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Glossary

ABT	Availability Based Tariff
AC	Alternate Current
ADS	Automatic Dispatch System
AGC	Automatic Generation Control
AVR	Automatic Voltage Regulator
BAU	Business As Usual
BBC	British Broadcasting Corporation
BOOM	Build Own Operate and Maintain
CAES	Compressed Air Energy Storage
CAISO	California Independent System Operator
CB	Circuit Breaker
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CEEP	Critical Excess Electricity Production
CERC	Central Electricity Regulatory Commission
CGS	Central Generation Stations
CHP	Combined Heat And Power
CLFR	Compact Linear Fresnel Reflector
CPP	Captive Power Producer
CSP	Concentrated Solar Power
CTU	Central Transmission Utility
C-WET	Centre For Wind Energy Technology
DC	Direct Current
DDSG	Direct Drive Synchronous Generator

DFIG	Doubly Fed Induction Generator
DGVCL	Dakshin Gujarat Vij Co. Ltd.
EES	Electrical Energy Storage
EHT	Extra High Tension
EPS	Electric Power Survey
EWITS	Eastern Wind Integration And Transmission Study
FIT	Feed-In Tariffs
FoR	Forum of Regulators
FRT	Fault-Ride-Through
GEB	Gujarat Electricity Board
GEDA	Gujarat Energy Development Agency
GERC	Gujarat Electricity Regulatory Commission
GETCO	Gujarat Energy Transmission Company
GHG	Greenhouse Gases
GIDC	Gujarat Industrial Development Corporation
GMR	GMR Energy Limited
GoG	Government of Gujarat
GPCL	Gujarat Power Corporation Limited
GRU	Gainesville Regional Utilities
GSECL	Gujarat State Electricity Corporation Limited
GUVNL	Gujarat Urja Vikas Nigam Limited
GW	Giga Watt
ICTs	Interconnection Terminals
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEGC	Indian Electricity Grid Code Regulations

IMD	India Metrological Department
IPP	Independent Power Producer
IPTC	Independent Private Transmission Company
ISO	Independent System Operator
JNNSM	Jawaharlal Nehru National Solar Mission
JV	Joint Venture
LBB	Breaker Back-Up
LDC	Load Dispatch Centre
LILO	Loop-in Loop-out
LOC	Loss Of Opportunity Costs
MGVCL	Madhya Gujarat Vij Co. Ltd.
MNRE	Ministry of New and Renewable Energy
MUs	Million Units
MVAR	Mega Volt Ampere Reactive
MW	Mega Watt
NAPCC	National Action Plan on Climate Change
NaS	Sodium Sulphur Storage
NDRC	National Development and Reform Commission
NEDO	New Energy and Industrial Technology Development Organisation
NLDC	National Load Dispatch Centre
NREL	National Renewable Energy Laboratory
PCC	Point of Common Coupling
PFC	Power Finance Corporation
PGVCL	Paschim Gujarat Vij Co. Ltd.
PHS	Pumped Hydro Storage

PJM	PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia
PLF	Plant Load Factor
PMUs	Phasor Measurement Units
PPP	Public Private Partnership
PSS	Power System Stabilizer
PTC	Parabolic Trough Collector
PV	Photo Voltaic
RE	Renewable Energy
REC	Renewable Energy Certificate
REMC	Renewable Energy Management Center
RES	Renewable Energy Sources
RFB	Redox Flow Batteries
RoW	Right of Way
RPO	Renewable Purchase Obligation
RRF	Renewable Regulatory Fund
RTO	Regional Transmission Organization
RTU	Remote Telemetry Unit
SCEPA	State Clean Energy Policies Analysis
SCL	Short Circuit Level
SCR	Short-Circuit Ratio
SHP	Small Hydro Power
SIPREOLICO	It is a wind prediction tool for the Spanish peninsular power system
SLDC	State Load Despatch
SNG	Synthetic Natural Gas
SPV	Solar Photo Voltaic

SPV	Special Purpose Vehicles
STATCOMs	Static Compensators
SVCs	Static Var Compensators
TERI	The Energy and Resources Institute
THD	Total Distortion Harmonics
TPL	Torrent Power Limited
TSO	Transmission System Operator
UCTE	Union for the Co-ordination of Transmission of Electricity
UGVCL	Uttar Gujarat Vij Co. Ltd.
UI	Unscheduled Interchange
UMPP	Ultra Mega Power Project
UPEC	Universities Power Engineering Conference
VAT	Value Added Tax
VSI	Voltage Stability Index
VSM	Voltage Stability Margin
WAMs	Wide Area Monitoring Systems
WTG	Wind Turbine Generator
WWSIS	Western Wind and Solar Integration System

Executive Summary

Introduction

Renewable energy contribution in terms of its installed capacity in India has reached about 12% of the total installed capacity and the electricity generation from renewable energy sources in 2011-12[1] was around 5.5% of the total power generation in the country. Around 97% of the installed renewable energy capacity is grid-connected and off-grid power constitutes a small share. The growth of renewable energy has been the results of various policy thrust, incentives and schemes for the deployment of RE. Specific targets have been set for renewable energy such as 20,000 MW of solar capacity addition target by 2022 under JNNSM, total RE addition target of about 30,000 MW capacity during the twelfth five year plan. The National Action Plan on Climate Change (NAPCC) envisages a dynamic renewable purchase obligation target of 10% at the national level for 2015 with an annual increase of 1% so as to reach around 15% by 2020.

The 17th EPS report projected that the total electricity demand of India by the end of 12th Plan will be 13,92,066 MUs and by the end of 13th plan it will be 19,14,508 MUs. Corresponding renewable energy generation requirement to meet 17% national RPO is estimated to be 325466 MUs. Considering the fact that wind and solar energy are the main renewable energy source having huge potential available in the country and all other renewable energy sources are limited, it is established that by 2021-22 total renewable installed capacity should be 136,097 MW out of which 98,555 MW is estimated to be wind energy and about 20,000 MW is estimated to be solar energy.

The large grid infrastructure required to take this large scale variable renewable generations brings lot of issues and challenges such as investment needs, division of institutional responsibilities, handling right of way issues, challenges in development of scheme for proper management and schedule of generation, interstate RE power transmission and trading arrangements etc. The Energy and Resources Institute (TERI) undertook a study for identifying the issues and challenges specific to Gujarat and the way forward to tackle these issues.

Objectives of the study

The objectives of this study were:

1. To identify the policy and regulatory concerns on development of grid infrastructure for large scale renewable energy development in Gujarat
2. To recommend possible technical, policy, regulatory, institutional and market measures that can be adopted by relevant agencies to enable aggressive renewable energy deployment in the state in the next ten years

Renewable Energy development scenarios for Gujarat

Gujarat has been developing its renewable energy capacity through various conducive policies, which have attracted the private sector investments mainly in wind and solar power projects. The commissioning of about 600 MW solar power project by the year 2011-12 is an example of the same. This was due to the state initiatives through the progressive

[1] Monthly generation report, renewable energy sources, August 2012- Central Electricity Authority

solar power policy and the development of solar parks. Wind power installation has already shown an upward trend in last few years. Gujarat Energy Development Agency set a target of about 4400 MW renewable energy capacity addition in the state during 12th Five Year Plan and the scope for the development of renewable energy is much more in the state. Since the state has lot of wind and solar energy potential, it is envisaged that Gujarat will contribute significantly in meeting the national RPO targets specified under the National Action Plan for Climate Change (NAPCC). To understand the level of renewable energy capacity which the state would be having by the year 2021-22, the installed capacity projections in the state has been made based on following four different scenarios

1. Business as usual (BAU) scenario: This scenario considers RE capacity addition to occur as per the GEDA targets.
2. "5% of integrated RE potential" scenario: It assumed that the small hydro, biomass and waste to energy projects will be developed as usual as per GEDA targets.Wind and solar power projects will be developed up to5% of the potential estimated by TERI in its report titled "Integrated Renewable Energy Resource Atlas of Gujarat, 2012"
3. "10% of integrated RE potential" scenario: It assumed that the small hydro, biomass and waste to energy projects will be developed as usual as per GEDA targets. Wind and solar power projects will be developed up to 10% of the potential estimated by TERI
4. "NAPCC RPO target" scenario: It is assumed that the small hydro, biomass and waste to energy projects will be developed as usual as per the GEDA target, considering their limited potential. Solar power capacity will be 50% of JNNSM target, i.e. 10,000 MW solar capacity in Gujarat by 2021-22. Wind power installation will be as per the percentage of potential estimated by CWET, i.e. about 35% of total wind power installation in Gujarat (35 GW of about 100 GW) to meet the national NAPCC RPO

Based on these scenarios, the projected RE installed capacity, electricity generation and the RE penetration (out of total energy demand of Gujarat, that is projected as per 17th EPS report) are given in below figures respectively.

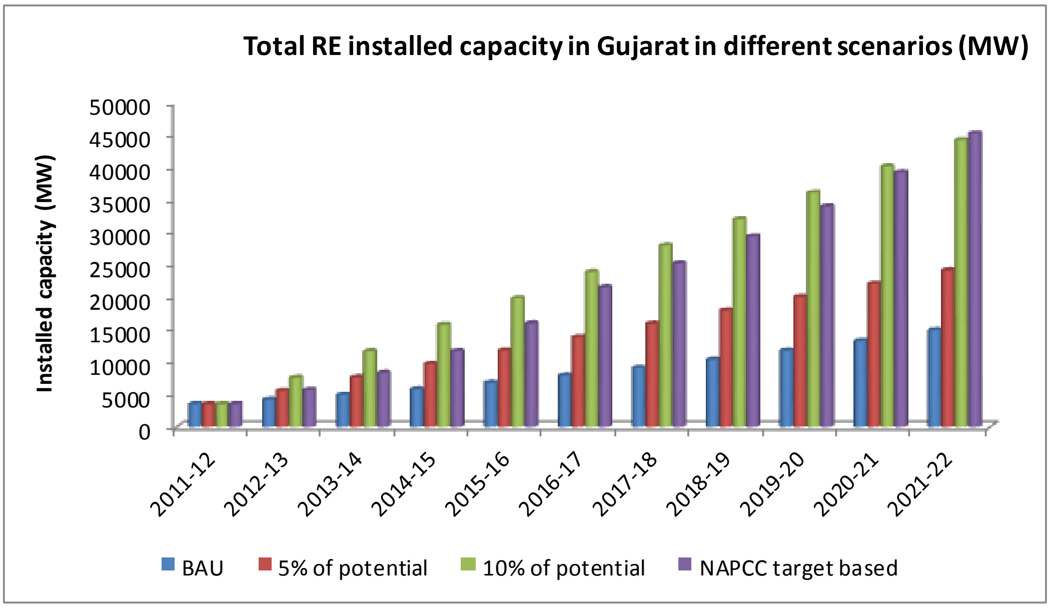


Figure A: Projected RE installed capacity in Gujarat for different scenarios

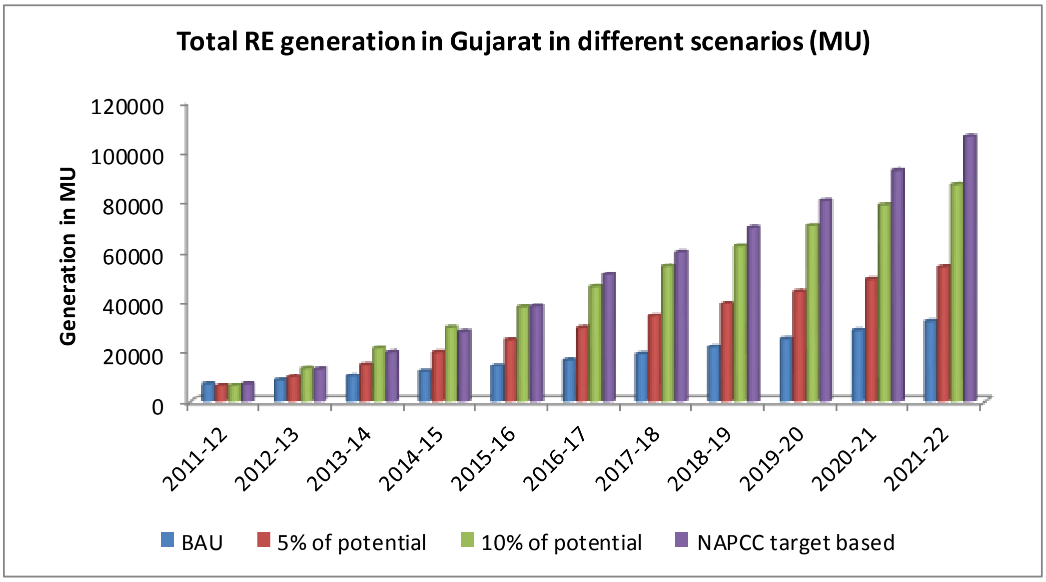


Figure B: Projected RE generation in Gujarat for different scenarios

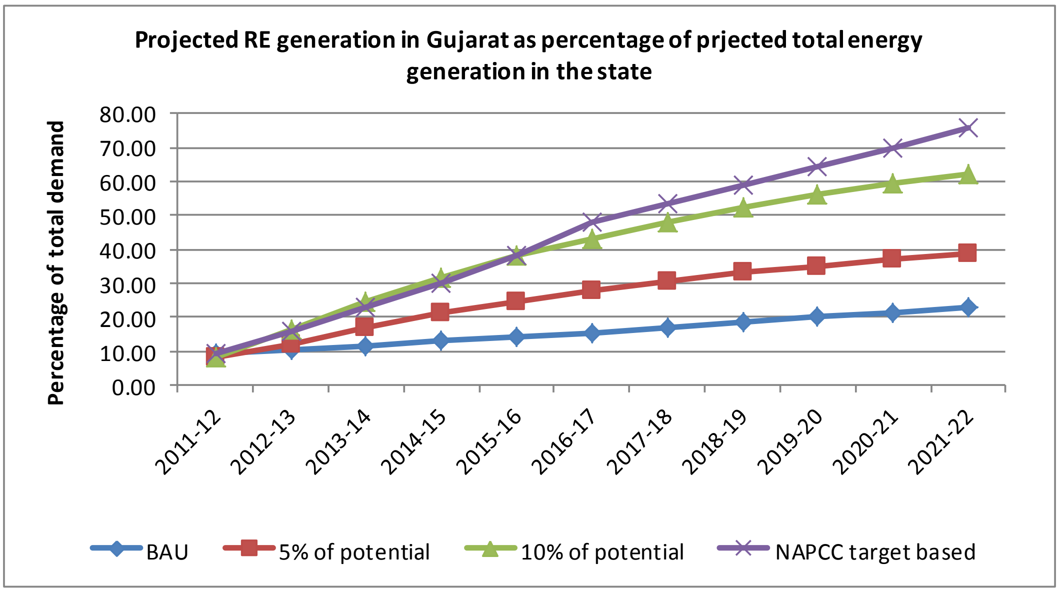


Figure C: Projected RE generation as % of total energy generation in Gujarat for different scenarios

Based on the above projections it is observed that the quantum of renewable energy installation in Gujarat will be huge. Gujarat will experience a power surplus situation and it will require large grid infrastructure to transmit the power within the state as well as outside the state. This will require mechanisms for the interstate trading of renewable energy, proper scheduling of RE generation etc. Associated issues that the state will face are listed out in next section.

Issues and challenges in large scale grid integration of renewable energy

Various literatures show that the large scale renewable energy generation mainly wind and solar energy when integrated with the grid brings lot of technical challenges and issues in the operation and management of the grid system. These technical problems are mainly related to power quality and its balancing which include voltage and frequency variations, reactive power imbalance, harmonics and flickers reverse power flow etc. The impact of these variations depends upon the size of the renewable energy projects, grid capacity and the voltage level at which the RE project is interconnected with the grid..

To handle the technical integration and operational issues, there are various technological advancements and integration methodologies available for the grid systems which once implemented would help much in making grid strong enough to withstand the large variability of renewable energy. Some of these are (a) deployment of synchrophasor technology i.e. PMUs/WAMS (b) using STATCOM devices (c) development of flexible generation, ancillary services, spinning reserves and storages (d) renewable energy forecasting for proper scheduling e) better demand side management etc.

The deployment of these systems and methodologies is not that easy and brings out policy, regulatory and financial challenges. Based on the study carried out for Gujarat, the issues found after various interactions with the stakeholders such as GETCO, SLDC Gujarat, GERC, GEDA, solar and wind power developers, research institutions, distribution utilities etc. are given below.

Policy, regulatory and commercial issues

The state government including the distribution companies and transmission utilities have their own concerns relating to commercial implications of evacuating large quantity of these highly variable energy generations. The power generators also have different set of concerns relating to the policy and regulatory aspects of large scale renewable energy integration with the grid. These concerns, identified based on the stakeholders' consultations, are summarized below.

1. The transmission utility is concerned about the high cost involved in the development of the grid system with advanced equipment and long distance high voltage transmission lines, and in extending the grid network to the remotely located renewable power generation stations. Their concerns pertain to:
    a. Funding these investments
    b. Recovery of these investments: whether it could be recovered through increased transmission charges or these are supported by the state/central grant.
2. The distribution licensees are reluctant to purchase the variable RE generation at higher tariff.
3. SLDC is considering few gas power plants as spinning reserves but there is an issue of the high per unit cost of generation from these plants in case they are kept operational for only a small amount of time.
4. The UI charges being paid by the state government due to the import of power from the grid in case of sudden fall in the solar/wind energy generation ultimately makes the effective cost of electricity from these sources high.
5. Since the Discoms have to meet the RPO target, they first want to buy the electricity at the feed in tariff rate, rather than buying the variable energy at average power purchase

cost and then buying REC from market to fulfil their RPOs. The power producers, on the other hand find the option of selling power at average price and then selling REC in the market as better way for financial returns. This leads to ambiguity in signing of PPA.

6. For REC mechanism, the state's (specially the RE rich state) concern would be that it has to develop the vast grid infrastructure for evacuation of RE power.
7. Higher penetration of RE may also lead to power quality issues for the state's grid infrastructure, hence, that state may have to absorb poor quality of power due to large RE potential available.
8. Concerns for the state governments regarding funding arrangements for the large scale grid infrastructure development.
9. No defined mechanism for the ancillary power market and the payment mechanisms. Further the cost intensive technologies, required to be maintained for handling variable RE source would impact the increase of the retail electricity tariff, so it will again be the burden to the state government.
10. Though the Government of India through IEGC-2010 has made scheduling of wind power mandatory for the wind firms installed after January 2011.There are various concerns related to it due to the fact that the accuracy of the wind forecast models available today are not satisfactory. Further to these there are uncertainty about how the scheduling will be applicable for the wind farms connected to a single substation in which there are few already commissioned (before 1 January 2011) wind turbines and few will be commissioned later.
11. SLDC, Gujarat says that, it can take the task of setting up of a state level RE data management centre, for which the process and concept preparation has already been started, but today there are no experts available with SLDC who can understand the forecasting of renewable energy. Hence, there is a need to build capacity. Sources of funds for setting up the centre and operational costs are some other concerns.
12. Further concern of SLDC Gujarat, regarding the RE data management centre and forecasting was that the developers do not provide the plant specific data as well as the real-time data from their wind farm, without which it would not be possible to forecast. Hence, there is a need for regulations to guide the wind farm developers to provide the desired project specific data to the SLDC/RE data management centre.

Analysis of grid codes

The study also analysed the grid codes in terms of some of the important technical specifications for renewable energy projects which must be followed forsafe and stable operations of the grid systems. It is observed that the IEGC-2010 as well as GEGC-2004 do not elaborate on the following:

a. Fault ride through requirement
b. Active power restoration
c. Voltage control
d. Energy balance
e. Reactive power compensation
f. Active power and frequency control etc.

IEGC refers to the CEA grid connectivity standards for any technical requirement and it is found that CEA has these aspects covered in the draft grid connection standards for renewable energy. It is therefore important for CEA to come out with the final grid connection standards for renewable energy which can be referred to by the state as well as central grid code.

