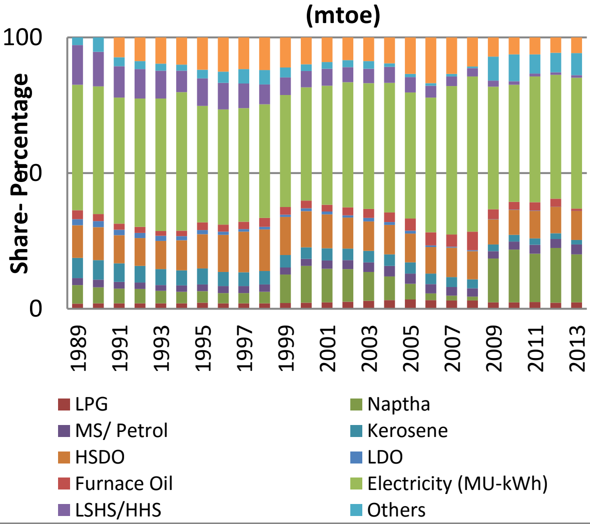


Figure-4 Overall energy consumption in Gujarat (mtoe)

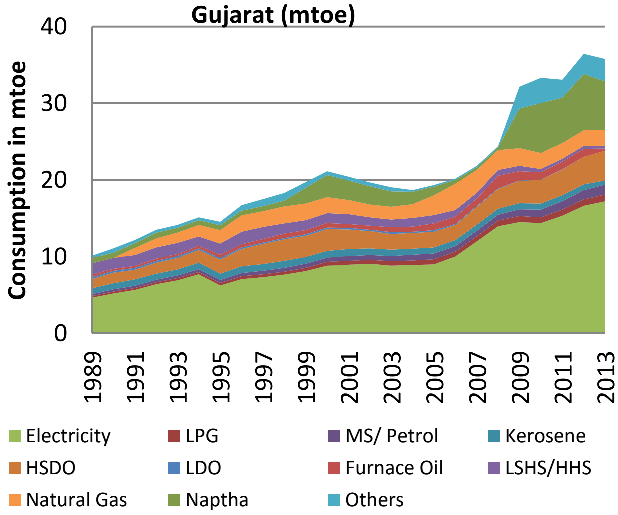


Table-1 Gujarat overall reserves and potentials

(Current production/capacity 2013-14)

Energy Source	Unit		Total
		Gujarat	India
Reserves			
Coal	Billion Tonnes	0	301.56
Lignite	Billion Tonnes	2.72	43.24
Crude Oil	Million Tonnes	135.72	762.74
Natural Gas	BCM	72.96	1427.15
Potentials			
Wind	@80m (MW)	35071	102772
Solar	(MW)	35770	748990
Small Hydro	(MW)	202	19749
Biomass Power	(MW)	1221	17538
Cogeneration	(MW)	350	5000
Waste to Energy	(MW)	112	2556

Source: Energy Statistics 2015, MOSPI, GoI, MNRE, GoI, MoP, MNRE, CWET, GEDA

7. Projections of Electricity Requirement

While analysing the future requirement, electricity has been given significant importance, as it constitutes around 50% of the overall energy requirement in the state. Energy requirement projections are made keeping in view various time-series data for different fuels and presenting multiple scenarios like dynamics-as-usual (DAU) with 8% growth rate of state GDP (SGDP), with high growth rate of SGDP (10%), energy efficiency (falling elasticities), etc. Other parameters considered are population, energy/SGDP, different sectoral growth patterns, etc. The projections for the next 20 years are based on suitable projection methods like regression framework that accounts for auto-correlation. Constant elasticity and assumption of falling elasticity is undertaken with the idea of business-as-usual scenario and a plausible improvement in energy efficiency the period.

By 2035 the requirement for electricity is projected to increase from 68 bkWh in 2013 to 274 bkWh with 8% growth rate of SGDP and to 378 bkWh with the higher growth rate of 10% in case of constant elasticity. These imply that in 22 years electricity requirement would be 4 to 5.5 times. Correspondingly, the capacity will be 3.7 times to 4.5 times the 23.8 GW of installed capacity in 2013. As can be seen in Table3 the installed capacity needs to be scaled up faster to meet the future electricity requirements.

Table-2 Elasticity of per capita total electricity consumption with respect to per capita SGDP

Nature of Elasticity	Period	Value of Elasticity
Constant	2004-2013	0.81~(Adjusted R-Square=0.99)
Falling	2014-2025	0.75*
	2026-2035	0.70*

Note: Estimated using data from 2004 to 2013.

~ indicates the estimated elasticity significant at 1% level and * indicates assumed elasticity.

Table-3 Total electricity requirement projection with the assumption of constant elasticity during 2014-2035 for 2 SGDP growth scenarios

Year	Consumption (MU)	Losses (TD and others)	Generation at Bus Bar (MU)	Peak Demand (MW)	Installed Capacity(MW)*
Case: 8% SGDP Growth Rate					
2020	107044	0.196	133139	21109	37089
2025	147150	0.184	180331	29408	50611
2030	201361	0.167	241730	39421	66700
2035	274477	0.150	322914	52660	76884
Case: 10% SGDP Growth Rate					
2020	118491	0.196	147377	23366	37886
2025	175144	0.184	214637	35003	54581
2030	257706	0.167	309371	50452	76160
2035	377720	0.150	444376	72468	105933

* Includes capacity required for electricity imported in the state

The projections in Table 4, where falling elasticities are assumed to reflect increasing energy efficiency, show that in 2035 electricity requirement would be 12% and 14% lower with SGDP growth rates of 8% and 10%, respectively, and that the required installed capacity would be lower by 19 GW and 15 GW, respectively, as compared to the constant elasticity scenario and is much more likely be consistent with improving energy efficiencies in all sectors.

Sectoral projections for electricity

Energy requirement depends not just on the growth rate of the economy but also on its sectoral composition. The share of industrial GDP is much higher in Gujarat's SGDP than in the national economy. Under the Vibrant Gujarat initiatives this share might become even larger. This will impact electricity requirement. We now explore this.

To project the electricity requirement in each sector under two scenarios– 8% and 10% growth rates–we assume for each scenario two alternative compositions of sector-wise contribution to total SGDP. In the first case, we assume the share of agriculture, industry and services in terms of SGDP are 10%, 35% and 55%, respectively in 2035. In the second case, these shares are assumed to be 7%, 50% and 43% for agriculture, industry and services, respectively.

The first assumption of sector-wise composition reflects an optimism of relatively higher growth in the service sector and growth trajectory observed in many industrialised countries. The second assumption of sector-wise composition takes into account the visionary approach of the state government in creating investor friendly ambience and possible resultant higher contribution of the industry sector in state GDP; it reflects the emphasis on industrial growth in Vibrant Gujarat and Make-in-India campaigns of the Prime Minister to make India a global manufacturing hub. Gujarat can be expected to spearhead this campaign.

Table-4 Total electricity consumption projection with the assumption of falling elasticity during 2014-2035 for 2 SGDP growth scenarios

Year	Consumption (MU)	Losses (TD and others)(MU)	Generation at Bus Bar(MU)	Peak Demand(MW)	Installed Capacity(MW)*
Case: 8% SGDP Growth Rate					
2020	104032	0.196	129393	20515	33263
2025	140124	0.184	171721	28004	43668
2030	185091	0.167	222198	36236	54700
2035	243542	0.150	286520	46725	68302
Case: 10% SGDP Growth Rate					
2020	114230	0.196	142077	22526	36524
2025	164489	0.184	201580	32873	51261
2030	231301	0.167	277672	45282	68357
2035	323993	0.150	381168	62161	90865

*Includes capacity required for electricity imported in the state

Electricity Requirement – Summary

Giving a summary of the projected requirements, Table5 shows the projections of 4 scenarios.

a) DAU – Dynamics as usual with constant elasticity
b) Energy Efficiency – Falling elasticity
c) Service Dominated Growth – based on growing share of services in SGDP
d) Vibrant Gujarat /Make-In-India based on industry dominated growth of SGDP

The table-5 also shows the projections made by the 18thElectric Power Survey (EPS)of Gujarat, are close to our DAU projection with constant elasticities and 10% growth rate of SGDP. These requirements depend upon policies and measures introduced. While considering supply strategies the impact on electricity requirement of policies and growth pattern would be appropriately adjusted.

Table-5 Electricity requirements of Gujarat in bkWh

Projection Parameter	8% SGDP Growth Rate				10% SGDP Growth Rate			
	2020	2025	2030	2035	2020	2025	2030	2035
Constant Elasticity	107	147	201	274	119	175	258	378
Falling Elasticity	104	140	185	243	114	164	231	324
Service led – Falling Elasticity	107	140	185	242	115	168	236	332
Industry led – Falling Elasticity	107	150	203	278	118	179	262	386
CEA					112	186*	256*	--

* Figures interpolated from CEA data presented in Appendix

8. Petroleum Products and Natural Gas Requirements for Gujarat

Petroleum products are integral inputs for a range of activities like transport, power generation, industry, agriculture, mining and construction, manufacturing, services, chemicals and petroleum derivatives, etc. They form the backbone in the overall economic growth and development. Petroleum products are a major driver for many energy applications and industries in the state. The demand for petroleum products is also growing with increasing number of vehicles, power plants, industries and overall growth of infrastructure projects in the state.