Recommendations and plan of actions

Recommendations for future RE deployment and safe integration of renewable energy in the Gujarat state grid as well as the national grid are broadly categorized as:

a) Appropriate renewable energy generation forecasting

b) Co-ordinated project development, grid planning and grid strengthening

c) Creating flexible capacity, spinning reserves and ancillary services market

d) Properly defining RE grid integration standards and regulations

The action required with the relevant responsible agencies for the implementation of above measures are given in table below

Focal area of intervention	Action required	Roles and responsibilities
Policy interventions		
Co-ordinated project development, advanced grid planning and network enhancement	Project development and grid planning • RE potential based planning - "Integrated Energy Parks" on PPP mode – (experience from Charanka) • Creation of land banks for RE parks • Call for long term development plans of developers (5-10 years) Grid strengthening and extension • Tariff based bidding for transmission network development Some funding options that may be explored • Gujarat Green Energy Fund • State govt. grant • 13th Finance Commission • Any other such as clean energy fund	• GEDA/GPCL- Integrated energy parks- Site identification, land banks, bidding, developer selection etc. • GETCO – grid planning, tariff based bidding (PPP)
Regulatory interventions		
RE generation forecasting	Forecasting • Setting of state level, regional and central level (SLDC/RLDC/NLDC) forecasting center for RE • SLDC to consolidate the forecasts from all project owners	• GERC to introduce amendment in grid code • Forecasting- GERC directive to project developers and owners to provide the desired data to SLDC
Flexible capacity, spinning reserves and ancillary markets	Hydropower, gas based projects to be looked on for the purpose of spinning reserves CERC regulations for implementation of ancillary markets can serve as guidelines for Gujarat	• CERC and GERC – Regulations for implementation of ancillary market • Energy and Petrochemicals Department, Gujarat –

Focal area of intervention	Action required	Roles and responsibilities
	Primary responsibility of procuring ancillary services (SLDC). SLDC to pay through ARR/ separate budget provision • Manner of procurement of services -Power exchange, bi-lateral contracts, tendering etc. • Tariff determination by GERC • Fixed- For availability Rs/ MW/month • Variable- As and when services is called for (Rs/kWh) • Energy storage: Potential energy storage technologies to be explored	Policies for gas exploration and production, pricing, allocation and utilization
Other measures		
Advocacy and coordination	Coordinated planning at regional and central level for • RE forecasting and scheduling • developing the forecast evaluation methodology • Spinning reserves and ancillary market (coordination with other states) • Transmission network planning	GEDA, GUVNL, GERC, SLDC and GETCO with CTU / Central Govt. to coordinate appropriately

1. Introduction

1.1 Power scenario of India

India had an installed capacity of around 2,10,952 MW as on December 31, 2012. Thermal power continues to be the mainstay of electricity generation and it constitutes more than 65% of the total power generation capacity. The electricity generation at present is not enough even to meet India's per capita electricity consumption of about 815 kWh (For the year 2010-11)[1]. The peak and energy deficit during the year 2011-12 stood at 10% and 8% respectively (CEA 2012). Electricity demand is growing exponentially and is projected to grow at a rate of 8.5%[2] annually till 2021-22, as per the report of 18th Electric Power Survey carried out by CEA. To meet the growing demand of energy, the associated concerns of energy security, current account deficits, energy access, environment, and climate change, renewables have now become priority for India. Government of India is committed to its growth and at the same time has voluntarily committed to reduce its GHG emissions. The activities towards the promotion of renewable energy sources in India were initiated in early 80s. With various demonstration programs, enabling policies and financial incentives, the government has been able to achieve more than 25 GW of installed grid connected renewable energy capacity (Figure 1)[3]

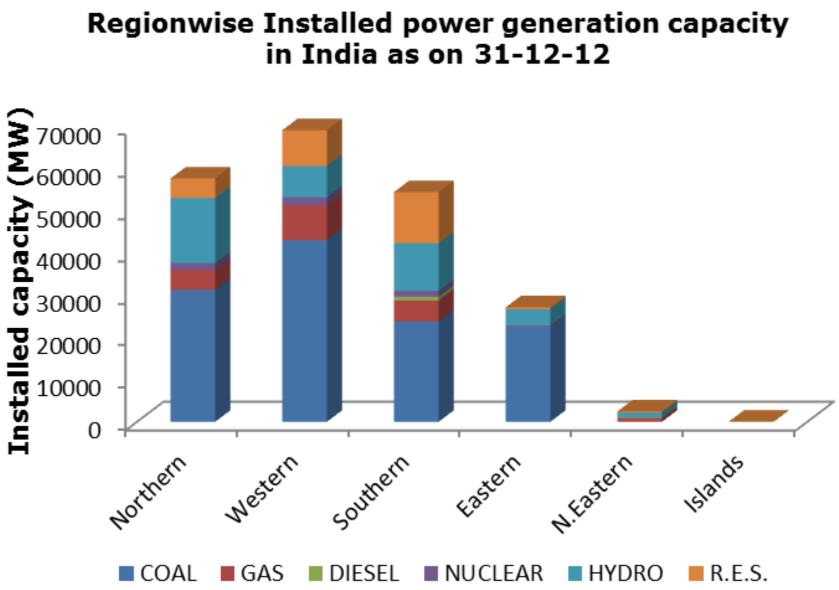


Figure 1: Installed power generation capacity in India as on 31-12-2012

[1] Power scenario at a glance, CEA Nov-2012 http://www.cea.nic.in/reports/planning/power_scenario.pdf (last accessed on 23 January 2013
[2] http://www.infrawindow.com/reports-statistics/power-consumption-projected-to-grow-8-5-per-annum-up-to-2022_101/
[3] http://www.cea.nic.in/reports/monthly/executive_rep/sep12/8.pdf (last accessed 25 Oct2012)

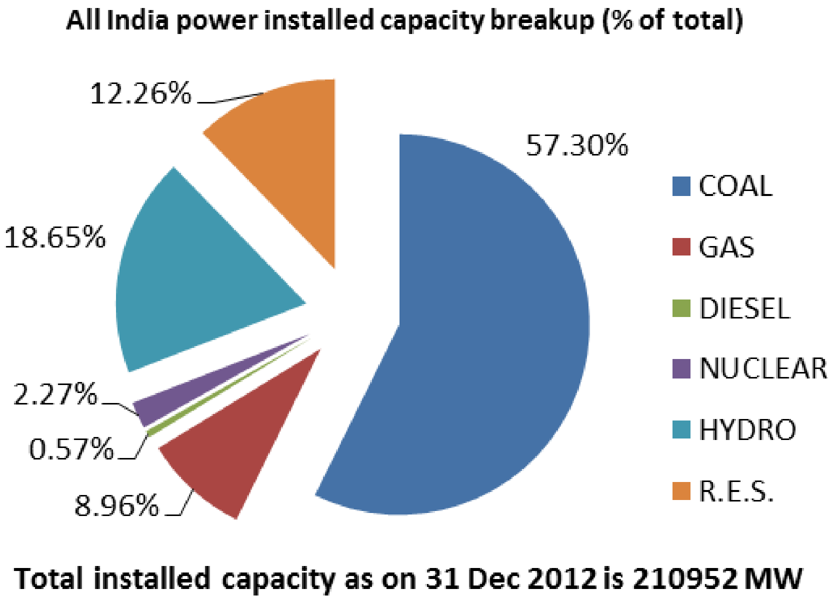


Figure 2: Breakup of all India installed power capacity in percentage of total installed capacity

1.2 Current Status of Renewable Energy Development in India

There has been a significant policy thrust to renewables and specific targets have been announced to accelerate the deployment of RE. The National Action Plan on Climate Change (NAPCC) envisages a dynamic renewable purchase obligation target of 10% at the national level for 2015 with an annual increase of 1% so as to reach around 15% by 2020.

Renewable energy contribution in terms of its installed capacity in India has reached about 12% of the total installed capacity and the electricity generation from renewable energy sources in 2011-12[1] was around 5.5% of the total power generation in the country. Around 97% of the installed capacity is grid-connected and off-grid power constitutes a small share. Wind continues to be the main stay of grid connected renewable power in India (Figure 3). Globally, India ranks fifth in terms of wind installed capacity. The historical growth of the renewables has been tremendous with a compounded annual growth rate of 22% over the last decade (2002-2012). Figure 4 shows the plan wise growth of renewable capacity. The rate of growth has been particularly significant for solar over last three years (2009-2012), mainly due to the capacity installations under the state solar policies and the National Solar Mission. Solar capacity grew from 10 MW in 2010 to more than 1047 MW in 2012. Much of the solar capacity (approx. 760 MW) has come under the state solar policies and solar schemes and predominantly in Gujarat. Gujarat has been a frontrunner in adding solar capacity with a cumulative installation of 699 MW over 2009-12.

[1] Monthly generation report, renewable energy sources, August 2012- Central Electricity Authority

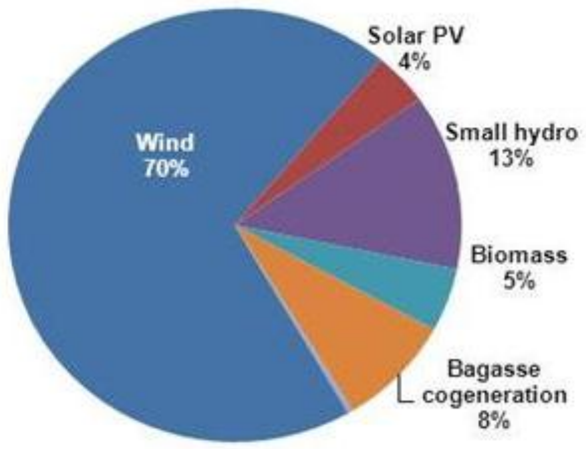


Figure 3: Percentage share of various sources in total RE installed capacity in India

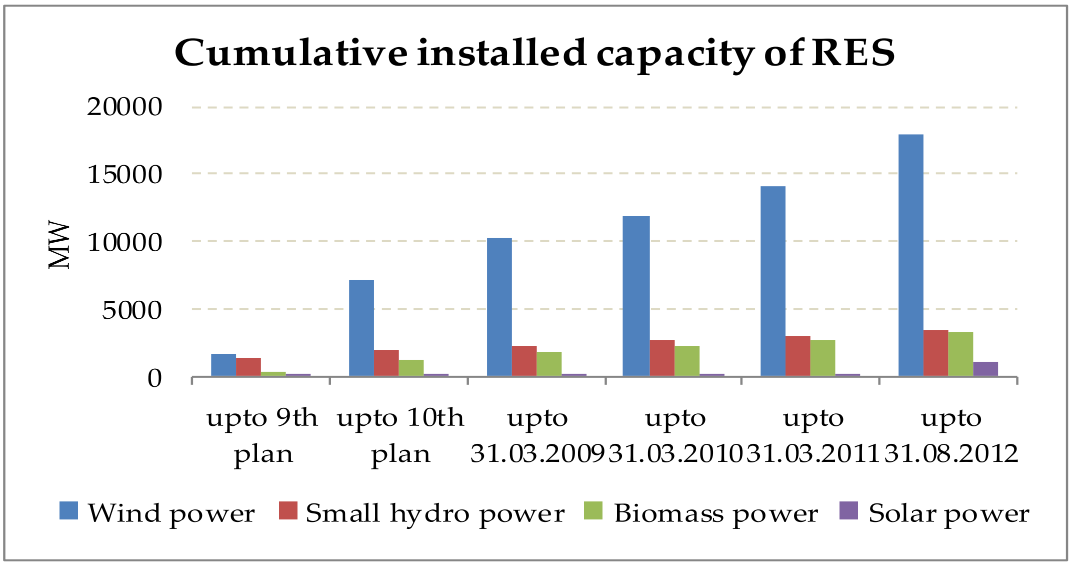


Figure 4: Plan wise and source wise cumulative renewable energy installed capacity in India

Further, the Government of India has projected capacity addition of 72,400 MW by end of 13th plan (2022) of which solar is expected to contribute 20,000 MW i.e. approx. 28%. For the twelfth five year plan (2012-17), MNRE has set a target of 31,664 MW. The RE technology wise annual target capacities are given in table 1.

Table 1: Planned RE capacity addition in 12th five year plan[1]

Resource	2012-13	2013-14	2014-15	2015-16	2016-17	12th Plan
Wind	2,500	2,750	3,000	3,250	3,500	15,000
Solar	1,000	1,000	2,000	2,500	3,500	10,000
Biomass	350	625	825	950	1,300	4,050

[1] Source: Forum of Regulators report on 'Assessment of achievable potential of new and renewable energy resources in different states during 12th Plan period and determination of RPO trajectory and its impact on tariff' March 2012

Resource	2012-13	2013-14	2014-15	2015-16	2016-17	12th Plan
Small Hydro	350	400	400	450	500	2,100
Waste-to-Energy	40	60	100	100	200	500
Tidal/Geothermal	1	2	3	4	4	14
Total (MW)	**4,241**	**4,837**	**6,328**	**7,254**	**9,004**	**31,664**

This target is less than the one estimated by The Forum of Regulators (FoR) study on RPO trajectory assessment. [1] The FoR study has estimated that the above 12th plan target would not be able to meet the NAPCC target of 17% of national RPO by the year 2017. However, the projections made in the study were for short to medium term assessment only. Moreover, the large scale renewable energy development will require advanced planning of the grid infrastructure. The long term grid planning and its development to facilitate RE deployment to the required scale have multiple issues like, division of institutional responsibilities, handling right of way issues, funding sources and mechanisms, challenges in development of schemes for proper management and scheduling of generation, interstate RE power transmission and trading arrangements etc. To identify the related policy and regulatory concerns on development of grid infrastructure for large scale renewable energy development, The Energy and Resources Institute (TERI) undertook a study for identifying the issues and challenges specific to Gujarat and the way forward to tackle these issues.

1.3 Objectives of this Study

The objectives of this study were:

- To identify the policy and regulatory concerns on development of grid infrastructure for large scale renewable energy development in Gujarat
- To recommend possible technical, policy, regulatory, institutional and market measures that can be adopted by relevant agencies to enable aggressive renewable energy deployment in the state in the next ten years

1.4 Study approach

The following tasks were undertaken during this study.

1) Review of literature and international case studies
2) Data collection
3) Site visits to identified substations in RE rich clusters in Gujarat
4) Extensive stakeholder consultations

Each of the steps has been explained below.

1) Literature review

A review of secondary literature was undertaken to understand the technical, commercial and regulatory issues due to large scale integration of renewables into the grid. A review of grid codes of select countries with high RE penetration such as Germany, China and USA was undertaken and compared with the provisions of the Indian Electricity Grid Code

[1] Forum of Regulators report on 'Assessment of achievable potential of new and renewable energy resources in different states during 12th Plan period and determination of RPO trajectory and its impact on tariff' March 2012

(IEGC-2010) as well as the Gujarat Electricity Grid Code (GEGC-2004). The experience of these countries with respect to their grid integration practices was also reviewed. This review helped in identification of issues with respect to RE integration and the impact on the grid with the level RE penetration in the energy mix. The key points emerging from the literature survey are given in Annexure 6.

2) Data collection

To understand and analyse the renewable energy penetration level in Gujarat and the variability of the demand as well as the renewable energy generation, extensive data have been collected on a) Details of existing and planned power plants (both conventional as well as renewable energy) in Gujarat with their capacity, location, grid interconnection voltage levels b) Details of existing and planned grid substations with their capacity and expected commissioning period c) hourly wind energy generation from wind farms in Gujarat d) hourly electricity demand in Gujarat e) solar energy generation pattern, f) information on cases of overvoltage or under voltage situations, congestions in power lines g) targets for future renewable energy capacity additions in the state as well as at the country level h) renewable energy potential distribution in the state etc. The main sources of these data has been GETCO, GEDA, SLDC Gujarat, MNRE, renewable energy project developers and multiple other sources.

3) Site visits to identified substations in RE rich clusters in Gujarat

Site visits were undertaken to two identified substations in the Kutch region in Gujarat (i) 220 kV S/S in Nanikhakhar and 220 kV S/S in Shivlakha, which have a high wind penetration to understand the ground level challenges faced in grid integration.

Table 2: Description of substations visited

Parameters	Nanikhakhar 220kV S/S	Shivlakha 220kV S/S
Installed Capacity connected to S/S	Wind installed capacity of 585.1MW is connected to Nanikhakar s/s with TPS Adani and captive power plant APL Mundra. As of now this s/s has received maximum generation of 300MW from wind. In case of surplus generation from wind, power is supplied to Adani switchyard which is stepped up to 400kV and transferred	Wind installed capacity of 360MW, solar installed capacity of 39MW directly and Charanka solar park (Charanka solar park is connected to Shivlakha and Deodhar s/s through LILO (till date maximum generation of 150MW from Charanka solar park supplied to Shivlakha s/s) are connected to Shivlakha s/s.
Type of Load	Main loads agriculture and industry	Mainly agriculture
ABT meter	For billing purpose there are ABT meters at the s/s which record receiving power data from each of the power plant. Data is retrieved every 7 days and sent to SLDC. Similarly, at every power plant site there is ABT meter as well as RTU system which record feeding data (MW, voltage, current and frequency) and send to RLDC and SLDC.	Similar arrangement for ABT and RTU system are there in this substation as seen in Nanikhakar
Telemetry	This s/s transfers real time data (MW, voltage, current and frequency) to RLDC and SLDC through RTU (Remote Telemetry Unit) system (RTU system has accuracy level of 99.98%).	

4) Stakeholder consultations

Stakeholder consultations were carried out with the state transmission utility (GETCO), GUVNL, regulatory commission (GERC), state load despatch centre (SLDC), central transmission utility (PGCIL), renewable energy project developers and owners research institutions working in Gujarat etc. to understand the perspectives and concerns of various stakeholders and focus on issues specific to Gujarat.

The findings of the study has been presented and discussed during the project workshop organised at Gandhinagar, Gujarat on 23rd January 2013. The views given by the speakers and participants have been incorporated in the results analysis and in final recommendations.

1.5 Projected Renewable Energy Development Scenarios in India

A 10 year time frame has been taken for this analysis that is the development scenario up to year 2021-22. First step was to estimate the RE development capacity requirement by the year 2021-22 in India and then in Gujarat to meet the NAPCC RPO trajectory, which states that the national RPO of 5% in the year 2009-10 and then an increase of 1% ever year, i.e. 17% of RPO by the year 2021-22.

To estimate the RE installed capacity requirement to meet this 17% RPO, TERI considered the national electricity demand projection as per the 17th Electric Power Survey (17th EPS) Report. The 17h EPS report projected that the total electricity demand of India by the end of 12th Plan will be 13,92,066 MUs and by the end of 13th plan it will be 19,14,508 MUs. We projected annual electricity demand based on this for each year from 2011-12 to 2021-22, and correspondingly the renewable energy generation need to meet the NAPCC target of 17% RPO by 2021-22, which are shown in Figure 5.

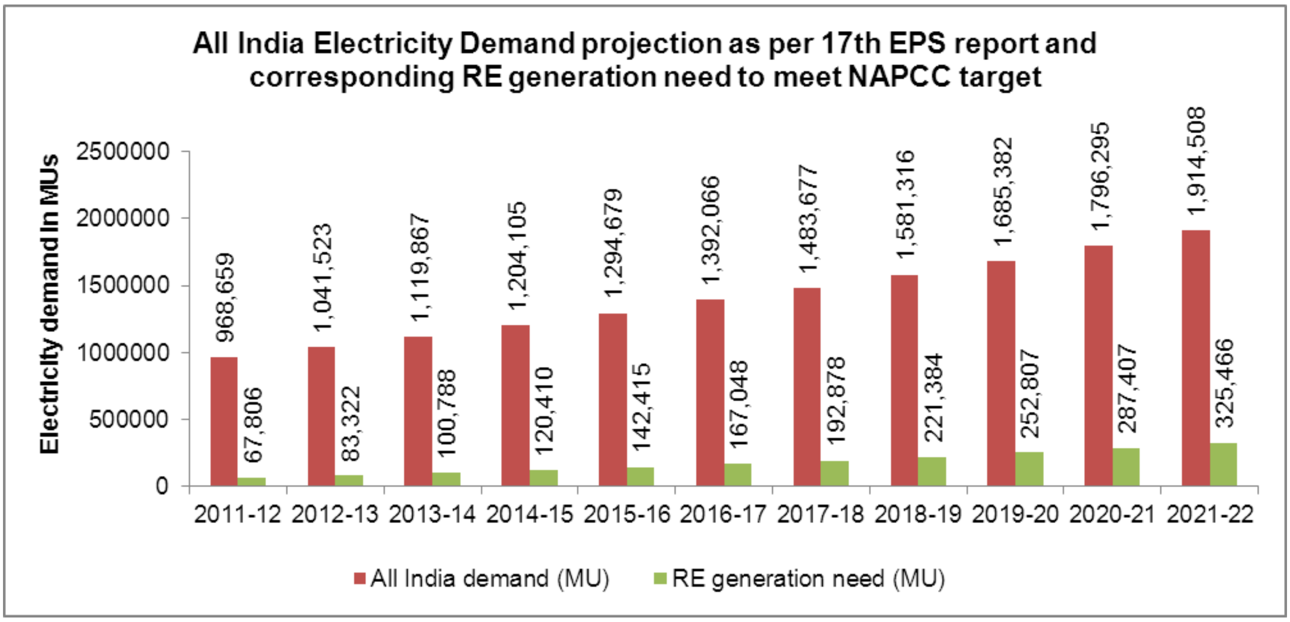


Figure 5: All India Electricity Demand and corresponding RE generation needed to meet RPO target of 17% by 2021-22

To estimate the RE installed capacity required to meet this generation need, it has been assumed that the small hydropower, biomass, waste to energy etc. will have minimal development due to their limited potential availability, very site specific projects and the technical and environmental issues and hence the main contribution will be from the solar and wind energy projects.