Energy Transition in Gujarat

Figure5 shows the fuel-wise time-series data of consumption of major primary fuels, LPG, motor spirit/petrol, diesel oil and natural gas for the past two decades in Gujarat. Energy use in Gujarat, in mtoe terms, suffers from a number of data infirmities. This is not as critical as the state government has relatively fewer options to affect the supply of oil and gas. Only policy options for demand and supply of some specific petroleum products are important.

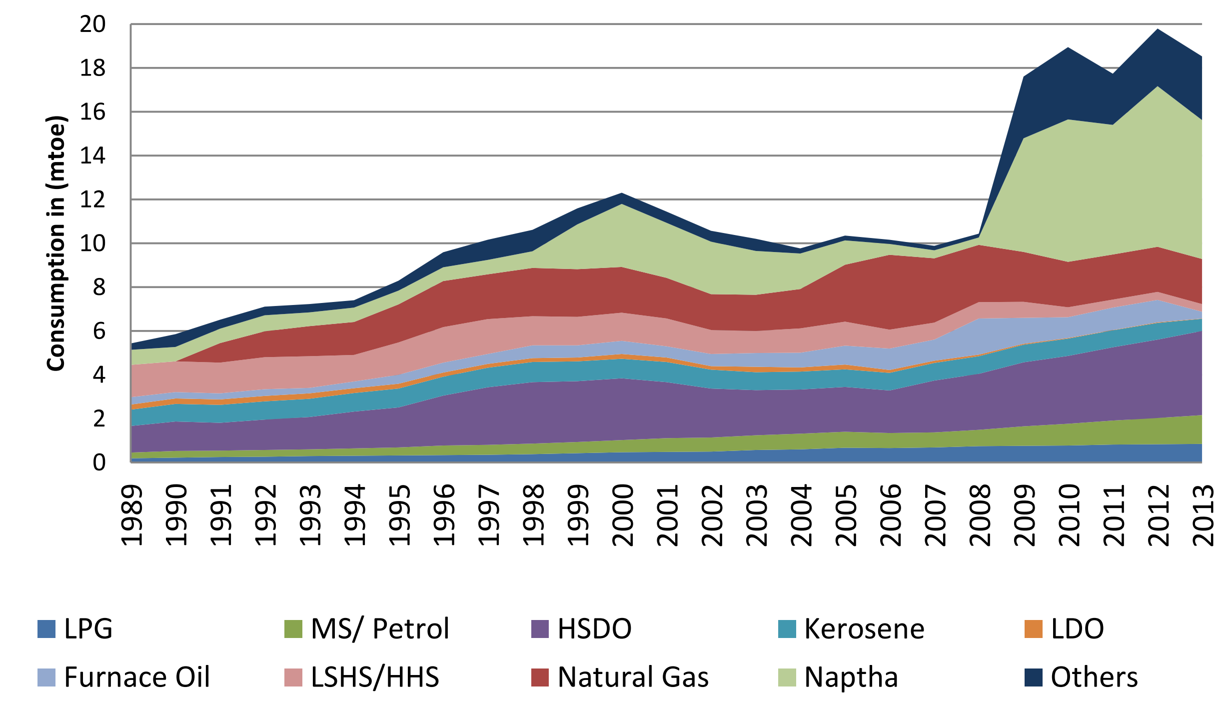
Figure5 shows significant and sudden changes in a number of petroleum products implying that quite a bit of substitution and fuel switching has been going on. This may be due to relative price changes, varying availability or changes in technology. It is difficult to pinpoint the reason. In any case, it is not critical for the exploration of Gujarat's strategic options.

Projection of Requirements of Petroleum Products

While analysing future requirements, projections have been done for LPG, Petrol, Natural gas and Diesel only as data for these seems to be consistent over the past 20 years. Data of other fuels do not lend themselves to econometric analysis.

Energy requirement projections are made using econometric regressions keeping in view various time-series data for different fuels and presenting multiple scenarios – dynamics-as-usual with 8% growth rate of SGDP, high growth rate (10% of SGDP), energy efficiency with lower elasticities, etc. Other parameters considered are SGDP, population, energy/SGDP, different sectoral growth patterns, etc.

Figure-5 Petroleum products consumption in Gujarat (in mtoe)



Integrated Research and Action for Development

Table-6 Projection of primary fuels under two different assumptions of growth rate of SGDP

Case: 8% SGDP growth rate					
Fuel-wise requirement(mtoe)	**2013**	**2020**	**2025**	**2030**	**2035**
LPG	0.85	1.158	1.435	1.769	2.174
Petrol	1.31	1.912	2.488	3.224	4.161
HSDO	3.84	4.943	5.881	6.966	8.219
Natural Gas	2.05	2.503	2.869	3.273	3.719
Case: 10% SGDP growth rate					
Fuel-wise requirement(mtoe)	**2013**	**2020**	**2025**	**2030**	**2035**
LPG	0.85	1.229	1.590	2.047	2.625
Petrol	1.31	2.071	2.853	3.913	5.347
HSDO	3.84	5.162	6.337	7.743	9.424
Natural Gas	2.05	2.575	3.010	3.504	4.062

The projected requirement of these products with 8% and 10% growth rates are shown in Table 6. It can be seen that petrol requirement in 2035 with 10% growth rate is four times the requirementin2013; with 8% growth rate it is 3.18 times the requirement in 2013. LPG requirement in 2035 with 10% growth rate would be more than tripled from the requirement in 2013. With a growth rate of 10% of SGDP Gujarat will need more than 21mtoe of these products in 2035. The requirement can be brought down with fuel substitution and fuel efficiency. These will be explored when we look at supply options.

9. Energy Supply Options for Gujarat

The state's energy supply strategy will depend on its projected requirement. Since the state government has more control over electricity supply, we first explore alternatives for electricity supply.

Electricity Supply Options

While exploring the electricity supply strategies for Gujarat, the following need to be kept in mind.

a. **Energy Efficiency**: Energy efficiency is the most important resource as appropriate demand side measures (DSM) could substantially reduce electricity or capacity requirements. We have assumed that the impact of DSM is reflected in our falling elasticity assumption. The difference in peak demand in 2035 between constant elasticity and falling one is 11% for 8% growth rate and 14% for 10% growth rate. We have, therefore, explored supply options for scenarios with only falling elasticity.

b. **Own Resources**: Among the conventional fossil fuel resources coal is almost absent in Gujarat. Lignite is limited to plants of about 5,000 MW for their lifetime of 35 years. The share of Gujarat in natural gas produced in the state depends on the Central government's policy on imports and pricing. The same holds true for oil. Hydro is limited and almost all aspects of nuclear plants depend on central policy. Nuclear plants usually take a long time to complete, so there is an element of uncertainty.

c. **Renewable**: Renewables, wind and solar, provide substantial scope but have their limitations as they are not available on demand and require balancing power from balancing sources such as hydro, open cycle gas plants or electricity storage. Thus, in exploring supply options, we have given particular attention to the absorption of substantial levels of renewable capacities and their implications for costs, balancing capacities and emissions.

We have developed a capacity planning model that minimises the cost of generating electricity to meet the hourly demand for a peak demand day. A representative load pattern corresponding to a day in October, which is the month with the highest demand over the past few years, is taken with its daily load curve. Electricity required at the bus bar is produced by different types of plants to meet projected demand for 2035 for every hour of the day. The model determines capacities of different plants by minimising levelized cost of generation. The options considered are sub-critical coal plants, super-critical coal plants, lignite, closed cycle gas, open cycle gas, nuclear, hydro, small hydro plants, biomass, on shore wind, solar photovoltaic (PV), solar thermal and solar PV with storage.

Upper bounds of the generating capacities of different types of plants are prescribed to reflect the resources availability. In different scenarios minimum capacities of certain types of plants are prescribed to reflect existing capacities and planned development and to explore the consequences of pushing in renewables. We do not prescribe installed capacity, as it will depend upon the mix of plants with their various availability factors. The following scenarios have been developed (Table 7) with falling elasticities to reflect reduction in energy requirement due to demand side measures as well as the trends in shift in economies.

Table-7 Electricity supply scenarios

Sl.	Scenario	Major Considerations
S-1	8% Growth	No constraint except that minimum capacities must reflect existing capacities and projected nuclear capacity of 7,960 MW in 2035
S-2	10% Growth Service dominant	Upper bounds on coal, nuclear, combined cycle gas, hydro, lignite, biomass and nuclear are imposed
S-3	10% Growth Industry Led	In addition upper bound on wind power is imposed.
S-4	Service Led - Renewables	10%, service led growth with minimum capacity of wind stipulated to be 35,000 MW and of solar 60,000 MW in 2035
S-5	Industry Led - Renewables	10% industry led growth, with 35,000 MW wind and 60,000 MW solar stipulated for 2035
S-6	Industry led-Coal contained and Gas-OC	Coal restricted to 20,000 MW. High renewables balanced by Open Cycle Gas Plant
S-7	Industry Led-Gas Combined Cycle-Coal contained and Solar PV with Storage	Coal restricted to 20,000 MW. High renewables balanced by Solar PV with storage.

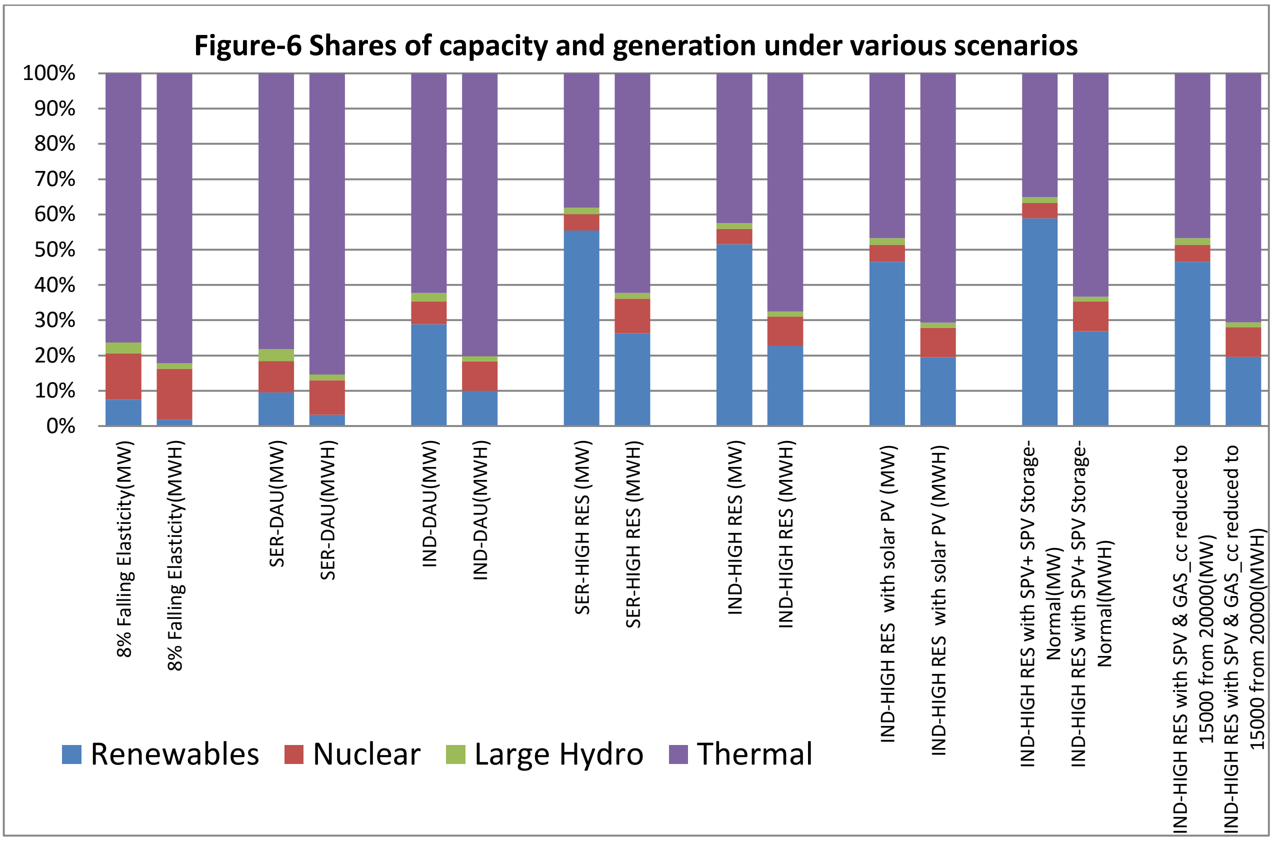
Table-8 Capacities (MW) needed in different demand scenarios for 2035 (falling elasticity)

Generation Technology/ Scenarios	8% SGDP Growth	10% SGDP Growth					
		Service Dominant	Industry Led	Service led High Renewable	Industry led High Renewable	Industry led-Restricted Coal	
						Gas Availability	SPV with Storage
	1	2	3	4	5	6	7
Renewables	**6364**	**11568**	**38833**	**98051**	**98051**	**79360**	**110471**
Wind on Shore	3542	6682	26755	35000	35000	35000	50000
Biomass	41	959	1350	41	41	1350	1350
Small Hydro Power	10	10	10	10	10	10	10
Hydro Power	1854	3000	3000	3000	3000	3000	3000
Solar PV	917	917	7718	60000	60000	40000	40000
Solar PVST	0	0	0	0	0	0	16111
Nuclear	**7960**	**7960**	**7960**	**7960**	**7960**	**7960**	**7960**
Fossil Fuels	**46210**	**70316**	**77224**	**65367**	**78344**	**76708**	**64000**
Gas open cycle	0	1316	8224	6493	13068	22708	15000
Gas combined cycle	4874	15000	15000	4874	11277	20000	15000
Lignite	2566	5000	5000	5000	5000	5000	5000
Coal subcritical	8155	9000	9000	9000	9000	9000	9000
Coal supercritical	30615	40000	40000	40000	40000	20000	20000
Total	**60534**	**89844**	**124017**	**171378**	**184356**	**164028**	**182431**
Peak Demand (MW)	46725	68981	80266	68981	80266	80266	80266
Peak/installed (%)	77	77	65	40	44	49	44
Cost (Rs/kWh)	2.12	2.29	2.57	2.83	2.84	3.18	3.25

Each scenario and its implications are detailed in Table 8. Some broad conclusions and characteristics emerge from the scenarios presented. Coal is the cheapest source, followed by lignite and closed cycle gas. The cost of power increases with demand, which increases with growth rate and industrial growth. Renewables increase the cost further and restricting coal leads to an even higher cost. Balancing renewables with open cycle gas costs less than balancing with solar PV with storage. The peak to installed ratio varies from 40% to 77%. Figure6 presents the shares of installed capacity and electricity generation for different fuels for all the scenarios.

Impact of growth

In the scenarios capacities for 2035 are imposed as minimum capacities to reflect existing capacities, projected nuclear capacities and what we impose as required for different scenarios. The scenarios reflect the outcome of the model that minimised cost and "upper bounds" reflect limitation imposed due to the availability of resources and policy consideration.



It is seen that with 8% growth rate only hydro and super-critical coal are developed above the minimum prescribed limit. It is mostly coal-based generation that meets the electricity requirement. Neither coal nor hydro reaches their prescribed upper bound limits of installed capacity. It is clear that coal is the cheapest alternative. All new coal capacities are supercritical plants as subcritical plants are restricted to more or less the present capacity level. As per government policy a small margin was provided as refurbishing may increase capacity of some plants.

With 10% service dominated growth rate, when peak demand increases from 47,000 MW to 69,000 MW, coal, hydro, lignite, closed cycle gas, all reach their prescribed bound, and some onshore wind and a small amount of open cycle gas come in. With 10% growth rate Gujarat will need to bring in renewables. We can compare 8% growth rate with 10% service led growth as the economic structure in the two scenarios is the same as we see in chapter 4. With 8% growth rate the upper bound for supercritical coal of 40,000 MW is not reached, but in the 10% growth scenario it is reached. Also following coal, gas based combined cycle plants are preferred; only after bounds on conventional plants, coal, lignite, hydro, nuclear and biomass are reached that onshore wind is expanded.

Impact of Economic Structure

Scenario 3 is the 10 % growth rate with emphasis on industry led growth reflecting the 'Vibrant Gujarat' and 'Make in India' objectives. The peak demand increases to 80,000MW compared to 69,000 MW in service led growth; 26,755 MW of wind and 7,717 MW of solar capacities are developed and to balance them open cycle gas capacity increases to 8,224 MW. Industry led growth requires significant increase in electricity requirement and Gujarat needs to push renewables substantially.

Impact of Renewables– Push for Solar and Wind

Scenarios 4 and 5 can be compared with scenarios 2 and 3 to see what greater emphasis on renewables leads to. In these scenarios minimum capacity for 2035 is prescribed at 35,000 MW for wind and at 60,000 MW for solar.

The targets for solar and wind are reached, but the capacity of closed cycle (CC) gas does not increase beyond the initial 4,874 MW and is more or less replaced by open cycle (OC) gas with its flexibility of operation that can help balance the much larger capacities of solar and wind. OC gas capacity reaches 6,493 MW. The total gas capacities thus add up to 11,367 MW, which is smaller than the gas capacity of 16,316 MW in the service led growth scenario. Even though OC gas uses more gas per kWh, the total amount of gas required in this scenario is less than in scenario 2. Thus Gujarat can absorb these ambitious levels of renewables. We will discuss the issues of cost and transmission capacity later.