Based on the existing installed capacity, total potential and the historical growth rate the installed capacity of small hydropower, biomass and waste to energy projects in India has been considered to be growing at the present growth rate only and will be limited to their identified potential.

The solar power project implementation has been considered as per the JNNSM target, i.e. by the year 2022 the installation of 20,000 MW solar power projects.

Corresponding energy generation from the above installed capacities of various renewable energy sources has been estimated considering the average Plant Load Factor (PLF) of 45% for SHP, 19% for SPV and 75% for biomass, cogeneration and waste to energy projects. The remaining RE electricity generation requirement is then considered to be generated from wind power.

Considering the PLF of 23% on an average, the total wind power installed capacity requirement in the country works out to be about 100 GW by year 2021-22. The estimated electricity generation contribution from various RE sources to meet the NAPCC target of 17% RPO by 2021-22 is given in Figure 6.

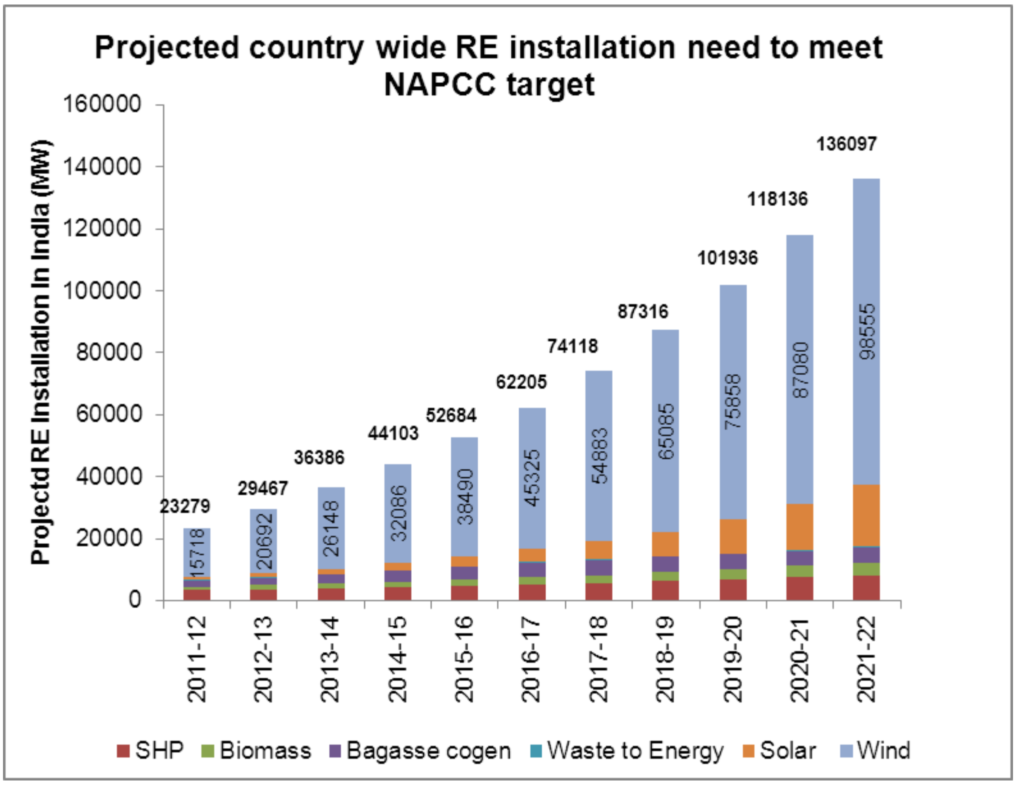


Figure 6: Estimated electricity generation need from various RE sources to meet the NAPCC target of 17% national RPO by the year 2021-22

The projected and required installed capacity for all these renewable energy sources to meet the above generation requirement is given in Figure 7. The detailed values are given in Annexure 1.

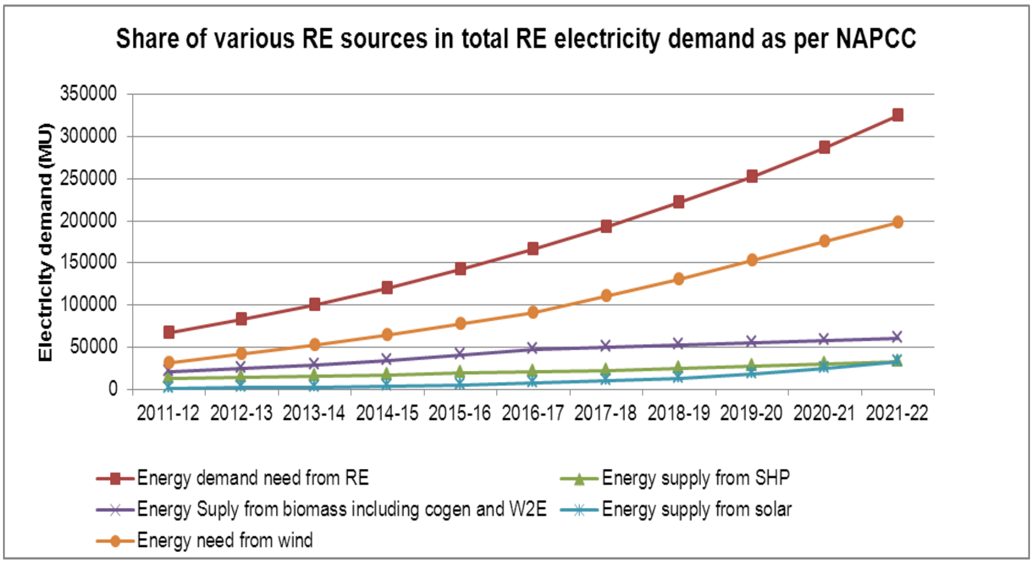


Figure 7: Projected and required installed capacity of various RE sources to meet the NAPCC target of 17% national RPO by the year 2021-22

It is evident from the above scenarios that the wind and solar power projects will be the main sources contributing to the renewable energy generation. From the distribution of RE sources it is observed that the small hydropower potential is mainly available in the Himalayan region, biomass is available in almost every state but in very limited quantities, cogeneration and waste to energy projects have very limited potential, solar power potential is highly distributed in the country while the wind power potential is distributed in only few states mainly Tamil Nadu, Karnataka, Gujarat, Maharashtra, Rajasthan, Andhra Pradesh and Madhya Pradesh. The Centre for Wind Energy Technology estimated the total wind power potential in the country at about 102 GW considering 80 m hub height of wind turbines. The Lawrence Berkeley National Laboratory in its recent study estimated that India has huge wind power potential and is in the range of about 2006 GW. In recent Integrated Renewable Energy Resource Assessment study carried out by TERI for Gujarat, it has been estimated that the total potential for renewable energy in the state is about 750 GW with major contribution coming from wind and solar energy resources. The solar power potential is widely distributed and there is no comprehensive study on the technical or gross solar power potential assessment in terms of MW installations as it depends totally on the strength of the solar radiation and land availability. TERI study on integrated renewable energy resource assessment for Gujarat estimated the solar power potential in Gujarat at more than 500 GW.

With these kinds of capacity addition required to meet the national RPO and the huge RE potential to be exploited, it will definitely require strong grid infrastructure in place to handle the variable nature of the power generation from renewables, mainly wind and solar energy resources. Generation mix in a grid should be such that it not only follows the load pattern but also responds to the sudden load changes, and being a resource-rich state, Gujarat is likely to play a major role in meeting these requirements at the national level.

Increased share of intermittent power poses difficulty in grid operation. Further, sudden changes in power flow in EHT transmission lines could also happen, where power from such sources are to be transmitted in large quantum over long distances. Problem of voltage instability necessitates provision of adequate regulating and compensating devices at strategic locations. The cost implication may vary widely depending upon the characteristics of power system, type of RE, and the nature/operating mechanisms of power markets etc.

The nature and complexity of these issues would vary depending upon the relative magnitude and spatial distribution of the RE source and grid characteristics. These need to be analysed upfront if we have to optimally utilize RE resources and ensure stable operation of the grid.

Apart from the technical constraints and challenges in the integration of this large amount of renewable energy into the grid, there are related policy and regulatory issues. While some of them need to be addressed at a central level, some other requires state specific interventions.

1.6 Selection of State

Reasons for selecting Gujarat for this particular study are as follows:

- Gujarat has the highest potential for solar and wind power in the country. CWET assessment at 80 m hub height estimates the wind power potential in the country as 102 GW out of which the maximum potential is estimated in Gujarat (about 35 GW) as shown in figure 8.

- Recent study by TERI on Integrated Renewable Energy Resource Assessment of Gujarat shows RE potential to be around 750 GW
- The state has taken a lead in deployment of grid connected solar power with an installed capacity of about 824 MW as on 31 December 2012. Also, it is the most preferred state for wind power development by the IPPs and project developers due to the supportive policies, government supports and infrastructure availability.
- Overall Gujarat is the most aggressive state in renewable energy development particularly solar and wind energy. Moving forward, it is likely to be a major contributor in meeting the national capacity addition as well as national RPO targets.

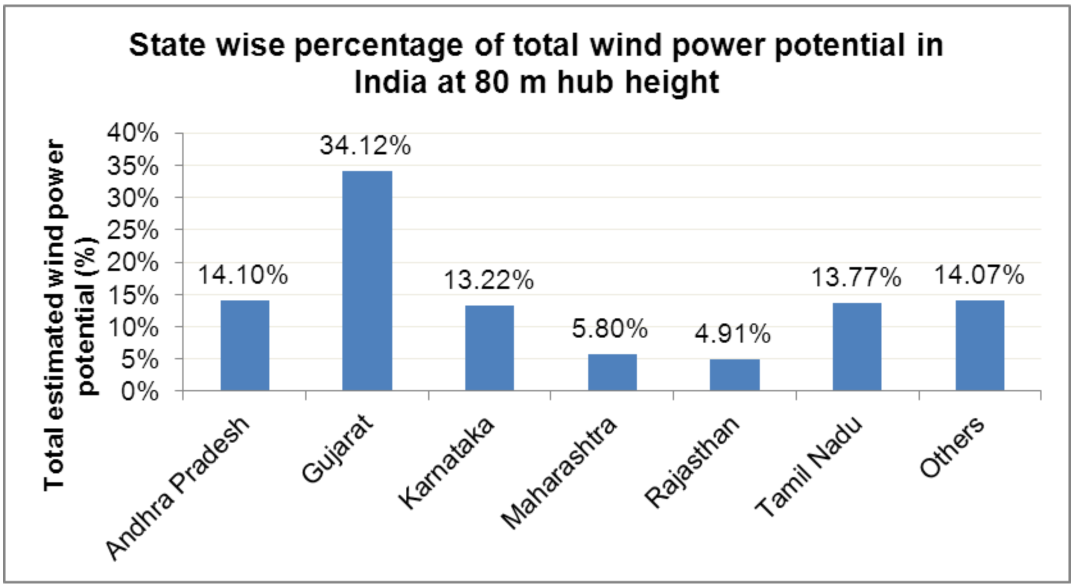


Figure 8: Percentage distribution of wind power potential in various states

The findings from the analysis and recommendations are discussed in detail in the subsequent sections.

2. Power sector profile of Gujarat

2.1 Institutional set up

As part of the reforms brought about by the Electricity Act 2003 and Gujarat Electricity Industry (Reform and Reorganization) Act 2003, the vertically integrated Gujarat Electricity Board (GEB) was restructured into 7 companies in 2005. Gujarat State Electricity Corporation Limited (GSECL) was entrusted the responsibility of power generation and Gujarat Energy Transmission Corporation Ltd. (GETCO) was made responsible for transmission of electricity in the state. Till now, the State Load Despatch Centre (SLDC) is being operated by GETCO.[1]

Four distribution companies have been functioning in Gujarat, namely, Uttar Gujarat Vij Co. Ltd. (UGVCL), Dakshin Gujarat Vij Co. Ltd. (DGVCL), Madhya Gujarat Vij Co. Ltd. (MGVCL) and Paschim Gujarat Vij Co. Ltd. (PGVCL) with effect from 1stApril, 2005. The four discoms serve the northern, southern, central and western regions of Gujarat respectively. In addition to this, a private distribution company Torrent Power Ltd. (TPL) is also operating in Gujarat. TPL has generation facility in Ahmedabad and distribution license[2] for Ahmedabad (Torrent AEC) and Surat areas (Torrent SEC).

As a co-ordinating entity, a holding company namely the Gujarat Urja Vikas Nigam Limited (GUVNL) has been established. It is responsible for purchase of electricity from various sources and supply to distribution companies as well as other activities including trading of electricity.

To augment the power generating capacity in the state through private sector participation, a state owned agency, namely the Gujarat Power Corporation Limited (GPCL) has been established. GPCL acts as a nodal agency for setting up of projects through the private participation mode, identification of power projects based on different fuels and preparation of techno-economic feasibility reports for such projects. It is also the nodal agency for the Gujarat Solar Park and for selection of sites for nuclear power plants in Gujarat.

The policies and guidelines for power sector development are framed by the Department of Energy and Petrochemicals, Government of Gujarat (GoG). Specifically, for the promotion of renewable energy and energy conservation, Gujarat Energy Development Agency (GEDA) functions as the nodal agency in the state. All the power utilities are under the regulatory purview of the Gujarat Electricity Regulatory Commission (GERC).The schematic of the institutional set up in Gujarat is depicted the Figure 9 below.

[1] Though SLDC has not been created as a separate legal entity, it files separate ARR petition.
[2] A company named GIFT Ltd (Gujarat International Finance Tec-city limited), a joint venture by Government of Gujarat and IL&FS has also applied for a licence to distribute power in the GIFT area with an estimated demand of approximately 740 MW. This company is awaiting a license by the GERC. GIFT has been conceptualized as a first of its kind global financial and IT services hub in India.

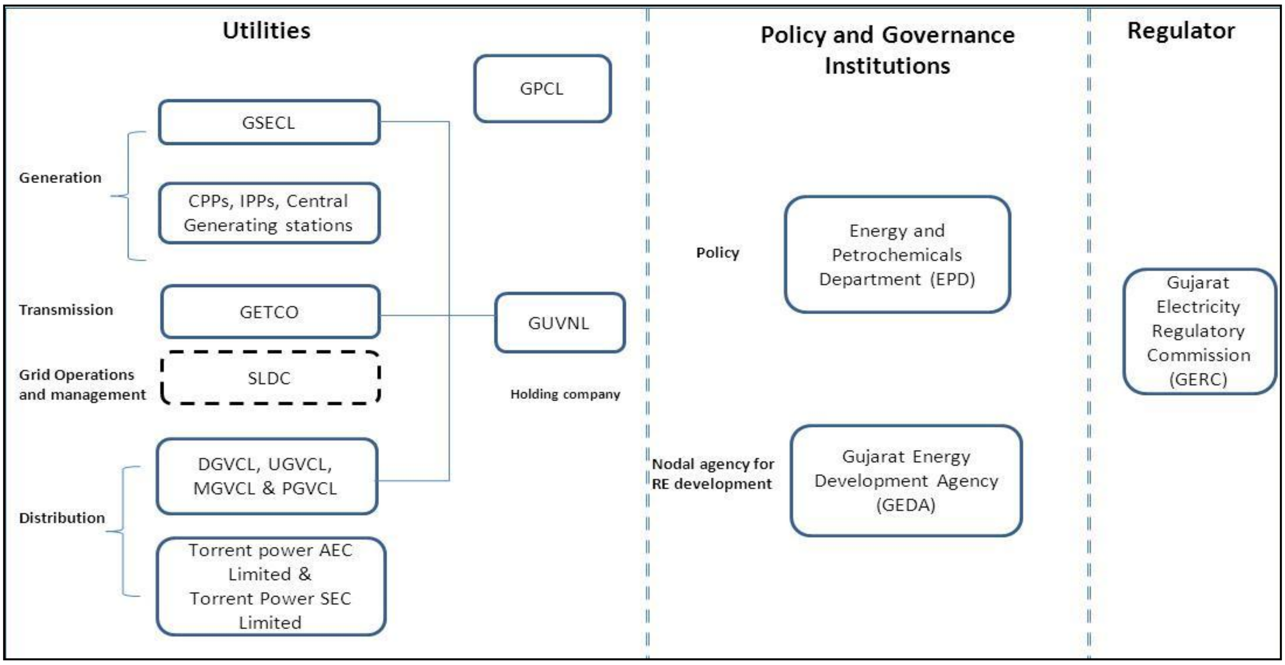


Figure 9: Institutional setup of the power sector in Gujarat

Source: TERI compilation

Notes: CGS – Central Generation Stations, CPP- Captive Power Producer, GPCL- Gujarat Power Corporation Ltd, IPP –GETCO – Gujarat Energy Transmission Corporation, Limited, Independent Power Producer, RE – Renewable Energy, SLDC – State Load Despatch Centre, DGVCL - Dakshin Gujarat Vij Company Limited, UGVCL – Uttar Gujarat Vij Company Limited, MGVCL – Madhya Gujarat Vij Company Limited, PGVCL - Paschim Gujarat Vij Company Limited.

2.2 Overview of the power sector

Generation

As of 31st March 2012, the total installed capacity in Gujarat was approximately 21,971 MW (including allocated shares in joint and central sector utilities) as shown in Figure 10. Thermal power continues to be the main stay of power generation, constituting nearly 78% of the installed capacity, followed by renewables which contribute around 16% of the total capacity. When classified according to ownership, of the total installed capacity, 58% is owned by the private sector, followed by the state sector at 29% and central sector at 14%. The above capacity is inclusive of the 4000 MW Ultra Mega Power Project (UMPP) at Mundra.[1]

[1] This green field coal-fired facility is owned by Tata Power and is split into five units of 800 MW each. It is the first private sector power project using supercritical technology and will supply power to Gujarat, Maharashtra, Haryana, Rajasthan and Punjab.

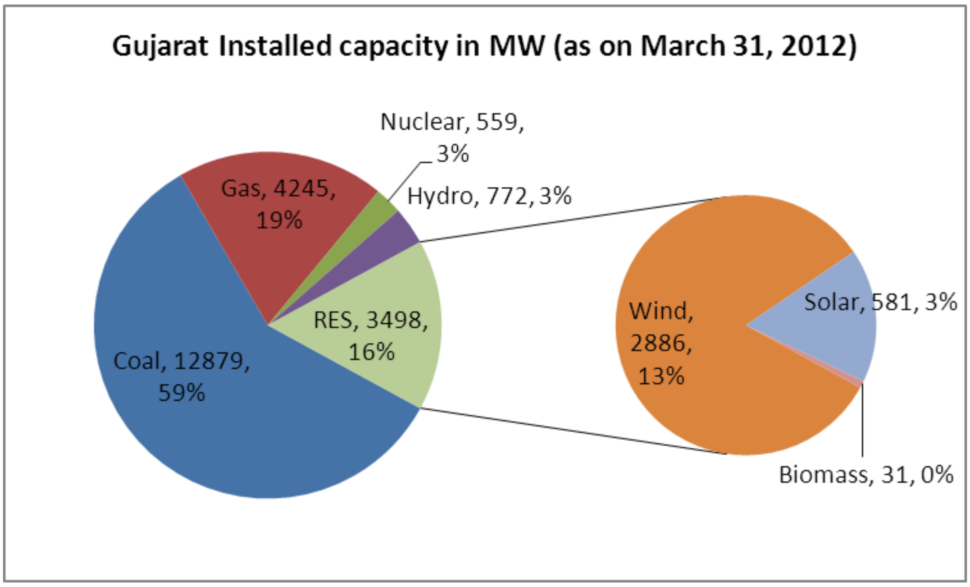


Figure 10: Source wise power generation installed capacity in Gujarat in MW (As on 31 March 2012)

Source: CEA, Monthly report, March 2012 (http://www.cea.nic.in/reports/monthly/inst_capacity/mar12.pdf)

The state also has a high share of captive power producers, owing to enabling policy and incentives provided by GoG[1]. There were about 60 Captive plants of 3337 MW capacity (as on March 2010).

The trend in capacity addition indicates that the growth has been primarily been driven by growth in thermal and renewables. Thermal capacity grew at a CAGR of 19%, from 8597 MW in 2007-08 to 17142 MW in 2011-12, whereas the RES capacity addition has been more aggressive clocking a growth of 42%. Figure 11 shows the power generation capacity additions in Gujarat over the last five years.