In the industry led 10% growth scenario, with the push for renewables (Figure6), the gas capacities both for CC and OC increase. The total gas capacities reach 24,345 MW.

Limiting Coal

In the scenarios so far coal capacity is around 9,000 MW of subcritical and 40,000 MW of supercritical plants. If we restrict coal plants to 20,000 MW of supercritical plants, due to concern over local air pollution and to limit carbon emissions, in addition to the existing 9,000 MW subcritical plants, the results are seen in scenarios 6 and 7.

We also specify in scenario 6 that onshore wind and solar PV should be at least 35,000 MW and 40,000 MW, respectively in 2035. Wind and solar capacities reach these minimum levels, but do not go beyond it. This is feasible with a much larger expansion of open cycle gas plants requiring 27,708 MW of capacity. Thus the total fossil fuel based capacity becomes 29,000 MW coal and 42,700 MW of gas based plants.

If gas is not available or if its import is considered undesirable from the point of view of costs or energy security, and if we want to restrict coal to 29,000 MW and gas to 30000 MW, we have to go for a storage system. We introduced solar PV with storage, assuming a battery cost of US $200 per kWh in scenario 7.

In this scenario onshore wind reaches its upper bound of 50,000 MW, solar PV without storage remains at the minimum level of 40,000 MW, but 16,111 MW of solar PV with storage is added. Gas is restricted to 30,000 MW and coal to 20,000 MW of super-critical plants. This shows that with significant development of wind and solar PV with and without storage it is possible to restrict coal based generation, provided either gas is available or storage technology is developed.

10. Costs and Emissions

The cost of generation in the various scenarios, at the bus bar, is calculated for each scenario and presented in Table 9. The cost to the consumer would have to factor in transmission and distribution (T&D) losses and distribution costs.

It is seen that the cost increases with growth because to generate more electricity relatively more expensive options have to be used. Thus the cost of generating electricity in 2035 with 8% growth is Rs 2.12/kWh, whereas with 10% growth it becomes Rs 2.29/kWh. With industry led growth it increases further to Rs 2.57/kWh. Emphasis on renewables pushes the cost further to Rs 2.83/kWh and restricting coal takes the cost to Rs 3.18/kWh and Rs 3.25/kWh, depending on whether gas or solar PV are the balancing options. Thus restricting

Table-9 Cost of generation and CO_2 emissions in different scenarios

Particulars/Scenarios	8% Growth	Service Led	Industry Led	Ser Led - High Ren	Ind Led -High Ren	Ind Led CC-HG	Ind Led - CC PV storage
% Change over SER-LED		1	0.83	-21.33	-12.22	-28.39	-29.29
CO_2 kg/kWh	0.70	0.63	0.55	0.50	0.48	0.39	0.38
Cost of electricity (Rs/kWh)	2.12	2.29	2.57	2.83	2.84	3.18	3.25

Source: IRADe analysis

coal leads to a price increase of electricity by some 40% in the 10% growth scenarios.

In terms of CO_2 emissions, the emission per unit generated is the highest in 8% growth scenario at 0.70 kg/kWh. Restricting supercritical coal to 20,000 MW lowers emissions to 0.39 kg/kWh even when natural gas is used as a balancing fuel. It is marginally lower at 0.38 kg/kWh when solar PV with storage is used. The total emission in million tonnes of CO_2 per day for a peak day of October that we have used comes to nearly 1 million tonnes/day in the 10% growth scenario. With restricted coal it falls to 0.70 million tonnes/day. Thus Gujarat can restrict its CO_2 emission from the power sector by restricting coal and pushing renewables by some 30%. However, it will raise the price of electricity by 40% or so. Table 9 highlights the costs and CO_2 emissions in different scenarios.

In case dramatic technological advancement takes place and the cost of solar and wind plants and the cost of electricity storage come down, these generation costs could then be much lower.

The total power generation from fossil fuel based power plants in Gujarat has increased from 58 to 85 BkWh from 2007 to 2012, while CO_2 emissions have increased from 44 to 70 million tonnes showing a two-fold increase. Use of old plant and technologies, low grade coal and lignite have kept the specific emissions of CO_2 at levels ranging from 0.76 to 0.82 tCO_2/MWh.CO_2/GDP at constant prices in Rupee terms has remained at around 0.015 kg/Rs and in USD terms has remained at around 0.70 kg/USD and 0.16 kg/USD (PPP 2004-05). Figure 7 shows the CO_2 emissions data for Gujarat for the power sector excluding hydro, nuclear and renewables. Power generation includes power sourced from central sector plants from coal, lignite and gas based power plants. Power generation is a significant source of CO_2 due to the major fuel used being indigenous coal with high ash content and low calorific value.

CO_2 Emissions from power generation for 2035

IRADe developed three scenarios for projecting the electricity requirement and seven scenarios for alternative technology mix for installed capacity of power plants for meeting out the requirements. The same were used to calculate the specific emissions under these scenarios (S-1 to S-7 as shown in Table 10, and have been presented in Figure 8.

The total power generation requirement in for 2035 Gujarat will increased from 85 BkWh to 287, 332 and 386 BkWh under the 8%, 10% service led and 10% Industry led scenarios, while CO_2 emissions will increase correspondingly in 2035, they will increase maximum under scenario S-3 (212 million tonnes) and least under scenario S-7 (147 million tonnes). Gradual phasing out of old plant and technologies, use of new coal technologies coupled with renewables, improved coal use (beneficiation) will result in significant reduction in specific emissions of $CO_2$and the new levels will range from 0.74 to 0.38tCO_2/MWh. CO_2/GDP at constant prices in

Rupee terms will range from 0.004-0.009 kg/Rs., CO2/GDP in PPP terms will be highest in S-1 (0.10) and lowest in S-7 (0.047) showing significant reductions on account of improved energy efficiency and technology use particularly renewables.

Figure-7 CO_2 per GDP comparision and specific emissions

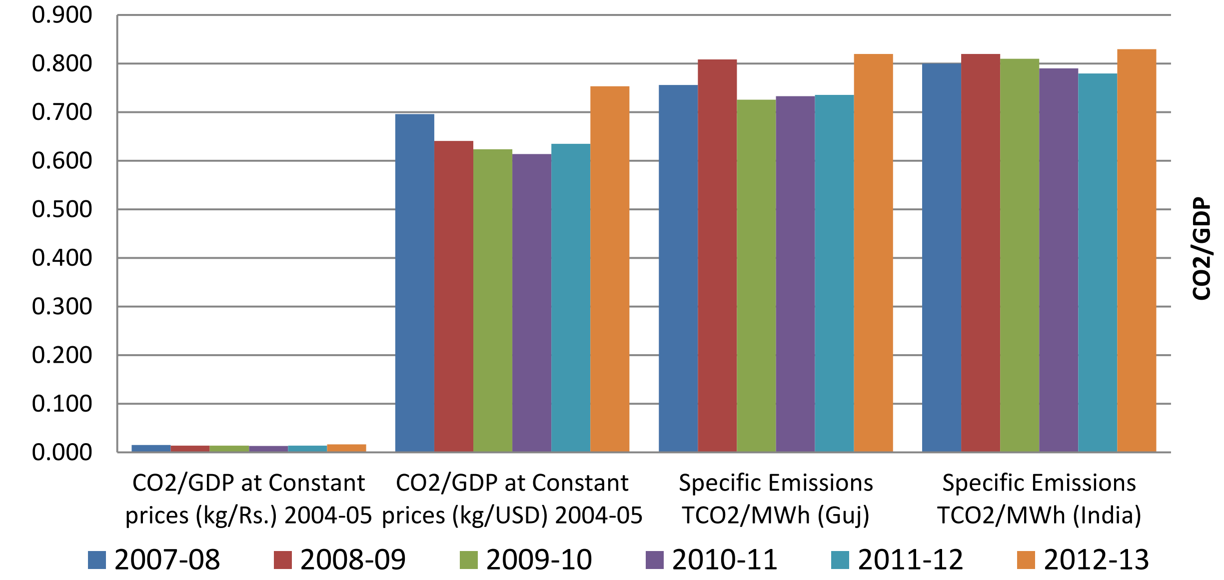
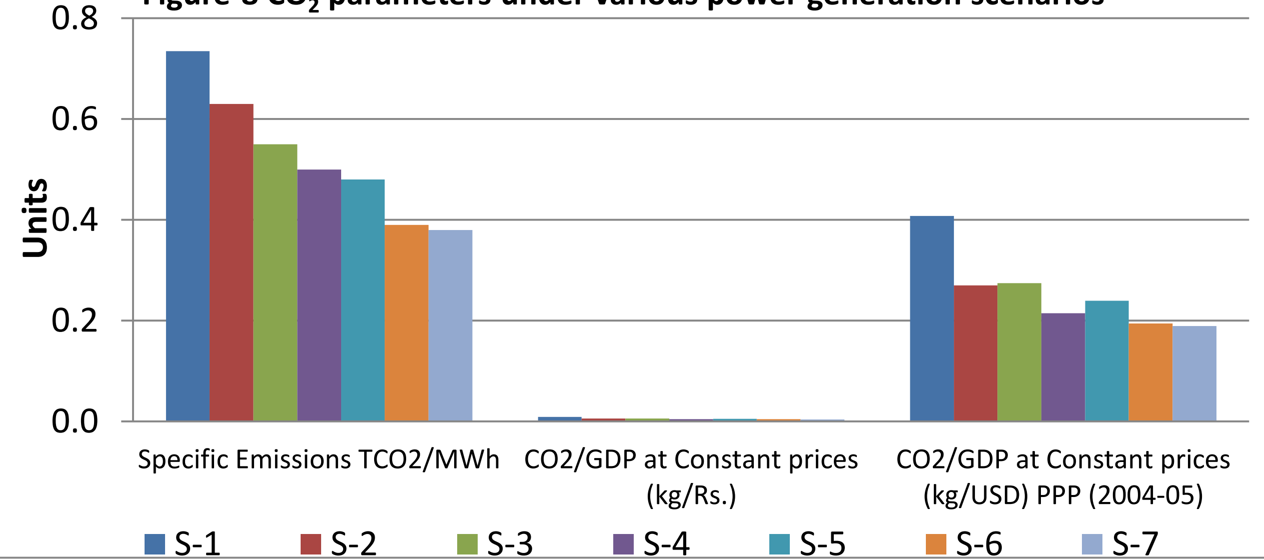


Table-10 Scenarios for power generation

Scenarios	S-1	S-2	S-3	S-4	S-5	S-6	S-7
Growth rate	8%	10%					
Elasticity Parameters		Falling Elasticity (FE)					
		Service led growth	Industry led growth	Service led growth – High Renewable	Industry led growth – High renewable	Industry led growth- Restricted coal and Gas availability	Industry led growth- Restricted coal and balancing with SPV storage

Figure-8 CO_2 parameters under various power generation scenarios



Overall emissions scenario of Gujarat in 2035 from energy sector

Overall CO_2 emissions will see an uptrend with improving economic activity and income levels. The overall CO_2 emissions scenario of Gujarat is presented below in Table 4. Per capita CO_2 will increase from 1.74 to around 3.20tCO_2/capita/year in 2035. CO2/GDP will see a decreasing trend showing improving energy intensities under all scenarios. Figure 10 shows the per capita CO_2 emissions globally in 2011,while India's total per capita CO_2 is well below world average and also the lowest among the top 10 emitters as seen in Figure 9, its CO_2 intensity from energy sector has been increasing gradually from 0.67tCO_2/capita in 1990 it now stands at 1.58tCO_2/capita in 2012[1], which is marginally lower than Gujarat which has per capita emissions at 1.74 tCO_2/capita/year. Increasing use of fossil fuels and reliance on coal power will push up India's and Gujarat's Figures. Gujarat will see a twofold jump under its projected scenarios.

India's INDC submitted to UNFCCC in October 2015 promises a reduction of 33 to 35 % in emissions intensity in 2030 compared with 2005. Compared with that our projection for Gujarat shows emissions intensity of 0.5 (kg CO2/USD PPP 2004-05) with 8 % growth rate and 0.29 (kg CO2/USD PPP 2004-05) with 10 % growth rate in 2035. This is a reduction of up to 55% with 8 % growth rate and nearly 75 % with 10% growth rate. Gujarat can make a substantive contribution to the country's ambition for sustainable development.

The first three scenarios S-1 to S-3 take into account the Dynamics as Usual (DAU) aspect of technology adoption wherein Coal power are promoted with improved technological options like super and ultra-super critical coal, still it manages to achieve 20-35% capacity through non-fossil technologies (RES, Nuclear and Hydro). While scenarios S-4 to S-7 with higher push for renewables coupled with Nuclear and Gas result in non-fossil installed capacity exceeding 40% and reaching up to 65% far more than the 40% committed by India's INDCs.

Summary of Main Conclusion for Power Sector

We summarize the main conclusions as follows:

- Peak electricity demand for the year 2035 will increase to 46,700 MW with 8% growth rate and to 69,000 MW with 10% growth, a margin of 48%.
- With Vibrant Gujarat mode of industry led 10% growth the peak demand will be 80,300 MW which is an increase of 16 per cent due to change in the structure of the economy.
- With emphasis on renewable, mainly wind and solar, the share of renewable capacity can be 50% or more; 35,000 MW of wind and 60,000 MW of solar energy can be absorbed with gas based plants providing balancing power.
- Even when supercritical coal plants are restricted to 20,000 MW compared to 40,000 MW in other scenarios, Gujarat can meet its power requirement with some balancing by natural gas or solar PV with storage.
- Significant reduction of 30 per cent in total power sector emissions is feasible, but with a 40% increase in the cost of electricity.
- Gujarat should push for the development of renewables. Its ability to restrict coal will depend on the availability of natural gas or development in electricity storage technology. It can adapt its strategy to evolving technology.

[1]Agenda notes for the Subsidiary Body for Scientific and Technological Advice, Forty-third session, Paris, 1–4 December 2015, UNFCCC

Table-11 CO_2 Emissions in 2035 under 3 Scenarios - 8% and 10% growth of GDP				
Scenarios	2013	S-1	S-2	S-3
		Falling Elasticity		
Parameters/Growth rate	Actual	8%	10%	
		BAU	Service led	Industry led
Total emission of CO_2/year (Million Tonnes) in Gujarat^	106	264	271	274
Per capita CO_2 emission (Tonnes/year) (Gujarat)@	1.74	3.14	3.23	3.27
Per capita CO_2 emission (Tonnes/year) (India incl. LULUCF)	1.70	--	--	--
Per capita CO_2 emission (Tonnes/year) (India fuel combustion) (UNFCCC, 2012)	1.58			
GSDP @ constant prices 2004-05 @8% GR (Billion Rs.)	4162	23226	34777	34777
CO_2/GDP at Constant Prices (kg/Rs.) (2004-05) (Guj)	0.026	0.011	0.008	0.008
CO_2/GDP at Constant prices (kg/USD) PPP (in 2004-05) (Guj)	1.17	0.51	0.35	0.35
CO_2/GDP at Constant prices (kg/USD) PPP (in 2004-05) (Ind)" (2011 data)	1.60			
Population in Gujarat	61.02	83.94	83.94	83.94

^Only coal, lignite and NG and major fuels considered for projections in 2035

Av Annual exchange rate (RBI) 2004-05 base year 1USD=44.93INR and 1USD=11.23INR (PPP).

@Excludes Agriculture, LULUC. "http://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD (2011)

Strategies to meet Demand for Petroleum Products

The supply of petroleum products is largely determined by the Central government. The state government does not have much policy space here. It can import petroleum products, but that would be expensive as the quantity would be small and would require setting up a distribution company.

However, the state government can take measures to reduce the demand for petroleum products. An important step would be to charge prices for petroleum products without any subsidy thereby inducing consumers to use them frugally. Opportunities to reduce the need for petroleum products exist in the transport sector, in industries, in households and in agriculture. The measures the state can take are described in Chapter 11.

Strategies for Gas Supply

In the gas sector, the state government has set up a gas distribution company, which lays the pipe network, imports LNG and distributes gas. Thus gas import becomes a real option for the state. If availability of domestic gas is restricted, LNG import is an option. We have seen that gas can play a critical role in absorbing renewable power. Until cheap electricity storage technology is developed gas would be vital for Gujarat. Once a gas pipeline network is established, it provides an option for combined heat and power (CHP) generation that can increase the use efficiency of gas to nearly 80% compared to 50% or so in closed cycle gas turbines. Thus a pipeline network and enabling regulation for CHP use would make gas imports at relatively high price economical compared to, say, importing coal. Providing piped gas to households can free up LPG for rural households who need to be provided clean cooking fuel.

11. Policies for Gujarat

We now bring together the policies required in various areas based upon the detailed calculations and scenarios worked out above. Since power is the most critical sector and provides maximum policy space, we look at it in some detail. We also look at policies for securing supply of various fuels, for providing energy access to all, for dealing with environmental issues and for issues of risk and infrastructure.

Policies for Power Sector

Even with falling elasticity, reflecting increased energy efficiency due to various demand side measures (DSM), Gujarat will need to expand its installed capacity from 24,000 MW in 2014 to around 65,500 MW with 8% growth of SGDP and to around 100,000 MW with 10% growth of SGDP. If the growth is primarily industrial, the required capacity in 2035 could be as high as 131,000 MW. Also, the installed capacity required depends on the shares of different type of plants, particularly renewables. With a limit on coal-based plants, the capacity needed with industry led growth would be around 182,000 MW in 2035. Thus Gujarat faces a massive challenge in the power sector if it aspires to achieve a growth rate of 10% and restrict coal-based generation.