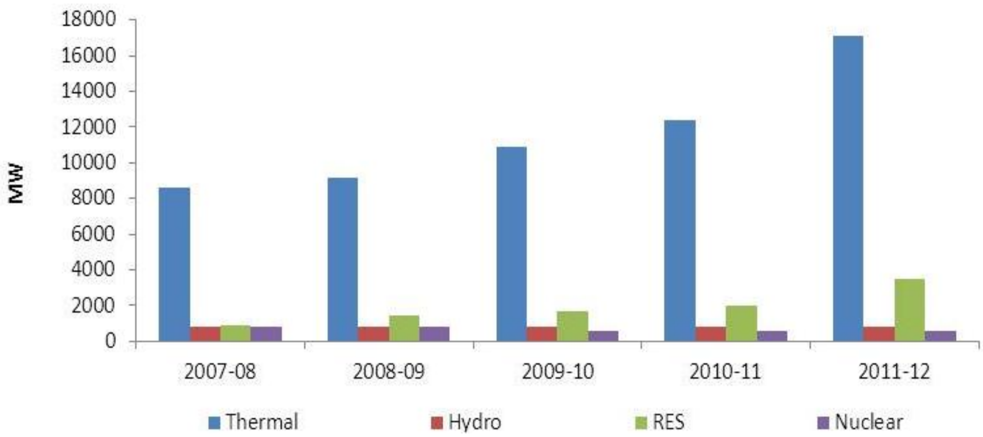


Figure 11: Power generation capacity addition in Gujarat (2007-08 to 2011-12)

Source: CEA

[1] Government of Gujarat, resolution no. CPP-1106-3805-K dated 12th July 2007 on 'Harnessing the installed captive generating capacity in the state- Incentives thereof"

About 78651 MU of electricity were generated in Gujarat during the year 2011-12 including the share of central sector. Thermal generation from coal forms the dominant part of the power generation, followed by gas based power plants and then by renewables mainly wind (Figure 12). The trend in electricity generation over the last three years shows that generation from renewables has been steadily rising, in view of the increasing share of wind and solar generation (Figure 11). In terms of ownership, private sector constituted more than half of the generation (52%) followed by state sector (36%) and central sector (11%).

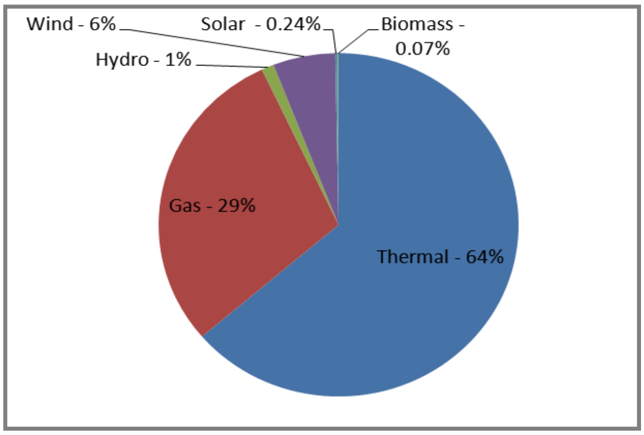


Figure 12: Electricity penetration from various sources of energy in Gujarat for the year 2010-11

Gujarat is one of the major sellers of electricity in the short term power market. It accounted for a significant 48.5% and 11%of the total electricity traded in the day-ahead market in PXIL and IEX respectively. In the bilateral trading segment, it accounted for about 7% of the total volume traded.[1]

Transmission

The intra state transmission network operated by GETCO consists of approximately 45,000 circuit kilometres of transmission lines and 1270 substations , while the interstate transmission network maintained and operated by PGCIL extends to up to 6732 Ckt kms consisting mainly of 400kV and 220 kV lines. In accordance with the provisions of the Electricity Act 2003, GETCO provides non-discriminatory open access to its transmission system. Many captive power consumers and HT consumers have opted for the same.

Under the "open access" regime, GETCO is responsible as a system operator to undertake system studies regularly and determine the loading of each of its lines to determine technical feasibility of open access applications/transactions.

Details of transmission network are provided in Table 3. Annexure 2 shows the power map of Gujarat.

[1] In 2011-12, total volume traded through day-ahead market in IEX was about 13796 MU, while it was about 1029 MU in PXIL.

Table 3: Transmission network as on March 31st 2012

Voltage Class	No. of Substations	Transformation capacity (MVA)	Transmission Lines in Ckt. Km
Network of GETCO (As on 31st March 2012)			
400 KV	11	8040	3188
220 KV	79	18970	14852
132 KV	49	5920	4807
66/33 KV	1131	23648	22107
Total	**1270**	**56578**	**44956**
Network of PGCIL (As on 31st March 2012)			
400 KV	4	1890	5282
220 KV	-	-	1450
Total	**4**	**1890**	**6732**

Source: GETCO

Six distribution companies collectively serve the whole of Gujarat. The map showing the geographical jurisdiction and districts covered by each of the discoms is given in the Annexure 3.

The total electricity consumption in 2010-11 was 52145 MU of which industry constituting the dominant share accounting for more than a third of the total consumption, followed by agriculture (25%) and domestic (18%) categories (Figure 13a). In terms of the discom-wise energy catered, PGVCL is the largest utility , as it serves a larger area in comparison to other discoms (Figure 13b).

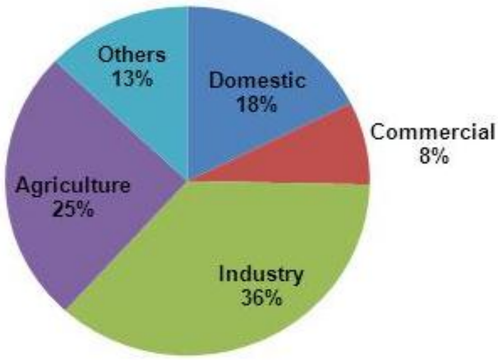


Figure13a : Category wise electricity consumption (2011-12)

Source: Tariff orders of various discoms

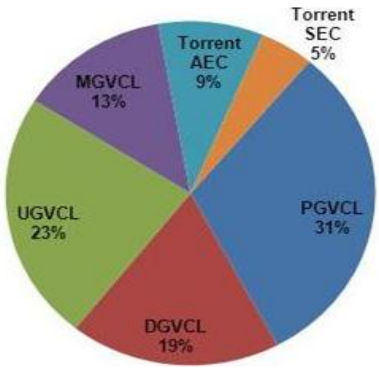


Figure 13b: Discom wise energy catered (2011-12)

Source: SLDC, Gujarat

Agriculture sector in Gujarat is being supplied power for eight hours a day as per government policy. The supply to agriculture sector is given as per pre-announced weekly schedule and power is supplied in time block continuously. However, supply is not given during two hours in the evening peak. The AT&C losses in the state have more or less remained stable (around 22%) since 2006-07[1]. Amongst all the discoms, PGVCL reported higher loss levels as compared to all other discoms in 2009-10. The reduction in technical

[1] PFC report on performance of state power utilities (2007-08 to 2009-10)

losses in the state could be attributed to Jyoti Gram Yojana, which was launched by the GoG in 2003, where in agriculture feeders were completely separated from rural category feeders supplying to commercial and residential connection at the sub-station itself. Meters on distribution transformer centres were also installed on both the sides of feeders to improve the accuracy for energy accounting.

Power supply position

The energy and peak deficit in the state has been steadily declining over the years (Figures 14 and 15). Gujarat has significantly lower peak and energy deficits as compared to the national average. The energy deficit and peak deficit in 2011-12 in Gujarat were about 0.4% and 2% respectively. In contrast, the all India average for the same year for energy and peak deficit stood at 8.5% and 10.6% respectively.

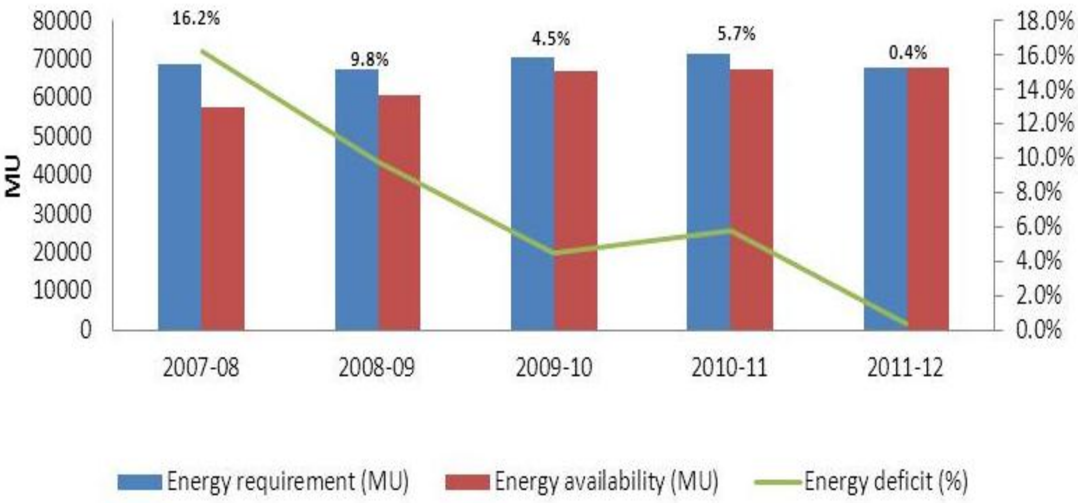


Figure 14: Trend in energy deficit in Gujarat (2007-08 to 2011-12)

Source: CEA

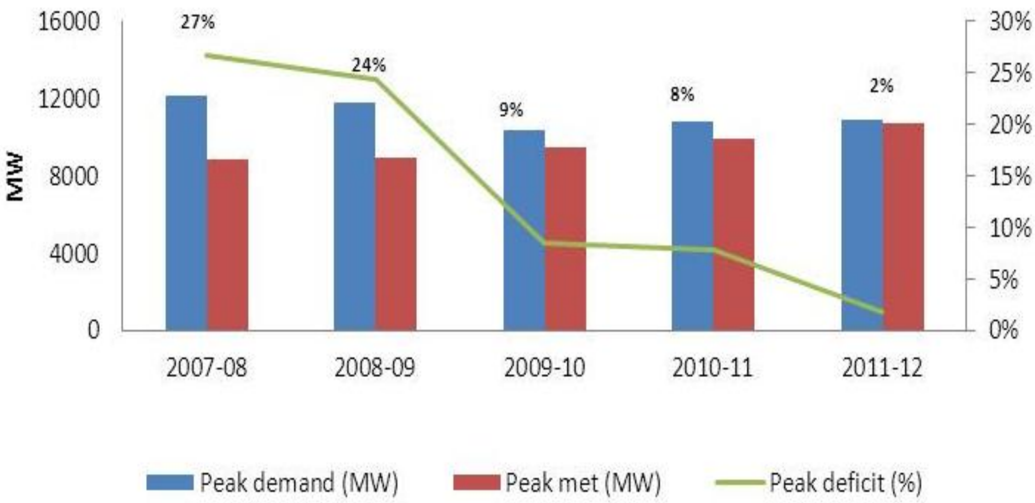


Figure15: Trend in peak deficit in Gujarat (2007-08 to 2011-12)

Source: CEA

2.3 Renewable energy sector in Gujarat

Renewable Energy (RE) potential of Gujarat

Gujarat is blessed with immense RE potential comprising variety of sources such as wind, solar, tidal, biomass, other industrial waste etc. It is one of the biggest states of India having a large amount of waste land along with good levels of solar radiation for most of the year.[1] It is also endowed with a huge tidal potential, owing to its long coast line and is one of the world's few high tidal potential sites. Of the identified tidal potential of the order of 8300 MW in the country, about 7000 MW is concentrated in the Gulf of Cambay and about 1200 MW in the Gulf of Kachchh.[2] As per the GEDA estimates, the RE potential in the state is of the order of 29 GW, significantly understated as compared to the potential estimated by TERI , which pegs the overall RE potential in the state at 750 GW (District and RE source wise estimated potential in Gujarat are given in Annexure 5). Further, the wind potential estimated by C-WET is to the tune of 35 GW at 80 m hub height. Table 4 indicates potential of various RE sources in Gujarat vis-à-vis potential in India.

Table 4: Source wise RE potential in Gujarat

Source	Estimated potential in Gujarat (MW)		Potential in India (MW)
	GEDA/CWET/MNRE estimates for Gujarat	TERI Integrated Resource Assessment Study	
Wind	10,600 MW at 50 m and 35,071 MW at 80 m	211,390 MW	102,000 MW*
Solar	5.5 kWh/Sq.Mt./day ~ 10, 000 MWe	535,480 MW	20-30 MW/ sq. km
Biopower**	900 MW	1898 MW	23,700MW
Small Hydro	-	-	15,000 MW
Tidal	8,200 MW	6,306 MW	8,300 MW
Total	29,100 MW	75,5074 MW	

*at a hub height of 80 m

** including biomass power, bagasse cogeneration, urban and industrial waste to energy

Source: GEDA, MNRE 2011, TERI, 2012

Installed RE capacity

RE installed capacity constitutes about 16% of the total installed capacity of 21,971 MW (including the central sector share) in Gujarat. The grid interactive renewable installed capacity in Gujarat was about 3498 MW as on 31st March 2012. Of the total RE installed capacity on March 31, 2012, wind constitutes the dominant share of 2886 MW (82%), followed by solar with a capacity 581 MW (16%) (Figure16). Most of the renewable installed capacity is owned by the private sector.

Historically, much of the capacity addition in Gujarat has happened only in wind while solar capacity has been added recently starting FY 2010-11 (Figure 17). More than 500 MW of solar capacity was added during FY 2011-12, owing to the enabling solar policy of Government of Gujarat. Of this capacity more than 210 MW has been commissioned in

[1] Gujarat receives second largest amount of solar radiation in India. Gujarat receives 5.5 to 6 Kwh/sq.m/day with 300 sunny days/year.

[2] The State Government of Gujarat formed Special Purpose Vehicles (SPV) with public private partnership and sponsored a study for large scale exploitation of tidal energy across the coastline of Gujarat (MNRE, 2012).

Charanka solar park, state's largest solar park of 600 MW capacities in Patan district while the rest of the capacity is spread throughout the state.

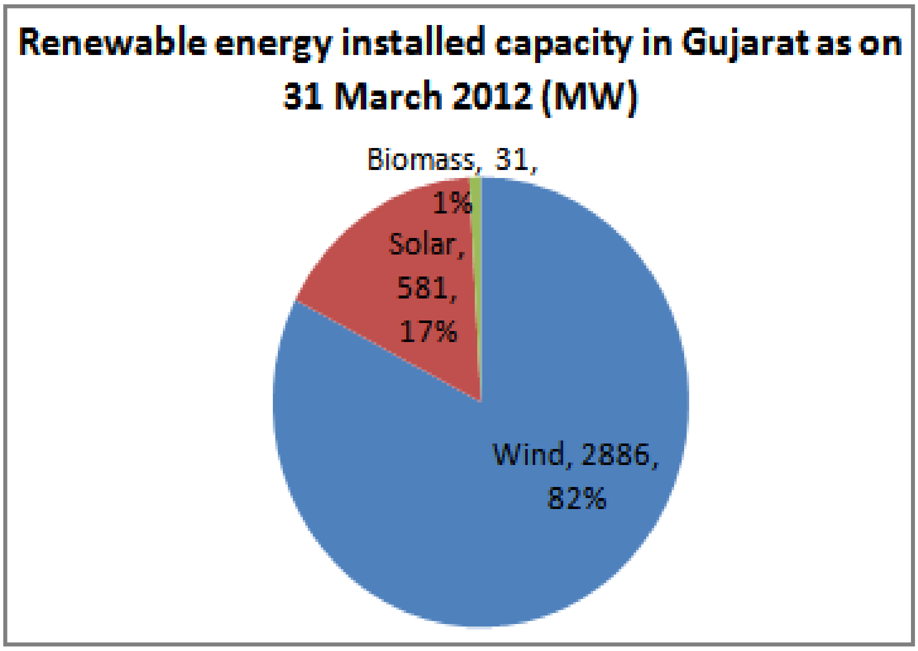


Figure 16 : Grid interactive renewable energy installed capacity in Gujarat (MW)

Source: SLDC Annual report 2011-12

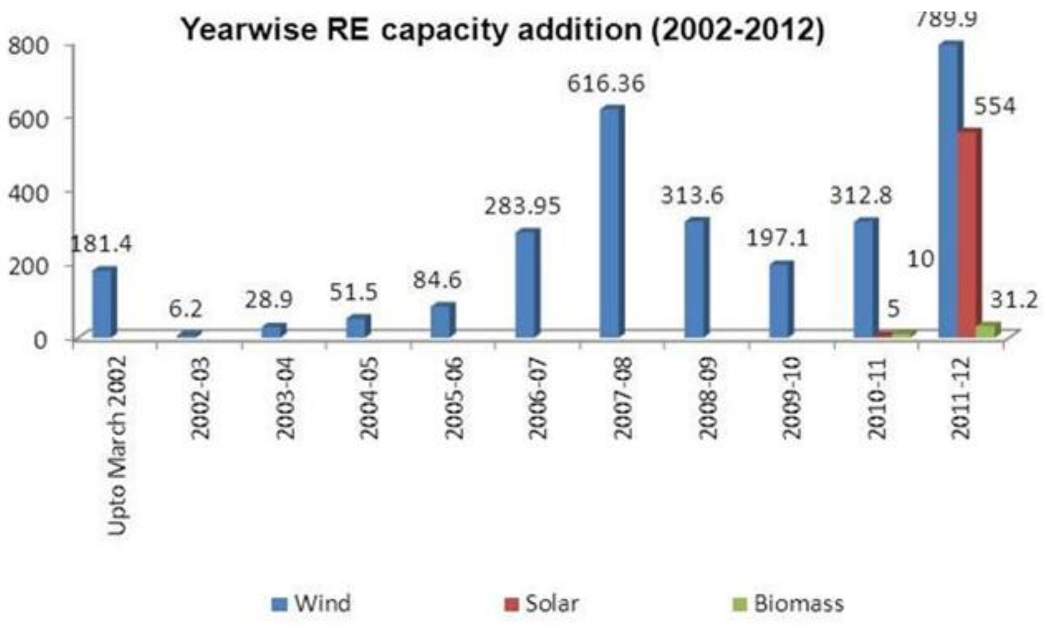


Figure 17: Year wise capacity addition in renewable energy (2002-03 to 2011-12)

Source: SLDC annual report 2011-12, C-WET, http://www.cwet.tn.nic.in/html/information_yw.html

Further, the state government has set the ambitious target of installing 1000 MW solar power capacity by the end of 2012 & 3000 MW in next 5 years. GUVNL recently signed PPA with 30 sites for 406.50 MW in GoG allotment I and 43 sites for 444 MW in GoG allotment II including 270 MW of solar power.[1]

Wind and solar capacity in the state is concentrated in the regions of Kutch and Saurashtra. The Figure 18 indicates the district wise spread of conventional and renewable plants. Annexure 4 gives the list of solar and wind power plants in Gujarat with their respective capacities in MW.

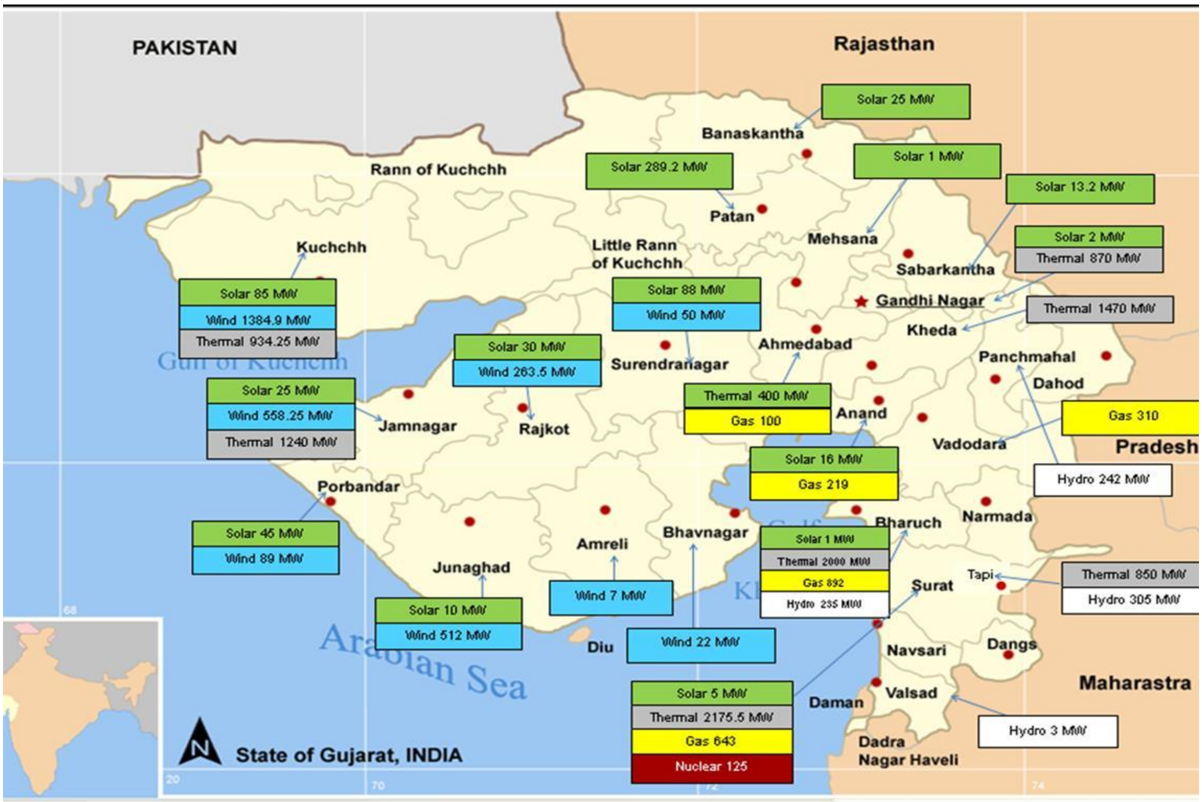


Figure 18: District wise capacity of conventional and renewable energy based power plants in Gujarat

Source: GETCO

Renewables contributed 5.3% of the total electricity generated in Gujarat during 2011-12. In volume terms, renewables in the state contributed around 4175 MUs out of the total 78,651 MUs of electricity generated (including central sector generation). The generation from RE has more than quadrupled from 1016 MU in 2007-08, mainly on account of increasing wind and solar generation (Figure 19). With this current level of penetration of RE in the grid, the real-time balancing mechanisms being adopted by GETCO have been explained in Chapter 3.