We have seen that Gujarat will need to depend on coal for some time. Renewables like wind and solar can make significant contributions. However, beyond some level balancing power has to be provided either with open cycle gas based plants or through some forms of electricity storage.

The policy challenges are – how to promote energy efficiency, how to access coal at the minimum cost, how to procure natural gas and, above all, how to promote renewable power and absorb it.

DSM for Energy Efficiency

The falling elasticities used in projecting electricity consumption in chapter4, implies a reduction of 14% by 2035. This implies a reduction in electricity use by 1% per year in industry, households and commercial establishments.

Increased absorption of labelled, star-rated appliances by households can lead to such reduction. What the state can do is to incentivise households by the following measures:

a. Meter and charge for all electricity
b. Provide finance for purchasing high star-rated appliances. Manufacturers could be incentivised to provide finance.
c. Invite competitive bulk supply bids for high energy consuming equipment for public sector and government purchases. This could reduce costs. This would also make it easy for public sector and government procurement officers to buy energy efficient products as otherwise they buy the lowest priced products.

Energy use efficiency in industry can also be increased through the government's PAT (Perform, Achieve and Trade) scheme. Gujarat should ask the Bureau of Energy Efficiency (BEE), a government energy conservation agency that steers PAT, to launch a similar scheme for small and medium enterprises, particularly when these are located in an industrial park.

A growth rate of 10% implies that many new commercial buildings would be built. If these buildings are made to effectively follow the Energy Conservation Building Code (ECBC), it could result in 30% reduction in energy consumption of new buildings. In order to promote ECBC the state needs to incentivise owners and builder-developers to build ECBC compliant buildings. To overcome the problems related to ECBC compliance the following needs to be done:

a. Gujarat needs to adopt the ECBC code with modifications if they are found to be desirable
b. Make ECBC mandatory for all commercial buildings above a certain size
c. Set up a certification mechanism in consultation with urban local bodies
d. Introduce third party verification on a random basis to ensure that inspectors of ULBs are doing their job properly
e. Third party verifiers may be approved by a professional body such as Institution of Engineers or BEE
f. Builders may be provided incentives for building ECBC compliant buildings such as:
   - Tax rebate
   - Permission for extra built-up area (Increase in FAR)
   - Priority in electricity, water, sewerage connections.
g. The challenge is to make such a system corruption free. Thus compliance certification with details should be made public and put on the website.
h. Installation on smart meters with which energy consumption per square meter of the house can be monitored can help verify if the building is ECBC compliant or not. Builders may be required to post a bank guarantee when they are given incentives

Time of the Day Pricing

The load curve of Gujarat is quite flat; the scope to reduce peak demand by shaving the peaks and filling valleys is limited. Yet time of the day pricing should be introduced so that it remains flat even when demand grows. With a lot of solar power, the supply curve will also have peaks and valleys and the time of the day pricing policy can help match the shapes of demand curve and supply curve.

Coal Power

Gujarat has no coal; it comes from outside. Gujarat bears a higher cost for coal than it should because of the irrational allocation of coal linkages, which is further aggravated by the distorted freight rates of Indian Railways that cross-subsidises passenger movement by over-charging freight movement.

Gujarat should make a strong case to the Centre to:

i. Either rationalise the coal linkages
ii. Or make coal linkages tradable, and
iii. Rationalise railway freight rates

This can make a significant reduction in the state's expenditure on coal. But the catch is that the attractiveness of coal power would increase and would make it that much more difficult to promote solar and wind power. The matter can be resolved by providing higher feed-in tariff to renewable power.

Gujarat needs to reduce the use of coal to reduce air pollution and CO_2emissions. Thus policies need to promote clean coal technologies and coal use efficiency. For example:

a) **Supercritical Plants**: Every new coal-based plant should be mandated to be a super-critical plant. This is the first step.
b) **Ultra Super-Critical Plants**: These can have efficiency of around 43 per cent compared to around 38% of super-critical plants. There is an active programme to develop the technology and once it is available, Gujarat should seriously consider it.
c) **IGCC**: Integrated Gasification Combined Cycle (IGCC) plants have higher efficiency and lower emissions. They also facilitate carbon capture, if and when needed. Unfortunately, IGCC for high ash Indian coal has not been developed yet, though, Bharat Heavy Electricals Limited (BHEL) is working on it. However, since Gujarat imports coal it can consider IGCC plants with imported coal, even though its initial

cost is higher than conventional plants. It would be worthwhile particularly if emission control is given due weight.

Lignite Power

Gujarat's lignite resource can at most supply 5,000 MW of power plants over their lifetime of 35 years. Rajasthan, which is near enough for Gujarat to import lignite, has resources that can supply 10,000 MW. Given the projected requirement of power, Gujarat should develop its own lignite resource to generate power first. Lignite's role, however, is going to be limited.

If in-situ gasification technology can be developed deeper seams can be exploited with much less environmental consequences. Unfortunately, even though Oil and Natural Gas Commission (ONGC) has been trying to develop the technology, the turf battle between ministries of coal and oil has not allowed it to make much progress.

Natural Gas

Availability of gas from domestic sources has become more uncertain as supply has dwindled from Krishna Godavari Dhirubhai 6 (KG-D6) offshore gas field. On the other hand, with shale gas production growing around the world, gas supply in the international market should be abundant.

Strategically, Gujarat needs to decide on the level of imports it would like and build domestic infrastructure for imports and if possible get into long term commitments for importing gas.

The gas uses that the Gujarat Government may want to encourage are the following:

i. Use of compressed natural gas (CNG) for transport: With the expected growth in motorised vehicles, urban air pollution is a growing problem. Many medium size cities are growing rapidly and the state should encourage them to set up efficient public transport systems. CNG buses, three-wheelers and taxis can help in limiting the growth of air pollution.

   The policies to encourage this would include appropriate pricing of auto fuels taking into account the externality of air pollution they create. Also it may be necessary to set deadlines for conversion of the old fleet and mandating that new vehicles will only be based on CNG.

ii. Gas for CHP: Combined heat and power (CHP) generation can significantly increase efficiency with which gas is used. Industries, commercial establishments, large malls, etc., are likely to find CHP and gas turbines to generate power very attractive because it will allow use of waste heat for cooling or heating. A pipeline network and assured supply of gas are critically important to promote CHP.

Renewables

In the long term Gujarat has to depend on renewable power from wind and solar energy if it wants to reduce its dependence on imported energy. Measures used to encourage renewables includes capital subsidy in the form of permitting accelerated depreciation, low interest long-term loans and generation-based subsidy in the form of feed-in tariff (FIT). The FIT may be fixed upfront or may be determined by the market through renewable portfolio obligation (RPO). Many state electricity regulatory commissions have announced RPO and the renewable energy certificates, given to those who achieve more than their obligation, can be traded for which power exchanges provide electronic trading platforms.

Capital subsidy is not considered efficient as it encourages gold plating and does not provide any incentive to generate electricity. Long-term low-interest loans are desirable as interest rate in the country is high. It requires a mechanism to ensure that the loan is used for the plant and not diverted to other uses.

The FIT and RPO are two generation based approaches and each has its advantages and disadvantages.

Renewable Portfolio Obligation (RPO) vs. Feed-In-Tariff (FIT)

FIT gives certainty to the plant owner because the cash inflows are predictable. This makes it easier to find finance and attain financial closure. The disadvantage is that it is technology specific –competitive efficiency may not be realised even when FIT is competitively bid, as one would not have a common bid for all kinds of renewables.

The RPO has the advantage that all renewable technologies compete. While it gives options to grid managers and distribution companies, it creates a lot of uncertainty for developers about the price one would get in the future. Getting finance becomes more difficult. The ability to trade may lower some risks, but uncertainty remains regarding not only price, but also regarding buyers. To minimise this, the following measures can be taken.

a) A uniform RPO across states: All states should stipulate a uniform RPO level. If states are free to set their RPO, the tendency would be to set it too low, and all states would have surplus renewable capacity and no buyer.
b) A floor price should be prescribed as minimum FIT. This would at least ensure a minimum cash flow and reduce uncertainty. A national mechanism would have to be worked out to pay for all unsold renewable power. This price should be valid for at least 10 years to facilitate financial closure for renewable energy (RE) plants. It should be set at a level that provides adequate return to the RE producer.
c) A forbearance price, an upper bound should also be set. In case of short supply of RE, forced buy-out at this price should be provided. The price may be set at the highest level of other subsidised power.
d) An effective penalty should be imposed on those who do not meet the RPO. This should be a multiple of, say, one-and-a-half times the forbearance price.
e) Banking of RE certificates for a period of three years should be permitted.

It should be clearly spelt out if the obligation to build the needed transmission line is of the distribution company or the plant operator.

Wind Power

The main problem with wind power is its unpredictability. It varies not only from season to season and day to day, but also from hour to hour. The variability can be up to five times as is seen in 2012-13, from a low of 172 MU in October to a high of 901 MU in July.

Maximum variations are observed in the months of May and December, when the hourly changes can be as much as 3-5 times the lows Even the daily load curves on some days how variations of up to 10 times the day lows. October, November and February are not only relatively low variation months; these are also low generation months.

Thus absorbing wind power is a big challenge even when there is balancing capacity in the system. Not only one needs a smart grid in the sense that it can react quickly, switch generators and manage the change in electricity flow in the network.

Management of even such a smart grid would be facilitated with advance warning of even a few minutes. Wind power forecasting methodologies have improved and one can predict wind energy with reasonable degree of confidence 15 minutes ahead. European countries have developed and improved significantly the wind forecasting techniques. Short-term wind forecasting models up to 15 minutes to several days are now available. These rely on parameters such as wind speed, wind direction, air pressure and humidity as the main input for day-ahead forecasting. These models can make fairly reasonable forecasts.

State-of-the-art Wind-forecasting models:

The latest models of forecasting wind are based on three dimensional weather models and numerical weather prediction (NWP) models such as German Meteorology Service (DWD), High Resolution Limited Area Model (HIRLAM), and UK (Met) official Meso scale Model (UK MESO).

Thus the following measures are indicated:

(a) Carry out load-flow and grid stability studies for projected plans of wind power generation to identify the kind of smart grid required.
(b) Initiate studies to forecast wind power ahead of time, which can be a day ahead, an hour ahead or even 15 minutes ahead.

The problem of absorption arises after wind power plants are set up. Policies are needed to encourage entrepreneurs to set up such plants in the first place.

Gujarat wind power policy-2013 has many attractive features that create an environment conducive to the development of wind power in the state.

It provides for evacuation line by Gujarat Energy Transmission Corporation (GETCO), well defined transmission charges and facility to sell power directly to a third party. It also exempts wind electricity from payment of electricity duty and cross-subsidy charges. In addition, the newly revised renewable portfolio obligations will ensure adequate demand for wind electricity for some time.

Solar Power

Solar power is more predictable than wind as one knows the hours of its availability. The only uncertainty is due to cloud or rains. There is however variability from month to month. During 2013-14, the minimum generation was in July (75 MUs) and the maximum generation was nearly twice as much in March (143 MUs) while the installed capacity was 857 MW only.

Gujarat has been a pioneer in solar energy. Its policies provide incentives, reduce uncertainty and risk and provides infrastructure support that creates ease of setting up plants and getting them running.

The solar policy of 2009 guaranteed purchase at an announced price for a period of 25 years (Rs 15 per unit for first 12 years and Rs 5 per unit for next 13 years). The feed-in tariff has been lower in subsequent rounds. In the assured FIT market risk is not shared by the generator. It is borne 100%by the grid operator.

GETCO provided the transmission infrastructure for power evacuation. The project developer was also provided land at a solar park, which frees him/her of the often difficult and time consuming process of land acquisition.

Putting a number of plants together at a solar park reduces the cost of transmission lines. Being located at a solar park also helps to get skilled workers and maintenance services. As a result, in a short span of 13 months, 'Asia's largest solar park' at Charanka had 214 MW capacity from 26 individual solar projects.

Gujarat should continue with its policies, except perhaps it might consider reverse bidding for FIT that is followed by the Central government instead of announcing a fixed FIT upfront.

Since Gujarat needs to push up solar energy by an order of magnitude, finding appropriate land for solar parks becomes a priority.

Canal-top Solar

Canal-top solar PV plants reduce the risk of land acquisition. And because of cooling by water underneath the panels, canal-top solar PV plants increase the efficiency of generation, compensating for the additional cost of installation on a canal. This is an idea that needs to be fully exploited.

Another option to reduce land requirement is to have grid connection rooftop solar plants.

Rooftop Solar

There is a big push in the country to develop rooftop solar power plants.Net metering is also encouraged in many states. Gujarat was also pioneered in this development with its Gandhinagar rooftop programme. The main policy issues here are:

(a) Should subsidy be provided?
(b) What should be the price of electricity – for feeding electricity into the grid and for withdrawing from it?

There may be some justification for subsidy for rooftop installation installed on large institutional or commercial buildings. Providing subsidy to households installing a solar plant on the rooftop is subsidising the relatively richer households as they are the ones likely to have appropriate roofs. Thus there is little justification for it. Also with a target of 40,000 MW for rooftop solar set-up by the Government of India, the outlay for subsidy would be huge.

A household, which installs a rooftop solar plant would draw power from the grid only when solar power is not adequate or available. The load factor of its demand from the grid would be very low. If the distribution company has to maintain capacity to serve such a demand, its cost of providing electricity would be high.

The price at which power is supplied by the grid to households with rooftop solar plants should account for this. A simple solution would be to charge a capacity charge and then electricity charge at normal rates.

Petroleum Products

Since the state can do little to augment supply, the best strategy is to reduce need by taking a number of measures that increase efficiency of use and replace use by alternatives. The measures the state can take are described below:

A move towards electrification can reduce dependence on petroleum products, be it for transport or households.

Transport Sector

Providing mass transport, public transport and facilitating and encouraging non fuel transport is in the long run unavoidable if cities are not to choke with traffic. Also cleaner vehicles have to be promoted to keep air pollution in check. Promoting better driving habits can reduce fuel requirement. The following measures are required:

- Develop mass rapid transport systems and solutions like Bus Rapid Transit System (BRTS), Metro rail, mono rail for mass travel along with end-of-mile connectivity options like e-rickshaws, CNG auto rickshaws and mini vans.
- Provide workable solutions for inter modal connectivity.
- Proper traffic management and road design, satellite and GIS based traffic monitoring can substantially improve road traffic and result in reduced fuel consumptions.
- Promote use of electric vehicles like cars and scooters to reduce dependence on fossil fuels and improve air quality and CO_2 emissions. Government can provide incentives for buying

electric vehicles in the form of lower interest rates and longer payback periods for loans to consumers.

- Night-time charging of electric vehicle batteries can also improve grid stability. Solar charging stations for the day-time can also be employed.
- Promote non-fuel transport systems wherever possible for short-distance travel like pedal cycles and rickshaws by providing cycle paths.
- Use of BS-IV and higher standards for vehicles and fuels need to be adhered to and strict timelines drawn up.
- Promote better driving habit that can save fuel. Education campaign should be mounted to propagate measures drivers should take.

Industrial Sector

Industries can undertake the following measures to improve and reduce their fossil fuel requirements. Proper energy pricing will encourage them to do so:

- Regular energy audit to reduce energy consumption and take into account oil leaks, incomplete combustion to improve efficiency and reduce fuel consumption.
- Recover and utilise waste heat from furnace flue gases for preheating of combustion of air.
- Reduce heat losses through furnace openings, recover heat from steam condensate.
- Improve boiler efficiency by checking radiation loss, incomplete combustion, blow down loss, excess air and save up to 20% fuel.
- Maintain steam pipe insulation to save considerable amount of fuel.
- Use solar water heaters for process hot water requirement for up to 80°C and meet balance requirement with conventional fuels.
- Use SPV systems to meet at least 50% of lighting needs through rooftop systems wherever space is not a constraint.

Domestic Sector

Apart from transport, the main petroleum products used by households are LPG and kerosene for cooking and lighting. Electricity or solar lights in remote villages are replacing use of kerosene for lighting. The use of cooking fuels can be reduced by a number of measures improved stove design, efficient fuels, etc.

Agriculture Sector

24x7electricity supply has facilitated switching from costlier diesel pumps to electric pumps. Metered supply of electricity will encourage farmers to use it efficiently. They can take the following measures:

- Use of a low friction ISI marked foot valve can save up to 10% diesel consumption for irrigation pump sets.
- Bigger diameter rigid PVC Pipeline saves considerable amount of energy in pump irrigation systems as compared to flexible and corrugated pipes.
- Avoiding bends, in the irrigation pipeline arrangement, suction and discharge pipe lengths can save electricity and diesel consumption.
- Proper design as per site requirement should be taken up.

Apart from energy saving from pumping, scope to reduce diesel use in tractors also exists. Running tractors efficiently, stopping diesel leakage, turning off engine when not in use, matching hauling capacity with tractor load and driving in correct gear all save fuel. Excess smoke indicates improper combustion, dirty engine, increases fuel consumption and indicates need for servicing.

Energy Access

With 24x7 electricity supply to most villages, Gujarat has taken a giant stride in providing energy access. This is reflected in the significant reduction of use of kerosene for lighting. As per the 2011 census around 1 million households, out of a total of 112.2 million households, were still using kerosene for lighting. These may be mostly in remote rural areas or people living on the periphery of habitations. While some of the un-electrified villages in 2011 may have been electrified by now, others may be too difficult to reach or supply restricted with the conventional grid. They should be provided solar lighting either through a small local level grid or through home lighting systems.