[1] GETCO Business plan

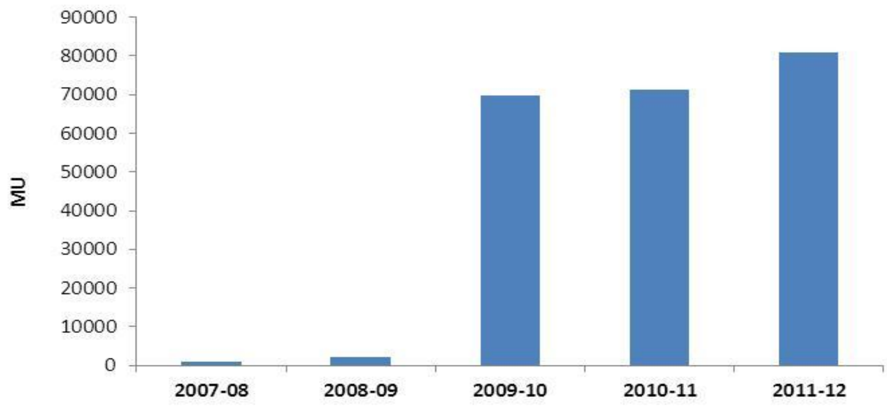


Figure 19: Trend of renewable energy generation in Gujarat (2007-08 to 2011-12)

Source: SLDC Gujarat Annual reports

Policy and regulations facilitating promotion and grid integration of RE plants in Gujarat

The increasing share of renewables in the state can be attributed to the enabling policy framework provided by GoG. The state has announced specific policies for wind and solar power projects which provide a host of incentives to the developers. The salient features of the solar and wind policies are briefly summarized below.

Solar policy, 2009

The solar power policy2009 promotes solar power by defining and facilitating various aspects such as wheeling charges, exemption from payment of electricity duty, exemption from demand cut, high feed-in tariff for a period of 25 years, grid connectivity and evacuation facilities, open-access for third party sale, relaxation from forecasting and scheduling, mandating renewable purchase obligation and assigning of state nodal agencies for ease of implementation. This policy is effective up to 31 March, 2014, and targets a net installed solar generation capacity of 500 MW.

Wind policy, 2007

The GoG had notified the 'Wind Power Policy 2007' in June 2007 for the development of wind power projects in the state. This policy was further amended in January 2009 as 'Wind Power Policy (First Amendment 2007)'. This policy was valid up to 30 June 2012 and was further extended up to 10 August 2012 by the state government.[1] Some important provisions of this policy are given below:

- Electricity generated from wind generators is exempted from payment of electricity duty, except in the case of third-party sale.
- The project developers are required to furnish Bank Guarantee of Rs.5 Lakh/MW to GETCO. In order to ensure the timely completion of wind power projects and to ensure

[1] Wind policy extended up to 10 August 2012 vide Government of Gujarat letter no. EDA/10/2001/3054/B dated 14 Jun 2012. Source: GERC Wind Tariff order 2012

the timely utilization of infrastructure created by GETCO, the bank guarantee will be forfeited after the due date.

- Concessional transmission and wheeling losses in case the energy is wheeled below 66 kV voltage level or in case of single wind generator.
- The evacuation facility from the wind farm substation to GETCO substation within the range of 100 km shall be erected by the developer at his own cost and beyond this limit, GETCO shall erect the evacuation facility.
- The voltage level of evacuation of wind power in the grid shall be at 66 kV and above.
- Feed-in-tariff announced by GERC's in its latest tariff order is Rs. 4.23 per unit of wind power.

Banking of wind power

Banking is allowed for one month for captive wind power producers. Wind generators opting for captive use of the energy generated are eligible to get set off against the energy generated during peak and normal hours as specified by the Commission in the tariff orders.[1] The banking facility is not available for third-party sale of wind energy. Further, the surplus power after one month's banking shall be deemed to be sold to the concerned discom. As per the wind tariff order 2012, in case of wind power projects availing open access for captive use / third-party sale but not opting for REC, the surplus power after set off will be purchased by the distribution licensee at the rate of 85% of the wind tariff determined by GERC. In case of wind power projects availing OA for captive use / third-party sale and opting for REC, the surplus power after set off will be purchased by the Discom at Average Power Procurement Cost (APPC) applicable for that year.

Provisions for grid interconnections for evacuation of power from renewables

For grid connectivity of RE plants, policies have been put in place by the central and state government. The salient features of the key policies and regulations have been summarized below.

As mentioned above, both the wind and solar policies of the state have specific provisions for grid connectivity and evacuation facility up to the GETCO substation. The wind energy generators in the state have to construct the evacuation facility from their substation to the GETCO substation up to 100 kms at their own cost. However in case of solar plants, the evacuation lines from the solar power generating substation/switch yard to the GETCO substation have to be laid by GETCO.

For facilitating the connectivity of RE generation into the inter -state transmission system, the CERC has amended the Grid Connectivity Regulation allowing cluster of renewable energy generators of aggregate capacity 50 MW or more to get direct connectivity to Central Transmission Utility (CTU) network. The CERC has also notified that no transmission charges and no transmission losses shall be charged to solar based generation for the use of ISTS network. This shall be applicable for the useful life of the projects commissioned in the next three years i.e. up to 2014.

[1] Peak hours are defined as 7.00- 11.00 hrs in the morning and 18.00 to 22.00 hrs in the evening in the tariff order.

Renewable purchase obligations and compliance

GERC issued the RPO regulations in 2010, which specifies RPO targets for obligated entities till 2012-13. The RPO applies to distribution licensees as well captive and open-access users consuming electricity (i) generated from conventional captive generating plant having capacity of 5 MW and above for own use and/or (ii) procured from conventional generation through open access and third party sale. The state has historically been able to meet its RPO[1], because of increasing RE energy generation in the state. Table 5 gives the status of RPO compliance and RPO targets set by GERC.

Table 5: RPO compliance in Gujarat

Year	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
RPO target	1%	1%	2%	2%	Wind -4.5% Solar-0.25% Others-0.25% **Total- 5%**	Wind -5% Solar-0.5% Others-0.5% **Total -6%**	Wind -5.5% Solar-0.5% Others-0.5% **Total -7%**
Actual	NA	2.07%	NA	2.55%	NA	Wind -4.3% Solar-0.26% Others-0.15% Total – 4.7%	

Source: GERC 2010, Singh A

2.4 Renewable energy development scenarios for Gujarat

As discussed earlier, the state has been developing its renewable energy capacity through various conducive policies, which have attracted the private sector investments mainly in wind and solar power projects. The commissioning of about 600 MW solar power project by the year 2011-12 is an example of the same. This was due to the state initiatives through the progressive solar power policy and the development of solar parks. Wind power installation has already shown an upward trend in last few years. The Gujarat Energy Development Agency (GEDA) has set some RE capacity addition targets for the 12th Five Year plan, which are given in table 6.

Table 6: RE capacity addition targets in Gujarat during 12th Five Year plan period (as per the GEDA)

Source /Technology	Installed capacity As on March 2012 (MW)	Annual capacity addition during 12th Five year Plan Period					Total Capacity Additions 12th Plan
		FY 12-13	FY 13-14	FY 14-15	FY 15-16	FY 16-17	
Wind	2884	326	377	456	498	508	2165
SHP	12.60	2	3	4	3	3	15
Biomass	31.20	35	45	55	60	44	239
Solar	639	300	330	330	440	560	1960
Waste to Energy	--	0	2	2	0	2	6
Total	**3566.80**	**663**	**757**	**847**	**1001**	**1117**	**4385**

[1] RPO for a particular year is inclusive of the transmission and distribution (T&D) losses during that year.

On analysing the information received from GETCO, it has been observed that the wind farm developers have already filed applications for more than 10,000 MW wind power projects in Gujarat to be commissioned in next few years, out of which GETCO has given evacuation approval for about 4000 MW for the next 3-4 years, based on the existing transmission capacity. The rest of applications are pending for approval due to the lack of transmission capacity availability in the areas (mainly Kuchchh) for which the application has been filed by the project developers.

Projection of energy demand in Gujarat

During the year 2011-12 the total energy demand in Gujarat is recorded as 76,072 Million Units (MU). As per the 17th EPS report the Energy demand in Gujarat is projected to grow at the annual growth rate of 6.86% during 12th plan and at the rate of 5.66% during 13th plan. With these growth rate the total energy demand in the year 2015-16 is expected to be 1,05,999 MU and by the year 2021-22, it is expected to be 1,39,590 MU. The annual energy demand projection in Gujarat is shown in Figure 20.

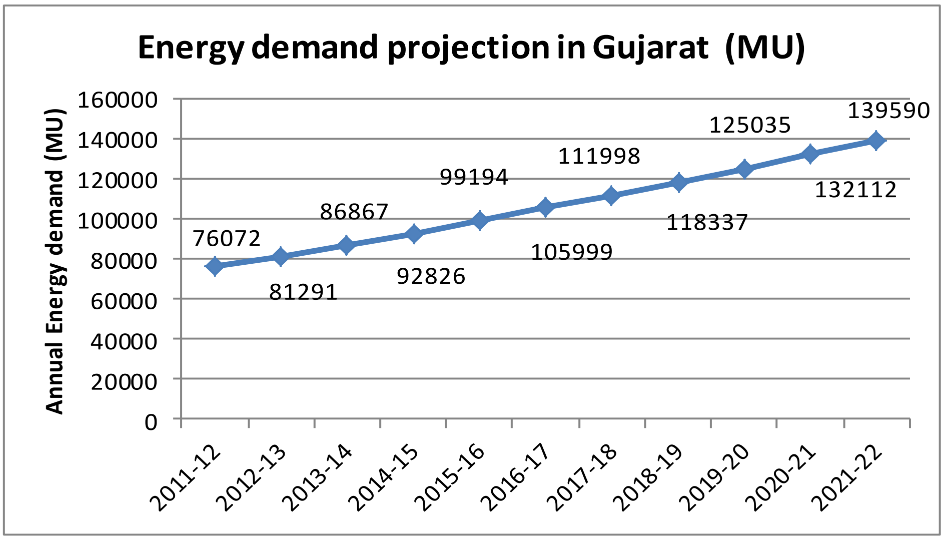


Figure 20: Annual energy demand projection in Gujarat

RE penetration scenarios

To estimate the future RE penetration levels in the state till the year 2021-22, following scenarios have been developed.

1. Business as usual (BAU) scenario: This scenario considers RE capacity addition to occur as per the GEDA targets.
2. "5% of integrated RE potential" scenario: It assumed that the small hydro, biomass and waste to energy projects will be developed as usual as per GEDA targets.Wind and solar power projects will be developed up to5% of the potential estimated by TERI in its report titled "Integrated Renewable Energy Resource Atlas of Gujarat, 2012"
3. "10% of integrated RE potential" scenario: It assumed that the small hydro, biomass and waste to energy projects will be developed as usual as per GEDA targets. Wind and solar power projects will be developed up to 10% of the potential estimated by TERI
4. "NAPCC RPO target" scenario: It is assumed that the small hydro, biomass and waste to energy projects will be developed as usual as per the GEDA target, considering their

limited potential. Solar power capacity will be 50% of JNNSM target, i.e. 10,000 MW solar capacity in Gujarat by 2021-22. Wind power installation will be as per the percentage of potential estimated by CWET, i.e. about 35% of total wind power installation in Gujarat (35 GW of about 100 GW) to meet the national NAPCC RPO

Based on these scenarios, the projected RE installed capacity, electricity generation and the RE penetration (out of total energy demand of Gujarat) are given in Figure 21, Figure 22 and Figure 23 respectively.

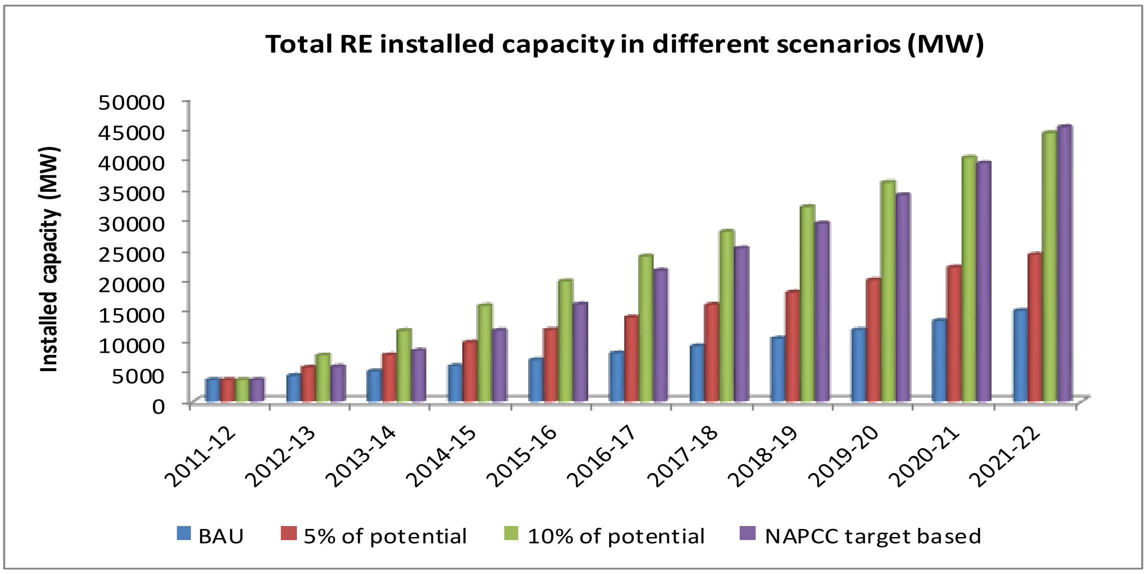


Figure 21: Projected RE installed capacity in Gujarat for different scenarios

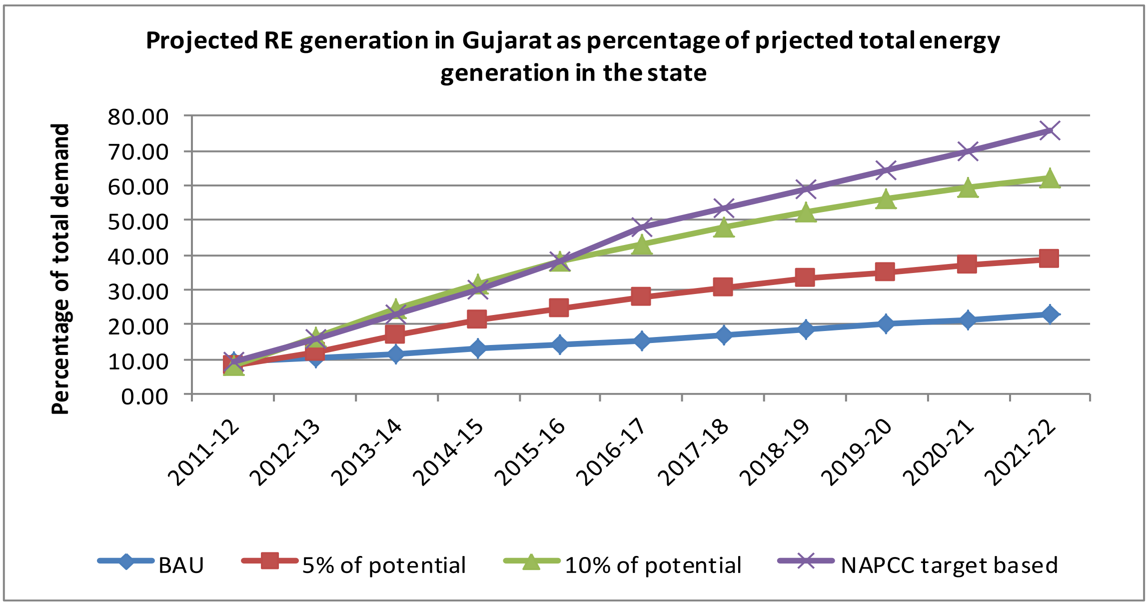


Figure 22: Projected RE generation in Gujarat for different scenarios

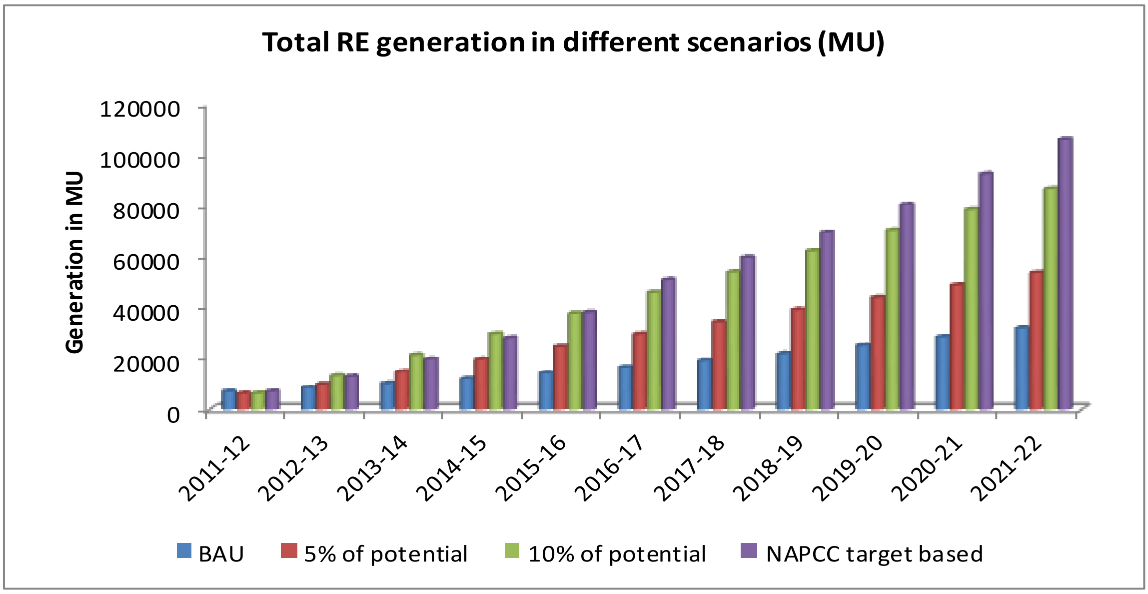


Figure 23: Projected RE generation as % of total energy generation in Gujarat for different scenarios

It is obvious that all renewable energy generated in the state will not be consumed in Gujarat alone, and the level of penetration, as projected, will bring issues along with it in terms of grid imbalances, commercial arrangement between states etc., which can be avoided if timely planning is carried out and appropriate provisions are adopted and implemented.

3. Issues and challenges in large scale grid integration of renewable energy

3.1 Literature review

Detailed literature review reveals that large scale integration of renewable energy resources -like wind and solar- poses entirely different set of challenges due to the variable nature of these resources and low plant load factor (PLF). International practices show that, countries such as US, UK and Australia, attribute a certain capacity value to wind and solar while planning their base-load capacity addition plans. As far as international methodologies for capacity value assessment are concerned, they do not take storage medium as an input while calculating this capacity value. It is correct that for optimal utilization of the resource and a stable grid operation, we would need grid integration protocols and proper balancing/market mechanisms.

Some of the major issues identified for large scale grid integration of renewable energy systems are given below:

1. Reserve requirements to maintain the flow of electricity (either storage or any source of generation which can immediately start to meet the demand)
2. Support during the disturbances in grid voltage and frequencies
3. Protection issues
    i. Change of short circuit levels
    ii. Reverse power flow
    iii. Lack of sustained fault current
    iv. Islanding
4. Voltage control
5. Power quality
    i. Harmonics and flicker
    ii. Reactive power imbalance

Further, the impacts of wind power on transmission depend on the location of wind power plants relative to load, and the correlation between wind power production and electricity consumption. Wind power affects power flow in the network. It may change the power flow direction, and reduce or increase power losses and bottlenecks. Grid reinforcement may be necessary to maintain transmission adequacy and security. When determining adequacy of the grid, both steady-state load flow and dynamic system-stability analysis are needed. Different wind turbine types have different control characteristics, and consequently, also have different possibilities to support the system in normal and system fault situations. For system stability reasons, operation and control properties will be required from wind power plants at some stage, depending on wind power penetration and power system robustness. Similarly, in case of grid integration of solar PV there could be restriction in penetration level of solar power. The key findings of the literature-review and the data collected are summarized in Annexure 6.

3.2 Variability of RE generation in Gujarat

Since wind and solar power are the variable sources of generation, to understand the level of variability and the correlation with the variation in the electricity demand in Gujarat; the wind and solar energy generation and the Gujarat electricity demand for the year 2011 have been analysed. This analysis shows that there is no fixed correlation between the wind and solar energy generation pattern and demand variation. For example, as Figures 24, 25 and 26 show, (i) wind generation is high in monsoon season, when the energy demand reduces and the variation in generation from wind follows the demand variation pattern during the peak hours in Monson season, and (ii) it is totally opposite in winter season. The detailed monthly variation assessment and correlation with the demand variation are given in Annexure 7.

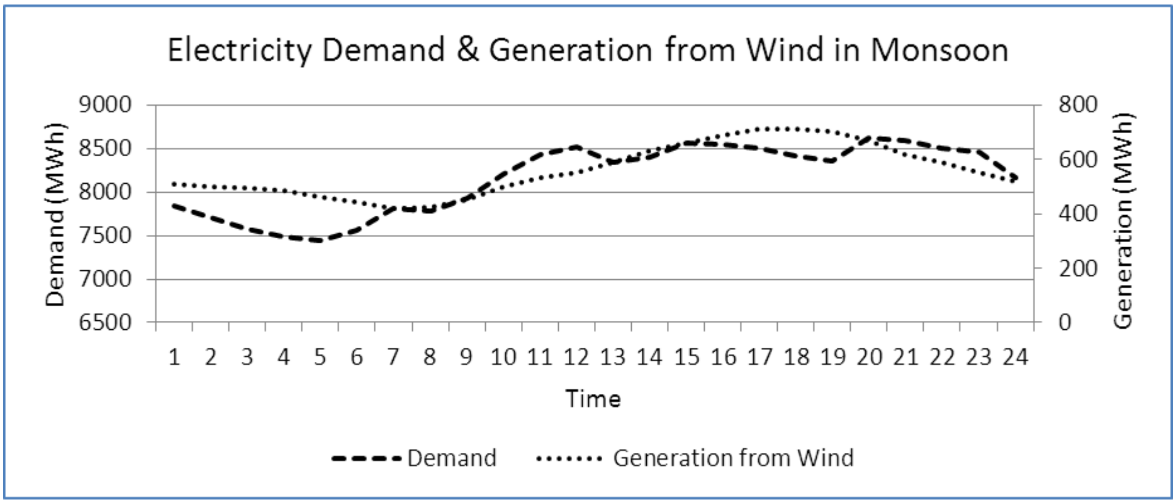


Figure 24: Hourly average electricity generation from wind and average electricity demand in Monsoon

In monsoon (June - September), electricity demand is minimum whereas generation from wind is maximum. Wind availability pattern in monsoon almost matches with electricity demand pattern during the peak hours. Electricity demand may increase due to requirement for water pumping in case of low rain fall.

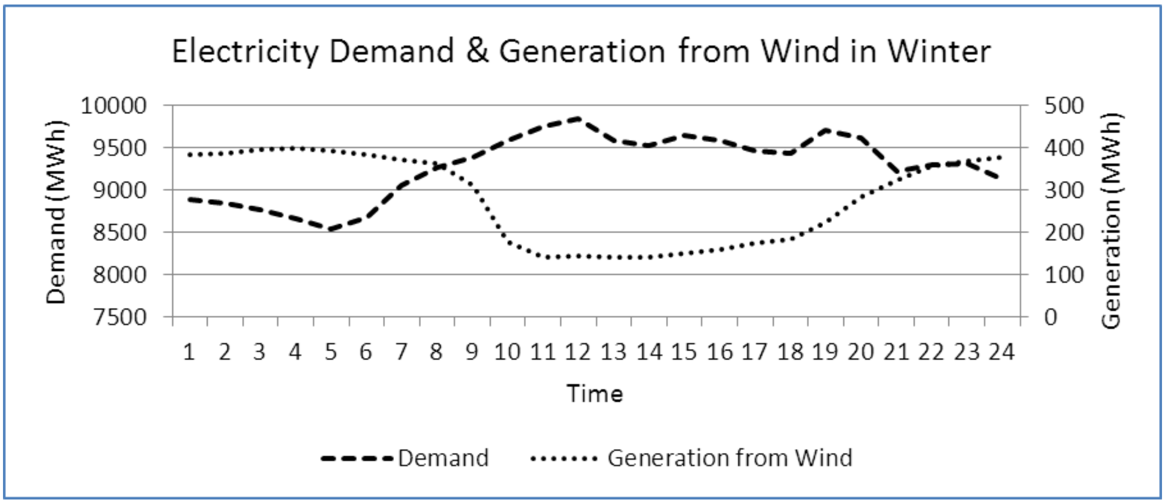


Figure 25: Hourly average electricity generation from wind and average electricity demand in winter

In winter (October-January), electricity demand is maximum compared to other seasons whereas generation from wind is minimum. Wind availability pattern in winter does not match significantly with demand pattern. Agricultural demand along with heating load in winter is higher as compare to other seasons.

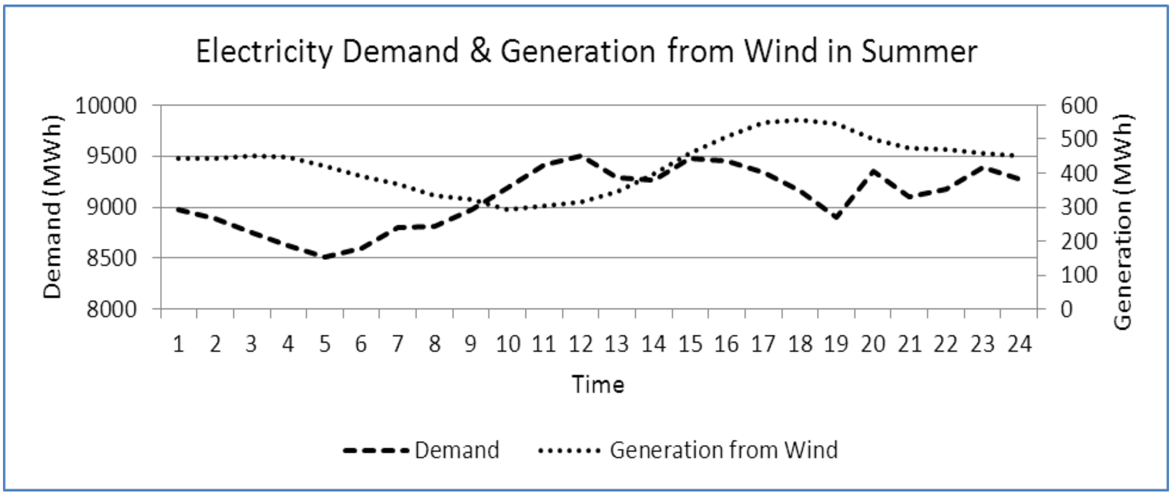


Figure 26: Hourly average electricity generation from wind and average electricity demand in Summer

In summer (February-May), both electricity demand and wind generation are moderate. For few hours in a day wind variability pattern matches with load variation. There is significant contribution of agricultural loads (summer crops; Bajri, paddy etc.) along with cooling loads in summer.

The solar energy generation variations from Charanka solar park are shown in Figure 27.

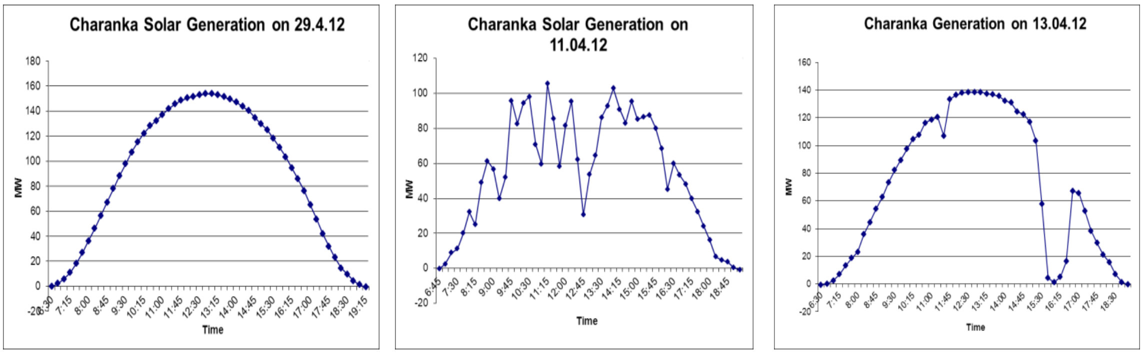


Figure 27: Solar energy injection pattern in Charanka (Source: GETCO)

From Figure 27 it is observed that daily and seasonally, solar generation vary both steadily and abruptly. Abrupt variation in generation appears due to sudden cloud cover. In a clear sunny day the solar energy is higher during 10:00 hours to 15:00 hours. In case of solar the magnitude of variation in generation could be as high as wind generation variation but the frequency of variation is much lower than wind generation. So if not affected by sudden cloud cover, the solar energy generation variability can be handled by shifting the loads in day time. However a good weather forecast is required to understand and manage the solar energy generation variability.

In this context, it is also important to mention here the findings of the recently concluded study on "Green Energy Corridors" of the Forum of Regulators and MNRE conducted by PGCIL. The CTU has carried out a detailed assessment to identify transmission infrastructure and other control requirements for RE capacity addition programme in 12th Plan and has prepared a comprehensive report with estimation of capex requirement and financing strategy. To take care of the intermittency and variability of RE, it has proposed several measures including:

- Strong grid interconnections
- flexible generation, Ancillary Services, Reserves etc. for supply-balancing, ,
- Demand side management, demand response and storage for load balancing.
- Forecasting of renewable generation and forecasting of demand
- Establishment of Renewable Energy Management Centers (REMC) equipped with advanced forecasting tools along with reliable communication infrastructure
- Deployment of synchrophasor technology i.e. PMUs/WAMS on pooling stations and interconnection with centralized control centre through Fiber Optic Communication for real time information, monitoring and control
- Capacity building at respective LDC/PCC/Conventional/Non-Conventional Generator regarding RE handling
- Institutional Arrangements with defined roles & responsibilities of various agencies/generation developer
- Technical Standard Requirements (Grid code, Connectivity standards, Real-time monitoring etc.)

- Policy advocacy for development of power-balance market and pricing mechanisms

The study has estimated the total cost of transmission system strengthening to be around Rs. 29,786 Crore, which has been categorized into cost for intra-state transmission, interstate transmission, establishment of REMC, energy storage, dynamic reactive compensation and real time monitoring of which more than 55% of the cost requirement is towards intra-state transmission strengthening of the seven RE rich states (Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Rajasthan and small hydro in Himachal Pradesh & Karnataka).

For Gujarat, the cost has been estimated to be Rs. 1680.41 Crores for intra state transmission strengthening and Rs. 602 Crores for inter- state grid strengthening.

3.3 Operation of grid with wind and solar power generation

Generally there could be three different scenarios in the grid with the variability of wind/solar power generation and the variation in the demand.

Scenario-1: An increase in load along with increase in wind/solar generation or drop in load along with drop of wind/solar generation.

In this case the grid management is easy and additional generation required for frequency maintenance is less. It is a safe operation for grid operators.

Scenario-2: A drop in load along with increase in wind/solar generation or the load remain constant with the drop in wind/solar generation

In this case the grid management needs backing down of other generators and there may be the high voltage problem in the grid. If local load is very low, then there could be the overloading of associated transmission systems.

To manage the system it would mainly require backing down of the conventional generators, or adding some electricity demand to the grid, which generally is difficult.

Scenario-3: An increase in load along with drop in wind/solar generation, or load remain constant with increase in wind/solar generation

This case is very critical to the system operators and need additional generation to be brought into the system very quickly for safe operation of the grid. If no additional generation is available, load shedding needs to be carried out. If frequency permits, there could be over drawl at the prevailing UI rate. It requires planning of oil/gas based power plants or pumped storage hydro plants as spinning reserves, to be utilized as balancing capacities for stable system operations.

This scenario becomes even more critical with the increasing penetration of renewable energy in the state's overall electricity mix. However, this situation can be appropriately managed with advanced and integrated power sector and grid planning and suitably designing our power markets.

It is important to note here that in an aggressive renewable deployment scenario, the required oil/gas/pumped hydro capacity will be lower as compared to BAU scenario since these will be used only for meeting the peak demand and supporting renewable capacities rather than serving the system demand per se.

Real time balancing of power in Gujarat

GETCO follows the following process for real time balancing of power.

1. It follows guidelines as per the Indian Electricity Grid Code Regulations that wind and solar power plants should be treated as must run plan and absorbs all the power being generated from these plants.
2. Conventional power plants are asked to back down their generation during light load periods or in case of increase in wind generation with load remaining constant to accommodate RE generation. Backing down is done on the basis of merit order dispatch.
3. Few gas power plants are kept as balancing power reserve, and are being asked to supply power to the grid in case of sudden drop in wind generation.
4. During high demand and low wind availability period, load regulation is done only in the extreme cases when the wind generation goes down and the conventional power plants too are not able to increase their generation. Equal percentage of reduction in load at each feeder is followed on priority basis for load shedding.

SLDC analyses the trend of wind generation and plans for safe management of the grid. Till now SLDC has been able to manage the grid using above mentioned process and only a few times in a year in case of grid instability, wind developers are asked to back down their turbines. Apart from following the government policy, the SLDC Gujarat also carries out its own forecast of wind generation broadly by using BBC weather forecast data. Based on the long term experience of SLDC Gujarat on the wind power generation patterns from the existing wind farms in the state and the weather forecasts, the SLDC sends instructions to respective sub stations to take precautionary measurements and be ready for the expected situations.

However, the situations are not critical today as the renewable energy generation penetration level is about 5% only. But in future the grid management will be more challenging as the renewable energy penetration level in the gridincreases.

Problem of voltage regulation and harmonics with wind generation

Voltage regulation

New WTG machines with variable frequency drives have inherent control of reactive power output and can participate in voltage regulation. Old WTG machines with induction generators have not been required to participate in system voltage regulation. Their reactive power demand is currently being compensated by switched shunt capacitors.

Harmonics

The variable frequency generators in WTGs use AC-DC converter for connection with grid, which increases harmonics level in the system. Though Harmonics is being minimised at generating station level, there is no arrangement at GETCO s/s level for protection against Total Distortion Harmonics (THD). Till now harmonics has not created any major problem in the state grid.

Power congestion issues in Gujarat

During discussion with SLDC it was stated that power congestion had been seen in Deodhar, Shivlakha and Shankhari networks. Overloading of 220/66 kV Shivlakha ICTs has also been experienced in the past. RE plants provide lesser grid support during system disturbances than conventional power plants in terms of MVAR/active Power regulation.

Till now no major issues in the operation of grid has been observed due to wind and solar energy variations. This scenario may change with increase (over 30% from current 5%) in wind and solar energy penetration in the grid.

3.4 Policy, regulatory and commercial issues

Since wind and solar energy is variable and more expensive as compared to conventional power, the state government including the Discoms and transmission utilities have their own concerns relating to commercial implications of evacuating large quantity of these highly variable energy generations. The power generators also have different set of concerns relating to the policy and regulatory aspects of large scale renewable energy integration with the grid. These concerns, identified based on the stakeholders' consultation, are summarized below.

1. The transmission utility is concerned about the high cost involved in the development of the grid system with advanced equipment and long distance high voltage transmission lines. Also the cost involved in extending the grid network to the remotely located renewable power generation stations. Their concerns pertain to:
    a) How to fund these investments
    b) How to recover these investments: whether it could be recovered through increased transmission charges or these are supported by the state/central grant.
2. The distribution licensees are reluctant to purchase the variable RE generation at higher tariff.
3. SLDC is considering few gas power plants as spinning reserves but there is an issue of the high per unit cost of generation from these plants in case they are kept operational for only a small amount of the time.
4. The UI charges being paid by the state government due to the import of power from the grid in case of sudden fall in the solar/wind energy generation ultimately makes the effective cost of electricity from these sources high.
5. Since the Discoms have to meet the RPO target, they first want to buy the electricity at the feed in tariff rate, rather than buying the variable energy at average power purchase cost and then buying REC from market to fulfil their RPOs. The power producers, on the other hand find the option of selling power at average price and then selling REC in the market as better way for financial returns. This leads to ambiguity in signing of PPA.
6. For the REC mechanism, the state's (specially the RE rich state) concern would be that it has to develop the vast grid infrastructure for evacuation of power and set higher RPOs due to the large potential in the state, whereas the other states would be benefiting from it by just purchasing the REC from the market at comparatively lower price. Higher penetration of RE may also lead to power quality issues for the states grid infrastructure, hence, that state may have to absorb poor quality of power due to large RE potential available. Hence there is a concern that how the funding requirements for these large scale grid infrastructure would be met by the state government State government thinks that there shall be central government incentives for this.

7. The need for ancillary power services and energy storage systems is now understood but the concern is that there is no mechanism defined for the ancillary power market and the payment mechanisms. Further the cost intensive technologies, required to be maintained for handling variable RE source would impact on the increase of the retail electricity tariff, so it will again be the burden to the state government.

Issues related to scheduling of wind power

1. The wind project developers and investors are concerned about the financial implication of the scheduling requirement of wind energy, since the forecasting models available till now are unable to accurately forecast the wind energy generation from Indian wind farms at 15 minute intervals.
2. The IEGC 2010 says that the scheduling will be mandatory for the new wind power projects, which are commissioned after January 1, 2011. Since there are many wind farms installed with large capacities before this date, there are few concerns like
   a. In a wind farm in there may be a few wind turbines that are commissioned before January 1, 2011 and few are commissioned after this date; and all the wind turbines are connected to a single substation. In such a scenario how the energy accounting will be undertaken for comparing the forecast. Taking just a fraction of wind farms forecasting will not actually help in grid operations.
   b. In a single wind farm, there are multiple owners of small capacity projects. How UI charges will be shared among these multiple wind farm owners.
3. The wind farm owners are also opposing the penalty on forecasting inaccuracy due to (a) the fact that the wind power forecasting is a new phenomenon for Indian wind farms and (b) due to lack of long term high resolution data and good wind power forecasting tools, the forecast accuracy is very poor. Essentially, the wind farm owners do not want the scheduling for wind generation. CERC already has given an extension of a year for the applicability of the scheduling for wind power but till now it has not been implemented.
4. Some of the wind developers have started providing the forecasts from their wind farms now on trial basis. While Gujarat has installed ABT meters at both ends (i.e. generator's end and the substation end) which can record the generation logs for every 15 minute intervals; many of the state utilities might not have the required infrastructure to record and compare the forecast with actual generation. .
5. SLDC, Gujarat says that it can take the task of setting up of a state level RE data management centre, for which the process and concept preparation has already been started, but today there is no experts available with SLDC who can understand the forecasting of renewable energy so it need the capacity building. Further concern is that from where the fund will come for setting up the centre and how the operational cost will be managed.

6. Further concern of SLDC Gujarat, regarding the RE data management centre and forecasting was that the developers do not provide the plant specific data as well as the real-time data from their wind farm, without which it would not be possible to do the forecasting by the central agency. So there is a need for the regulation to guide the wind farm developers to provide the desired project specific data to the SLDC/RE data management centre.

Box 1: Indian Electricity Grid Code Regulations, 2010

The IEGC, 2010 specifies the technical and commercial aspects for integration of these resources into the grid.

- **Scheduling**: It provides for scheduling of wind and solar energy. [1] This provision shall be applicable for new wind/solar farms with collective capacity of 10 MW and above connected at connection point of 33 KV level and above, which have yet to sign a PPA with states or others. It stipulates that RE plants except biomass plants and non-fossil fuel based cogeneration plants whose tariff is determined by the CERC shall be treated as 'MUST RUN' power plants and shall not be subjected to 'merit order dispatch principles.
- **Forecasting**: All the wind and solar generators shall be responsible for forecasting their generation up to accuracy of 70%. If the actual generation is beyond +/-30% of the schedule, wind/solar generators have to bear UI charges. If the generation is within +/-30%, the State which purchases power from the wind generators shall bear the UI charges for this variation. However, the UI charges borne by the State/s due to the wind/Solar generation shall be shared among all the States of the country in the ratio of their peak demands on a monthly basis, in the form of a regulatory charge known as the "Renewable Regulatory charge for wind/solar energy. Renewable Regulatory Fund (RRF), The RRF shall be maintained and operated by the National Load Despatch Centre on the lines of UI Pool Account at the regional level.