Providing clean cooking fuel is the bigger challenge. As per 2011 census, 69% of urban households and only 15% of rural households cooked with clean fuels, LPG, PNG, Biogas or electricity. The objective should be to provide clean fuels to all the households. The expansion of PNG network frees up LPG use, which should be expanded in rural areas. The Gujarat government should provide at least 6 LPG cylinders a year or equivalent to each household. The poorer households will have to be subsidised. The subsidy should be provided through direct cash transfer and not through subsidised cylinders. Cooking with dirty bio-fuels leads to indoor air pollution with serious impact on the health of family members, particularly women and children. Subsidy for clean cooking fuel is socially justified.

A district-wise drive with appropriate measures is needed. Kerosene free Delhi scheme has helped eliminating the use of the unclean fuel leading to associated benefits to all.

PNG

Transporting bulk LPG and cylinders by tankers, trucks, vans, burns up petroleum products that increase congestion on roads and increases air pollution, adding to the climate concern. All cities greater than a million population should be required to switch to piped natural gas (PNG). The LPG cylinders thus spared can then be used to provide clean cooking fuel in remote and rural areas

Environment

The main environmental concerns related to energy production and use are CO_2 emissions, local air pollution, fly ash disposal, water use and quality, indoor air pollution and land degradation.

The main options for cutting down CO_2 emissions are reducing energy use through efficiency measures, restricting the use of coal power generation, using only super-critical and ultra-super-critical plants for coal power generation and pushing renewable and non-fossil power as explored in Chapter 6. Also the measures to reduce petroleum product consumption as described above are also important.

Measures to reduce CO_2 emissions will also reduce air pollution. In addition, a number of steps are needed to reduce local air pollution.

- Require coal power plants to trap all particulates through electrostatic precipitators or ash bags
- Impose fuel efficiency norms on vehicles using petroleum products
- Have stricter PUC norms and enforce them

A cement plant or a brick kiln located near, a power plant can utilise the fly ash generated. Otherwise, fly ash disposal has to be strictly regulated. Fly ash ponds should be properly lined to prevent water pollution through leaching.

Water use in power plants need to be optimised. Water used for ash washing should be cleaned and recycled. Power plants should be charged appropriate price for water so that they have the incentive to reduce and reuse water. Zero wastewater generation policy should be promoted.

Indoor air pollution through use of biomass fuels for cooking has to be replaced by cleaner fuels as described above.
Proper disposal of fly ash is critical to prevent land degradation.

There is no reason why Gujarat cannot have an energy system and a clean environment.

Risks and Hazards

Gujarat is subject to a number of hazards, earthquakes, cyclones, flooding, droughts and tsunamis. Different types of plants are differently vulnerable to these hazards. Since a hazard map of Gujarat is available, the potential risk from hazards should be gauged before deciding on the location of a power plant. After the disaster that struck the nuclear power plant in Fukushima, Japan, during an earthquake, this cannot be neglected.

A vulnerability assessment should be carried out even for existing plants and any measures indicated to reduce the vulnerability should be followed through.

Gujarat as India's Energy Gateway

Gujarat is the key gateway for imports of energy resources into India. It plays a major role in India's energy security and energy trade. In FY13, Gujarat ports (major and non-major) alone handled 66 per cent of India's total imports of POL and its products. As for coal, Gujarat ports (major and non-major) handled 36 per cent of India's total coal imports. Similarly, Gujarat Liquefied Natural Gas (LNG) terminals accounted for 64 per cent of the installed LNG re-gasification capacities of India. All these facts highlight the importance of Gujarat's ports in overall energy imports and energy security of India.

With economic growth, the energy trade will increase for decades before substitution by renewables reduces energy imports. Gujarat needs to continue to develop its ports not only for itself, but also for the country as a whole. This also provides an opportunity to create employment and earn revenue.

We have also stressed that ports should be secured from all forms of risks and man-made or natural vulnerabilities

12. Concluding Observations

- If Gujarat is to progress as it aspires to and achieve double digit growth rate, led by industrial development, it faces a huge challenge to meet its energy needs.
- Gujarat's dependence on coal will continue for some time. Hence moving to more efficient supercritical and ultra-supercritical plants are a must.
- Today Gujarat is paying more than what it should for coal because of the coal linkage and railway freight rate policies of the Government of India. It should strongly ask for tradable coal linkages and rationalisation of railway freight rates.
- With its limited resources of fossil fuels its emphasis must be on renewable power if it wants to restrict the level of energy imports.
- Fortunately, Gujarat has significant potential of wind and solar power as well as a good policy framework to attract investment in these areas. With some suggested measures renewables have large potentials for growth in Gujarat.
- We have also seen that it is possible to absorb significant amounts of solar and wind power by balancing with open cycle gas based plants. Also, if advancement in electricity storage technology brings down costs, solar PV with storage can provide the needed balancing power. More detailed studies are needed in this sector.
- While availability of natural gas is limited, coal gasification based on imported coal or in-situ gasification of

lignite can provide gas. We have not considered these in our analysis, as the technology of in-situ gasification is not yet commercially developed.

- Apart from electricity, consumption of petroleum products has to be restrained. Here, development of mass transport, encouragement of non-motorised transport, discouragement of use of private vehicles by providing the option of efficient and convenient public transport and imposing parking and congestion charges, are required.
- At the same time, increased fuel efficiency from vehicles, more stringent emission norms and facilitating electric vehicles by providing supporting public infrastructure are needed. Regular environmental impact studies, with modelling needs to be undertaken in major cities.
- While supply policies are important, demand side measures to promote energy efficiency are equally critical. The state should push hard for more efficient use of energy. Appropriate pricing of energy is a vital element of pushing energy efficiency. Education and encouragement for saving energy can be cost effective.
- With 24x7 electricity supply, Gujarat has come a long way in providing energy access to all its residents. Even then action is needed to provide clean cooking fuel to a large segment of the population. The spread of Gujarat gas grid to all urban areas should help replace LPG use in urban households with PNG. The freed cylinders and LPG should be used to provide them to rural households. With 24x7 electricity and significant expansion of solar power, it might be more practical to provide induction cookers where supplying LPG may be difficult or impracticable.
- We have also looked at the environmental consequences of energy use. With emphasis on energy efficiency, mass transport, efficient vehicles, stringent emission norms, promotion of electric vehicles and large thrust on renewable energy can provide a much cleaner environment.

Finally, we have pointed out that Gujarat is the country's gateway for energy imports. Gujarat should continue to develop its port infrastructure and consider it an opportunity to stimulate its own development.

About IRADe

IRADe networks with the government, ministries/ departments, international organizations, public and private sectors, academic experts, NGOs, and consultants to work on projects awarded by them.

The ministries include Ministry of Environment and Forests and Climate Change, Ministry of New and Renewable Energy, Niti Aayog (formerly Planning Commission), Ministry of Power, Ministry of External Affairs, Ministry of Earth Sciences, Ministry of Urban Development, Department of Science and Technology, Central Statistical Organization under Ministry of Statistics and Programme Implementation, Technology Information, Forecasting and Assessment Council (TIFAC), etc. for many national level projects.

At the international level, IRADe has worked with multilateral organization like the World Bank, Asian Development Bank (ADB), U.S. Agency for International Development (USAID); United Nations Development Programme (UNDP); Stanford university, California and United States Environmental Protection Agency (USEPA), Wuppertal Institute for Climate, Environment and Energy, (WISION) Germany; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Germany; Rockefeller Foundation; British High Commission; International Institute for Applied Systems Analysis (IIASA), Austria; British High Commission (BHC), Centre for Clean Air Policy (CCAP), USA; International Institute for Sustainable Development (IISD), South North Trust (SSNT) etc.

IRADe has collaborated with private sector and multinational organizations and NGOs such as Shakti Foundation, Indian Council of Social Science Research (ICSSR), SEWA, Petroleum Federation of India, Price water House Coopers, ICF International, Rockefeller Foundation, Institute for Social and Environmental Transition (ISET), Centre for Clean Air Policy (CCAP), Indian Council for Research on International Economic Relations (ICRIER), InsPIRE Network for Environment, NATCOM and Sir Dorabji Tata Trust (SDTT) among others.

IRADe has also developed strategic partnerships and is part of global networks like the USAID Low Emissions Asian Development (LEAD) program - ASIA-LEDS, ENERGIA-International Network for Gender and Sustainable Energy, Netherlands; Global Clean Cook Stoves Forum, UN Foundation; Asian Cities Climate Change Resilience Network (ACCCRN), Global Technology Watch Group (GTWG-DST), Climate Action Network South Asia (CANSA)

IRADe has carried out some pioneering work in the field of state level energy planning, city level climate resilience planning and other climate change studies and livelihood studies in agriculturally vulnerable flood prone areas.

Thematic Areas of operation:

Energy and Power System (EPS)

Climate Change and Environment (CCE)

Agriculture and Food Program (AFP)

Poverty Alleviation and Gender (PAG)

Sustainable Urban Development (SUD)

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