3.5 Analysis of grid codes and the CEA grid connectivity standards

The Indian Electricity Grid Code (IEGC) 2010 and the state electricity grid code are the guiding documents for the connectivity of the power generation projects with the national and state grids. The CEA grid connectivity standard specifies all the technical requirements for the connection of a power projects into the grid. The latest documents are:

- Indian Electricity Grid Code-2010
- CEA draft grid connectivity standards for renewable energy
- Gujarat state electricity grid code-2004

An analysis have been carried out for all these grid codes and connectivity standards comparing them with the grid codes followed in countries like Germany, Denmark, USA, China, and Spain etc. which are the leading countries in renewable energy (mainly solar and wind power) installations. This analysis shows that the IEGC-2010 as wel as GEGC 2004 both do not specify all the grid connectivity criteria and CEA is referred for all the technical standards. CEA standards, although cover most of the aspects, they are still in the draft stage. On analysing these documents in detail and taking inputs from grid codes of the other countries, the identified gaps in the IEGC-2010 and Gujarat Electricity Grid Code 2004 are given in Table 7.

Table 7: An analysis of grid codes to find out the gaps

Parameter	International Grid Codes (Germany, UK, Ireland, Nordic Countries, Canada, USA, Spain, Italy & New Zealand)*	IEGC, 2010	Gujarat Electricity Grid Code, 2004
Fault ride through (FRT requirements)	Fault clearance time, interconnection time, fault duration cycle etc. are clearly mentioned in all grid codes	No detailed description regarding the same	Nil
Active power restoration	Provide guide lines for active power restoration	Nil	Nil
Voltage Control	Voltage control during faults has been mentioned	Nil	Nil
Energy Balance	A provision for sufficient energy reserves has been mentioned	Nil	Nil
Reactive power Compensation	Wind farms should support the grid by generating/stop drawing reactive power during a network fault, to support and restore the grid voltage. In Spain, an incentive mechanism has been developed for supply of reactive power (Annexure 3).	P.F. at WTG to be maintained between 0.95 lagging to 0.95 leading. But, it does not say that wind farm should support the grid by generating reactive power during a network fault.	Nil
Active power and frequency control	Ramp rates are mentioned i) Germany, with a ramp rate 10% of grid connection capacity per minute. ii) Ireland, with a ramp rate 1–30 MW/min iii) Nordic grid code, with a ramp rate 10% of rated power per minute In Danish technical requirements, it is suggested that it must be possible to change a wind turbine's regulation externally between frequency-independent and frequency-dependent control. In frequency-dependent control mode, a wind turbine's control equipment must change the production depending on the grid frequency. Frequency independent is the one provided by set points. [7]	Nil	Nil

Based on the detailed study and interaction with stakeholders following are the recommendations given for grid code and connectivity standards (Table 8). The details are given in Annexure 8.

Table 8: Recommendations for Gujarat Electricity Grid Code

Sl. No.	Parameters	Approach	Recommendations
1	Fault ride-through capability	Required / Incentive	1. Solar and wind generating stations shall remain connected during the network fault and they have fault ride-through capability of not less than some defined time which needs to be a-priori fixed according to local grid requirements. 2. Fault ride-through requirement should follow a pattern, mentioning percentage reduction in the grid nominal voltage vs. time for which plant should not trip. 3. Wind power plants installed before January 1, 2011 could be incentivized for fault ride-through capability.
2	Active power and frequency control	Required	The plant shall be capable of power output reduction steps as directed by SLDC. A set point given by the network operator must be reachable from any operation point in any operation mode.
3	Reactive power supply	Required / Incentive	1. Solar and wind generating stations connected at 66 kV and above shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within limits. A detailed system study should be performed for defining the power factor limits. 2. To maintain the Reactive power/voltage control with high penetration of renewables, the reactive power/ voltage control may be treated as ancillary service and the sources/devices contributing to reactive power for voltage control may also be appropriately incentivized. The proper pricing procedure can be formulated instead of flat pricing for reactive power exchanges (withdrawal/supply) by carrying out the exhaustive studies of various methods and their benefits and practical implications.
4	Power balancing	Required	Some generators should be kept for spinning reserve which can be done by formulating a proper pricing mechanism for such schemes. Technologies with greater operational flexibility should be promoted. To bring out a proper framework, exhaustive studies should be done.
5	Forecasting	Required & Incentive	1. Forecasting should be carried out at developer level as well as at SLDC/NLDC level. 2. Standardised models/algorithms should be developed for Indian context.
6	Power Quality	Required	The grid code should clearly mention the guidelines for power quality measures, e.g. allowable total harmonic distortion, flickers (e.g. 3% in Danish grid code).

4. International case studies

To understand the international scenarios around the issues related to the large scale integration of renewable energy with the grid and how it is being managed, the studies for three countries: USA, Germany, and China - all, leading countries in renewable energy installation - have been done. Table 9 summarizes these whereas the details are given in Annexure 9.

Table 9: Summary of case studies from various countries

Parameter	China	Germany	USA
Grid safety and balancing power	1. Implementation of ultra-high voltage transmission system 2. For balancing power, China makes use of secondary reserve capacities like hydro power. They also make use of long term reserve capacities like natural gas power system, nuclear power systems and coal based systems. 3. There are two types of energy storage systems currently available in China. First, physical energy storage systems such as wind powered pumped hydro storage systems and compressed-air systems. In addition, a number of electrochemical energy storage systems are available, such as lead-acid battery energy storage systems, redox flow cell energy storage systems and Sodium Sulphur battery energy storage system	1. Amendment in Energy Management Act with the proposal for "Act concerning measures to speed up the expansion of power grids" which is to make it possible to ensure faster construction of very-high-voltage transmission lines. 2. Implementation of very-high-voltage transmission lines. 3. Germany uses three different forecast tools. It receives wind power forecast data from four different forecast service providers. The forecast horizon is 96 hours and beyond that it's updated twice a day. The information is combined using a weighted sum. Dispatchers use the information to develop an operational forecast. 4. Dynamic grid support: Due to an increasing penetration of decentralized generating plants in the medium-voltage grid in Germany, following guidelines have been adopted ; ▪ To stay connected during a fault, ▪ To support the voltage by providing reactive power during the fault, and ▪ To consume the same or less reactive power after the fault clearance. 5. Germany specified new grid code for connecting solar PV with medium voltage grid	1. Forecasting is done in every 5 minutes interval. 2. There are four types of ancillary services products: regulation up, regulation down, spinning reserve and non-spinning reserve. Regulation energy is used to control system frequency that can vary as generators access the system and must be maintained very narrowly around 60 hertz.
Policy interventions	1. Most run plant status for RE generation 2. Feed-in Tariff mechanism 3. Introduced benchmark pricing according to four types of wind resource. The	1. To finance the accelerated energy revolution, the German government has established a special "Energy and Climate Fund". 2. Germany has different	A. To encourage the use of Renewable energy in US Renewable Portfolio Standard (RPO) are enforced there are generally

Parameter	China	Germany	USA
	pricing level is more reasonable and profitable for investors. 4. Established the renewable energy development fund	renewable energy support policies ; i. Regulatory policies a. Feed-in tariff (incl. premium payment) b. Biofuels obligation/mandate c. Heat obligation/mandate ii. Fiscal incentives a. Capital subsidy, grant, or rebate b. Investment or production tax credits c. Reductions in sales, energy, CO2, VAT, or other taxes iii. Public financing a. Public investment, loans, or grants	three ways that electricity suppliers can comply with the RPS: 1. Owning a renewable energy facility and its output generation. 2. Purchasing Renewable Energy Certificates (RECs). 3. Purchasing electricity from a renewable facility inclusive of all renewable attributes (sometimes called "bundled renewable electricity") B. Feed-in tariffs (FIT): According to NREL report of year 2009, the FIT policies are being experimented with in the United States, though at a smaller scale and less comprehensively than in a number of European countries.

The above case studies show that for the large scale integration of renewable energy into the grid and to maintain the power system balancing, advance planning for high quality transmission grid and the power balancing options is must. Also, it has been observed that the transmission utilities are more concerned about wind power forecasting in these countries and hence apart from receiving the forecasts from the wind power generators, the utilities have their own forecast systems as well. These utilities also involve independent service providers for providing the wind energy generation forecasts and then manage the power distribution based on their long term experiences.

Though in terms of policies for renewable energy generation promotion, Government of India and specially the Government of Gujarat have been aggressive, there is an urgent need to focus on the planning and on investments for the grid strengthening and expansion.

5. Recommendations

This section details out key recommendations for future RE deployment and safe integration of renewable energy in the Gujarat state grid as well as the national grid. These are broadly categorized as:

e) Appropriate renewable energy generation forecasting

f) Co-ordinated project development, grid planning and grid strengthening

g) Creating flexible capacity, spinning reserves and ancillary services market

h) Properly defining RE grid integration standards and regulations

a) Appropriate renewable energy generation forecasting

Renewable energy, mainly wind power forecasting, is an important aspect for the power system management through the scheduling of renewable energy generation. Though the IEGC-2010 mandated the scheduling of wind power for the new wind farm owners, it has not been implemented till now due to the fact that proper wind forecasting tools are not available for Indian site conditions till now, which can accurately forecast the wind energy at 15 minute intervals. Further, while the accuracy of forecasting is very low in low wind season compared to high wind season, the magnitude of the absolute error is quite high in even in high windy seasons.

While wind power forecasting is mandated for the wind farm operators, it is the grid system operator like SLDC and NLDC who are primarily responsible for proper management and safe operations of the grid.

Plan of action

It is important, therefore, to set up state as well as regional/central level specialised data management centres for renewable energy. These centres will also house the forecasting unit, that will analyse the forecasts being received from all the wind and solar power operators and then carry out their own forecasting for the purpose of proper assessment of the expected generation and help safe operation of the grid.

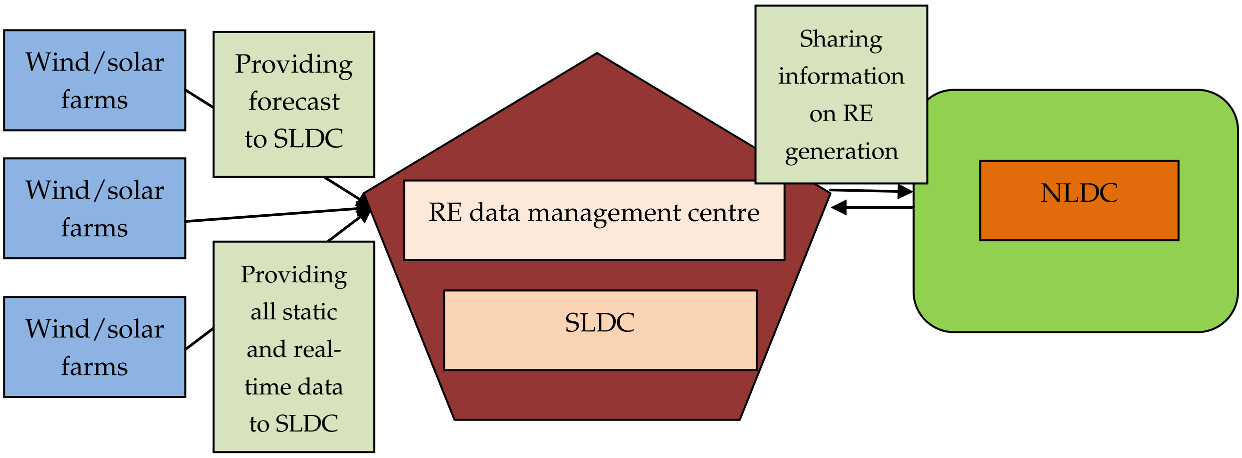


Figure 28: Institutional arrangement for RE forecasting

As the accuracy of forecast is generally different at low and high wind seasons, different range of margins and penalties for the error in forecasting may be prescribed for the two different seasons. Since Gujarat grid system has got the ABT meters and other advanced facilities required for the power data communications between the substations and the SLDC; SLDC Gujarat may take lead in evaluating the forecast data being provided by the wind farm developers on trial basis and then give proper methodology and mechanism for the evaluation of forecast, which will ultimately help in improving the forecasting methodologies as well as the mechanism for the penalization of the RE power generators.

b) Co-ordinated project development, grid planning and strengthening

As discussed in Chapter 2 of this report, RE penetration in Gujarat may reach about 75% of the total state demand in 2021-22 (under NAPCC RPO target), much of which will be transmitted out of the state considering Gujarat alone cannot absorb this huge quantum of RE power.[1] It is, therefore, suggested that a co-ordinated approach towards grid planning is required, wherein GETCO along with GPCL and GEDA consider the RE potential distribution in the state for future project development, project allocation, and the associated network planning.

While the gestation period of solar and wind projects ranges between 6-12 months, depending upon the capacity of the plant, the associated transmission network for power evacuation (includes development of transmission network, establishment of RE pooling station/sub-substation, as well as system strengthening for absorption of addition RE power) requires about 3 to 4 years' time. It may be desirable if GETCO implements the project development, advanced grid planning and network enhancement works involving competencies to deal with issues such as Right of Way (RoW) etc.

Co-ordinated project development, advanced grid planning and network enhancement for RE integration in Gujarat would require significant investments. The proposal submitted by GETCO to MNRE estimated the cost of intrastate transmission network strengthening is Rs3,064 Crore for the 12th five year plan.

[1] As Gujarat's RPO trajectory will be set in accordance with NAPCC trajectory which envisages RE penetration of 17% in 2021-22, therefore it is implied that much of the RE power will be transmitted outside the state.

Plan of action

The sites or zones in Gujarat, which have been identified as high potential areas for integrated solar and wind development can be developed as integrated energy parks on PPP mode. Here GoG may form joint venture (JV) with the private sector. GoG has already set up a solar park at Charanka providing a model for other states and this concept can be further scaled up to develop integrated wind-solar energy parks. The state government could create land banks by identifying suitable government wasteland and private land for such parks. Establishment of such parks will facilitate advanced grid network planning while also bringing down soft costs.

GEDA may invite the future development plans (3-5 years) from wind and solar power developers, and provide it to GETCO for advance planning of grid network. **This will help in boosting the RE project development and implementation rate, as the project developers will get timely evacuation approval. Also, this advanced planning would help minimizing the gap between RE project construction and grid connection.**

GETCO may also carry out tariff based bidding for developing the transmission network on PPP basis (for instance, in JV mode GETCO holds at least 26% stake, rest contributed by private entity or 100% equity contributed by private (IPTC route).[1]) States such as Rajasthan have already initiated the process where in November 2010 it awarded two large transmission projects through the tariff based competitive bidding route to GMR Energy, to be implemented in the BOOM mode over a 25 year period. The funding for grid strengthening and network development could be tapped from Gujarat Green Energy Fund[2], grant proposed by the 13th Finance Commission or any other state government grant.

c) Creating flexible capacity, spinning reserves and a market for ancillary services

To manage the intermittency and variability in RE generation, which is likely to become more pronounced as the RE penetration in Gujarat increases progressively, ancillary services[3] such as flexible generation and energy storage will be required. Hydropower, gas based power plants, ultra-modern coal thermal power plants and combined heat & power generating facilities are considered as good spinning reserves for balancing of power[4]. Response time of hydro and gas based generators are less as compare to ultra-modern coal thermal power plants and combined heat & power generating facilities. At present about 785 MW of hydro and 2,164 MW of gas based power plants capacity is operational in Gujarat. Since hydro power is limited in the state, gas based power plants are likely to be the main source in Gujarat for spinning reserves. This calls for a coordinated planning of conventional power plants along with that for renewable energy development. However, the provision of ancillary services and the success of its implementation will hinge on the incentives and

[1] The Ministry of Power on Tuesday has made it mandatory to procure transmission services for new projects through tariff-based competitive regime. As per the tariff policy the intra-state transmission projects would also be moving to the tariff-based competitive system from January 2013.

[2] Gujarat Green Energy Fund is administered by the Govt. of Gujarat by levying a cess of twenty paisa per unit of the electricity generated from conventional, captive and standby generating plants.

[3] Ancillary services include several services such as load following, regulation, voltage control, operating reserves, black start etc.

[4] Hydro power stations with pumping facility can be used to meet the peaking shortage and utilize surplus availability during off peak periods. During off peak periods the system operator may ask such hydro stations to pump some water upstream which would be later used to generate peaking power (NLDC, 2010).

market signals provided to such generators. The CERC is in the process of finalizing the procedure for the implementation of ancillary markets in the country, which could serve as guidelines for Gujarat to formulate its own regulations for ancillary market.

Ancillary services for Gujarat

The two important ancillary services along with the already existing ones can be reactive power/voltage control services and power balancing services.

Reactive power/voltage control service

Sufficient reactive power helps in maintaining the power flows and the voltages. Reactive power demand will increase with the increase in more quantum of renewable energy penetration. For example introduction of wind generators may require installation of synchronous condensers, STATCOMs, and static VAR compensators (SVCs) for the purpose of managing voltage levels in the vicinity of wind farms. It is also possible that some areas of power system may become congested, then additional reactive power support will be required and issues may arise concerning how such support will be procured. Hence, it is important to plan for reactive power support and its operational framework.

Reactive power should be locally supplied due to technical problems associated with its transportation. The value (cost) of the reactive power is location dependent; i.e. worth of 1 kVArh, of reactive power support may be different at different locations. While the supply of dynamic reactive power is a very real physical function, the payments for the service should be more of an accounting mechanism that helps to recover costs due to the above fact.

Devising [4] appropriate payment structure is important. It can be based on tender markets bid price offers, or bilateral contracts. One of the way mentioned in this paper is that an ISO buys the reactive power and devise its optimal contracts for reactive power provisions (short term or long term bid based) keeping in view the market environment. Actually, utilities typically require synchronous generators to provide an amount of dynamic reactive power capability which is then controlled by the system operator as a condition of interconnection. **Other devices (WTG/PV systems, FACT Devices) are also capable of providing dynamic reactive power/voltage control and it may be appropriate to take them also in to consideration. Of course the pricing framework should consider the fact that reactive power is supplied or consumed in order to help the system depending upon the network voltage. Hence, the pricing should have some reference to the voltage as in case of UI, the real power cost has a relationship with frequency.**

One option is that reactive power prices be set on a locational (nodal) spot basis. The pricing of reactive power can be virtually identical to the way that New York and the Pennsylvania—New Jersey—Maryland Interconnection (PJM) presently price real power on a locational hourly basis [4]. Such an approach has some important theoretical strengths, as well as important practical limitations. Other pricing methods are those that can be implemented in conjunction with the locational spot pricing framework. On the supply side, options include separately pricing different categories of cost (e.g. capability, utilization) or resources (e.g. static supply, dynamic supply), long-term supply arrangements, and prescribing penalties for failure to supply reactive power as promised or required.

To maintain the Reactive power/voltage control with high penetration of renewables, the Reactive power/ voltage control may be treated as ancillary service and the sources/devices contributing to reactive power for voltage control may also be appropriately incentivized. This may also be performed at country level. Gujarat being renewable-rich state, may take it forward for implementation. The proper pricing procedure can be formulated instead of flat pricing for reactive power exchanges (withdrawal/supply) by carrying out the exhaustive studies of various methods and their benefits and practical implications keeping various states in mind.

Benefits of reactive power support to the utilities

Reactive power has an intense effect on the security of power systems because it affects voltages throughout the system: deficiencies of reactive power cause voltages to fall, while excesses cause voltages to rise. Voltages that are too high or too low can result in increased power system losses, overheating of motors and other equipment, and system voltage collapse with consequent loss of customer load. In fact many of the major outages have been because of problems with insufficient reactive power support.

Power balancing

With the increase in penetration of more renewable energy sources, due to variability of these resources more power balancing services will be required. For example gas based power plants and hydro power plants are considered as most appropriate source of spinning reserves due to their ability of immediate response to the power demand so these can be used to work as balancing station. Since the availability of gas is limited, the gas based plants remaining idle due to gas shortage can be treated as balancing stations and can be operated with some appropriate pricing to incentivize them. Proper framework should be worked out for pricing the generators providing the power balancing services. A day ahead planning can be done for the same depending upon the resource availability. Also more operationally flexible technologies running on conventional fuels could be incentivized.

Energy storage systems as power balancing source

Apart from the conventional power plants as spinning reserves, the energy storage systems like Pump Hydro Storage, Compressed Air Energy Storage, Batteries, Fly wheel, Hydrogen storage, Battery/Hybrid Electric Vehicles, Lead Acid Batteries, Lithium-ion batteries, Sodium Sulphur Batteries, etc. are also being considered globally as the measures to handle the variability in RE generation, frequency and voltage control, spinning reserves, handling ram and emergency power supply source etc. Various type of batteries are suited for various grid conditions depending upon their power density, energy density, discharge time, time scale at which they can respond etc. The whitepaper prepared by IEC lists out various energy storage systems with their possible and suitable roles for integration with the grid and are given in the table 10.

Table 10: Grid side role of various energy storage systems[1]

Role	Time scale(s)	Description	Benefits to RE integration	Examples of EES technologies
Time shifting / Arbitrage / Load levelling	Hours to days	EES allows storage of off-peak energy and release during high-demand period	A solution to diurnal generation cycles that do not match load cycles	NaS batteries, CAES, PHS, RFB
Seasonal shifting	Months	EES stores energy for months at a time, releasing it at times of the year when RE output is typically lower	Allows use of renewably-generated energy year-round, reducing reliance on traditional generation in seasons with, e.g., low sunlight	Hydrogen, SNG
Load following / Ramping	Minutes to hours	EES follows hourly changes in demand throughout the day	May mitigate partial unpredictability in RE output during critical load times	Batteries, flywheels, PHS, CAES, RFB
Power quality and stability	< 1 second	Provision of reactive power to the grid to handle voltage spikes, sags and harmonics	Mitigates voltage instability and harmonics caused or exacerbated by uncontrollable variability of RE generation	L A batteries, NaS batteries, flywheels, RFB
Frequency regulation	Seconds to minutes	A fast-response increase or decrease in energy output to stabilize frequency	Mitigates uncontrollable moment-to-moment variability in RE generation output	Li-ion batteries, NaS batteries, flywheels, PHS (with advanced variable speed control)
Spinning Reserves	~10 Minutes	A fast-response increase or decrease in energy output to cover a contingency, e.g. generator failure	Mitigates partial unpredictability of RE generation output, providing (or removing) energy when the RE resource does not perform as expected	PHS, flywheels, batteries
Supplemental reserves	Minutes to hours	A slower response resource that comes online to replace a spinning reserve	Provides firm power in the event of an especially severe and long-lasting drop in RE output. Use for RE integration is expected to be infrequent and low-value	PHS
Efficient use of transmission network	Minutes to hours	EES can help grid operators defer transmission system upgrades through time-shifting and more efficient operating reserves	Reduced transmission costs, mitigates locational dependency challenges of RE generation	Li-ion
Isolated grid support	Seconds to hours	EES can assist in the integration of RE on small	Time-shifting and power-quality applications to	L A batteries

[1] Source: IEC whitepaper on "Grid integration of large-capacity Renewable Energy sources and use of large-capacity Electrical Energy Storage" October 2012, http://www.iec.ch/whitepaper/pdf/iecWP-gridintegrationlargecapacity-LR-en.pdf

Role	Time scale(s)	Description	Benefits to RE integration	Examples of EES technologies
		power grids, such as those in use on islands	mitigate variability and unpredictability of RE generation	
Emergency power supply / Black start	Minutes to hours	EES may be used to re-start the power system in the event of a catastrophic failure	No specific benefit accrues to RE integration, but storage resources may nonetheless provide black start capability to the grid	L A batteries

This is important to analyse the suitability of the energy storage system in respect to the capacity requirement, grid conditions like voltage variation and frequency variation, response time etc. specific to the state grid network as well as the interstate transmission network.

Plan of action

a) Regulations for ancillary market: GERC may formulate regulations specifying the procedure for implementation of ancillary services including procurement process for these services (e.g. power exchange, bi-lateral contracts, tendering etc.) and the incentives/remuneration to the generators. As an example, the tariff to the generator of spinning reserve (hydro/gas) could be determined by GERC consisting of two parts (a) fixed part (Rs/MW/month) applicable for the period when such service is made available. Such service should be available at least for a full month to enable payment against fixed part and (b) a variable component to be paid as and when the service is called for and may be reimbursed in Rs./kWh. Similarly, other options for availing service either through contracting with ancillary service providers for long-term provision of these services or market mechanisms such as exchanges could be explored. The primary responsibility of procuring the ancillary service would be of the system operator viz. SLDC. SLDC could have a separate budget provision to pay for the ancillary services or it could recover these through ARR.

b) Interstate collaboration needs to be sought for sharing of hydro generation capacity to address the variability of RE generation in the state.

c) Setting up of state level and regional/central level RE data management and forecasting centres.

d) GERC to come up with the regulations on the ancillary market and spinning reserves for power balancing in Gujarat with specific measures of technology suitability, resource availability, funding, payment mechanism, and regulations etc.

d) Properly defining RE grid integration regulations

CEA should come up immediately with the complete standards and the procedures to be followed by the renewable energy generators for the grid integration of renewable energy projects, clearly defining all the parameters for the safety of the plants and grid systems. All the central and state grid codes then shall refer to these standards and the same are strictly followed by the renewable energy generators. These recommendations are summarised in the table 11.

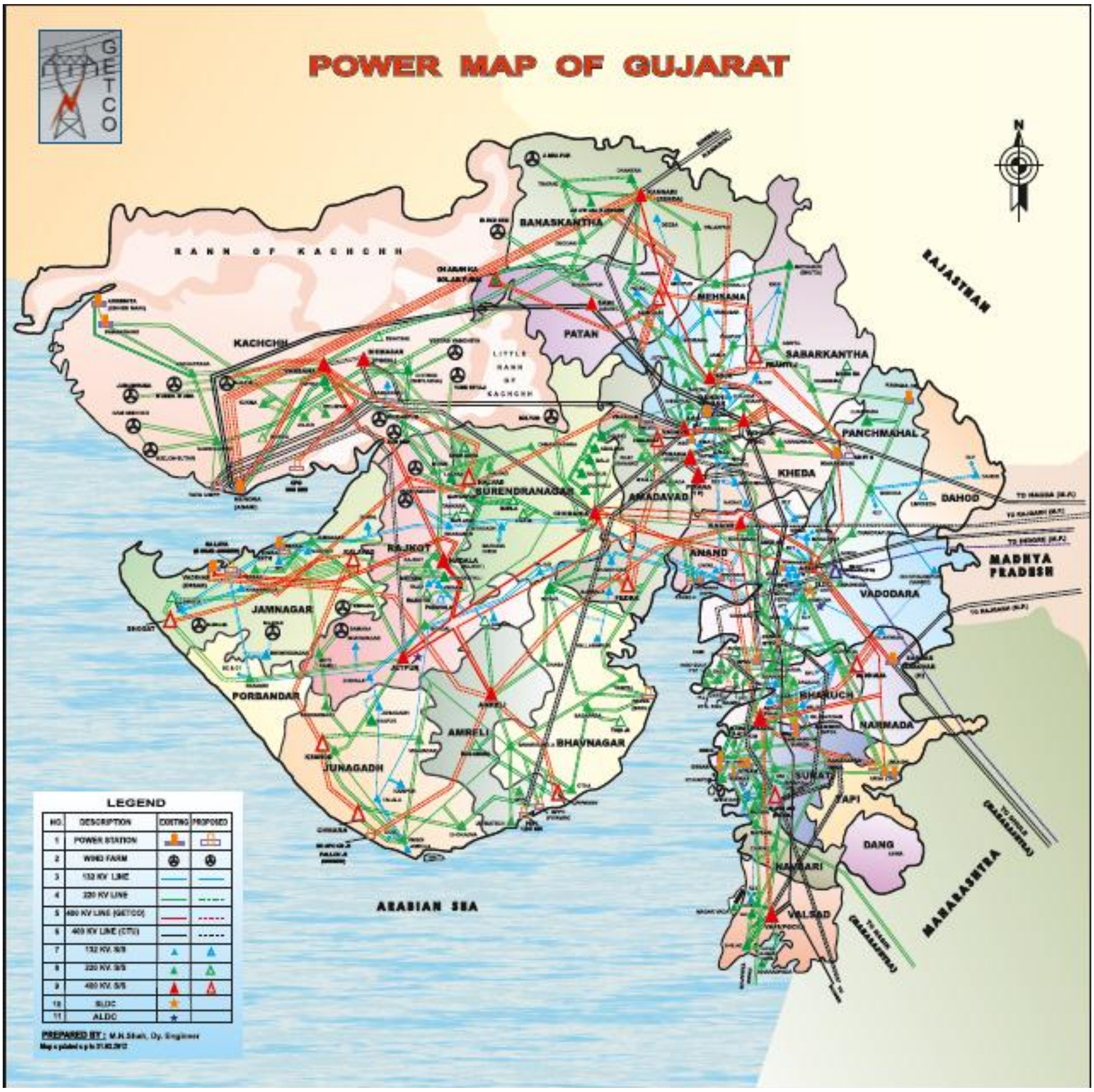
Table 11: Recommendations

Focal area of intervention	Action required	Roles and responsibilities
Policy interventions		
Co-ordinated project development, advanced grid planning and network enhancement	Project development and grid planning • RE potential based planning - "Integrated Energy Parks" on PPP mode – (experience from Charanka) • Creation of land banks for RE parks • Call for long term development plans of developers (5-10 years) Grid strengthening and extension • Tariff based bidding for transmission network development Some funding options that may be explored • Gujarat Green Energy Fund • State govt. grant • 13th Finance Commission • Any other such as clean energy fund	• GEDA/GPCL- Integrated energy parks- Site identification, land banks, bidding, developer selection etc. • GETCO – grid planning, tariff based bidding (PPP)
Regulatory interventions		
RE generation forecasting	Forecasting • Setting of state level, regional and central level (SLDC/RLDC/NLDC) forecasting center for RE • SLDC to consolidate the forecasts from all project owners	• GERC to introduce amendment in grid code • Forecasting- GERC directive to project developers and owners to provide the desired data to SLDC
Flexible capacity, spinning reserves and ancillary markets	Hydropower, gas based projects to be looked on for the purpose of spinning reserves CERC regulations for implementation of ancillary markets can serve as guidelines for Gujarat Primary responsibility of procuring ancillary services (SLDC). SLDC to pay through ARR/ separate budget provision • Manner of procurement of services -Power exchange, bi-lateral contracts, tendering etc. • Tariff determination by GERC • Fixed- For availability Rs/ MW/month • Variable- As and when services is called for (Rs/kWh) • Energy storage: Potential energy storage technologies to be explored	• CERC and GERC – Regulations for implementation of ancillary market • Energy and Petrochemicals Department, Gujarat – Policies for gas exploration and production, pricing, allocation and utilization
Other measures		
Advocacy and coordination	Coordinated planning at regional and central level for • RE forecasting and scheduling • developing the forecast evaluation methodology • Spinning reserves and ancillary market (coordination with other states) • Transmission network planning	GEDA, GUVNL, GERC, SLDC and GETCO with CTU / Central Govt. to coordinate appropriately

Annexure 1: Projected installed capacity of various RE sources required to meet the NAPCC target of 17% national RPO by the year 2021-22

	Required RE Installed Capacity (MW) required to meet national RPO of 17% by 2022						
Year	SHP	Biomass	Bagasse cogeneration	Waste to Energy	Solar	Wind	Total
2011-12	3395	1150	1985	90	941	15718	23279
2012-13	3710	1307	2381	99	1277	20692	29467
2013-14	4053	1486	2855	110	1734	26148	36386
2014-15	4429	1689	3424	121	2354	32086	44103
2015-16	4839	1920	4107	133	3196	38490	52684
2016-17	5287	2182	4925	147	4338	45325	62205
2017-18	5777	2481	4925	163	5889	54883	74118
2018-19	6312	2820	4925	179	7995	65085	87316
2019-20	6897	3205	4925	198	10853	75858	101936
2020-21	7536	3643	4925	218	14733	87080	118136
2021-22	8234	4141	4925	241	20000	98555	136097

Annexure 2: Power map of Gujarat



Source: GETCO (≡). Updated map till 31 March 2012.

Annexure 3: Discoms operational area in Gujarat

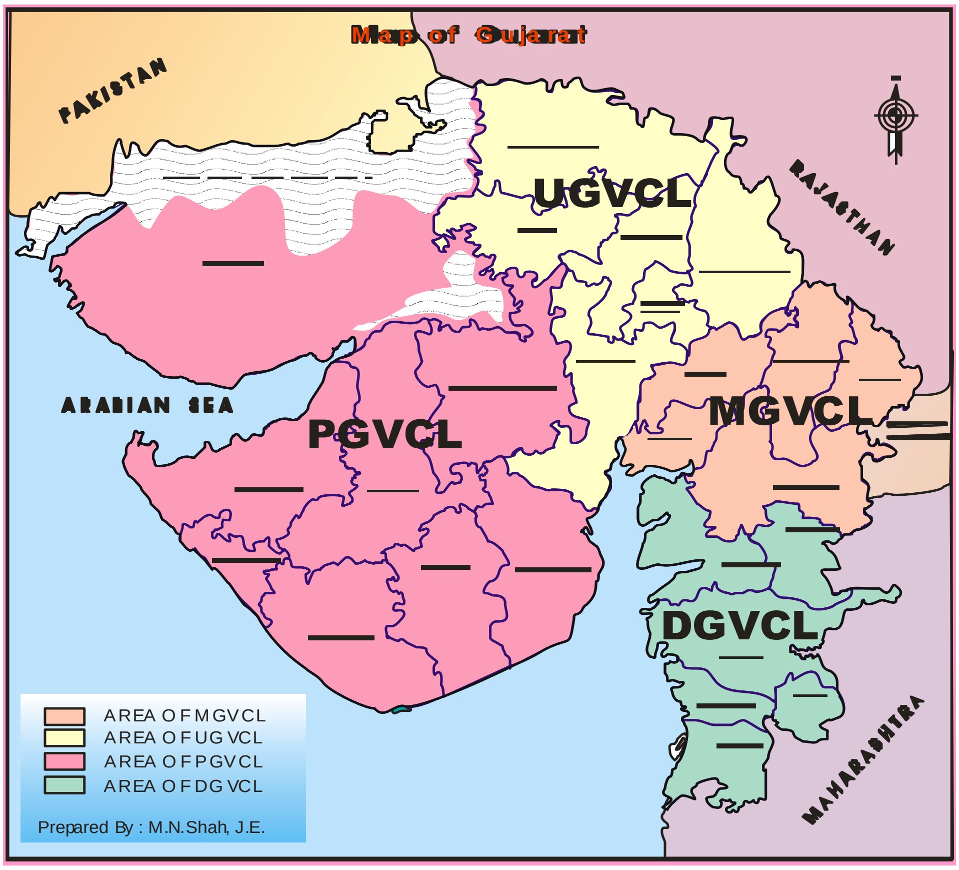


Figure A3.1: Map showing Geographical area covered by discoms in Gujarat

Table A3.1: Discoms in Gujarat and respective districts being covered.

Discom	Districts covered
Paschim Gujarat Vij Co. Ltd (PGVCL)	Rajkot, Porbandar, Junagadh, Jamnagar, Kutch, Bhavnagar, Amreli and Surendranagar
Madhya Gujarat Vij Co. Ltd (MGVCL)	Vadodara, Anand, Kheda, Panchmahal and Dahod
Uttar Gujarat Vij Co. Ltd (UGVCL)	Ahmedabad (except city), Gandhinagar (except city), Mehsana, Banas Kantha, Patan and Sabar Kantha
Dakshin Gujarat Vij Co. Ltd (DGVCL)	Surat (except city), Bharuch, Narmada, Dang, Valsad and Navsari
Torrent Power AE Co. Ltd	Ahmedabad and Gandhinagar
Torrent Power SE Co. Ltd,	Surat, Bhiwandi and Agra

Source: Websites of various Discoms

Annexure 4: List of Wind and Solar power plants installed in Gujarat

Table A4.1: List of solar power plants in Gujarat

S. No.	Solar Plants	Installed Capacity(MW)
1	Lanco Infratech (Bhadrada)	5
2	Lanco Infratech (Chandiyana)	15
3	Azure (Haryana)	10
4	Jaihind Projects	5
5	Precious Energy	15
6	Solitaire Energy	15
7	Azure (Gujarat)	5
8	ESP Urja	5
9	Millennium	10
10	Green Infra Solar	10
11	Adani Power	40
12	Visual Percept	25
13	Backbone	5
14	PLG Photovoltaic	20
15	Konark	5
16	Sadla-Waa	10
17	GaneshWani	5
18	Cbc	10
19	Ghi	10
20	Mosearbear	15
21	Aravali	5
22	Welspun	15
23	Hiraco	20
24	Louroux	25
25	Ganesh	10
26	Acame	15
27	Sunkon	5
28	Icml	9
29	Monosteel	10
30	Unity	5
31	Emco	5
32	Sandland	25
33	Charanka (TOTAL)	214
	TOTAL	603

Source: SLDC, Gujarat

Table A4.2: List of wind power plants in Gujarat

S. No.	Wind Plants	Installed capacity (MW)
1	Vershamedi (SUZLON)	120
2	Suthari (SUZLON)	285
3	Sindhodi (SUZLON)	312
4	Vandhiai (VESTAS)	174
5	132KV Sikharpur (VESTAS)	84
6	66KV Sikharpur (SUZLON)	55
7	Jangi (SUZLON)	107
8	Rrb(RRB)	77
9	Veer(VEER)	50
10	Navadra (GEDA)	29
11	Bhogat (GEDA)	25
12	Bita (SUZLON)	48
13	Sadodar (ENERCON)	462
14	132 KV Enercon (ENERCON)	180
15	Ukharla (SUZLON)	13
16	Gandhvi (SUZLON)	22
17	Baradiya (SUZLON)	20
18	Vasai(SUZLON)	28
19	Kuchhdi(SUZLON)	30
20	Layza(SUZLON)	38
21	Tunkar(SUZLON)	33
22	Jamanwada (SUZLON)	61
23	Tebhda (ENERCON)	140
24	Mota Gunda (ELECON)	25
25	Vinjalpar (ELECON)	35
26	Lamba (GEDA)	35
27	Changdai (SUZLON)	25
28	Vanku(SUZLON)	50
29	132 KV Mota gunda (SUZLON)	25
30	Sanodar (SUZLON)	9
31	Bhojpuri (SUZLON)	50
32	Jodiya (SUZLON)	33
33	Gorsar(SUZLON)	26
34	Parevada(SUZLON)	25
35	Barwada(SUZLON)	40
36	Rasaliya (ENERCON)	38
37	Kotda Pitha(SH.RAM EPC)	7
38	Arni Timba(AZALEA)	28
39	Jasdan Golida(GUJ FLURO)	50
40	66KV Amarapur (KINTECH)	6
41	Dhank(GEDA)	29
42	Mervadar (GEDA)	21
43	Patelka(GEDA)	19
	TOTAL	2969

Source: SLDC, Gujarat

Annexure 5: District wise estimated RE potential in Gujarat

TERI estimated following integrated RE potential for all the districts in Gujarat, based on the integrated renewable energy resource assessment for Gujarat

Table A5.1: Integrated wind, solar and biomass power potential in Gujarat

District	CSP with water availability (GW)	SPV Wind hybrid excluding CSP land (GW)	Only SPV excluding wind and CSP	Only wind excluding solar potential land (GW)	Biomass (GW)	Total integrated potential (GW)
Ahmedabad	1.61	1.45	1.01	0.00	0.06	4.13
Amreli	5.87	6.91	0.00	0.11	0.14	13.03
Anand	0.00	0.00	0.00	0.00	0.02	0.02
Banaskantha	7.74	5.87	0.27	0.95	0.08	14.90
Bharuch	22.74	1.84	0.00	0.24	0.04	24.86
Bhavnagar	3.93	9.04	0.00	0.01	0.19	13.17
Dahod	24.96	5.34	0.00	0.00	0.02	30.32
Gandhinagar	0.80	0.07	1.00	0.00	0.03	1.90
Jamnagar	37.11	12.67	0.41	1.04	0.21	51.44
Junagadh	3.94	5.26	0.38	0.00	0.19	9.77
Kachchh	87.76	148.13	8.92	133.26	0.07	378.14
Kheda	5.48	2.72	0.00	0.00	0.04	8.24
Mahsana	0.33	0.39	0.76	0.00	0.05	1.53
Narmada	17.76	1.69	0.00	0.00	0.03	19.47
Navsari	0.48	0.59	0.14	0.10	0.01	1.32
Panchmahal	7.21	3.39	0.00	0.00	0.01	10.61
Patan	7.03	1.20	0.00	1.87	0.04	10.14
Porbander	0.00	0.94	0.00	0.00	0.04	0.98
Rajkot	17.61	11.19	2.46	0.08	0.23	31.57
Sabarkantha	14.49	5.83	5.27	0.00	0.09	25.68
Surat	25.88	3.70	0.60	0.01	0.03	30.23
Surendranagar	4.26	4.29	0.00	1.11	0.14	9.79
The dangs	0.00	0.51	0.00	0.00	0.02	0.54
Vadodara	44.00	5.34	0.00	0.00	0.10	49.45
Valsad	4.71	2.24	0.13	0.43	0.02	7.53
Total	**345.71**	**240.60**	**21.36**	**139.21**	**1.89**	**748.77**

Apart from these the tidal power potential was estimated to be about 6800 MW

Annexure 6: Findings from literature survey

Table A6.1: Findings from literature review

S. No.	Reference	Key Findings
1.	Grid Integration of Wind Energy: A case study on a Typical Sub-transmission Network in Namibia, UPEC 2010, 31st Aug-3rd Sept, 2010 By A.I. Elombo, S.P. Chowdhury, S. Chowdhury, H.J. Vermeulen	Transient performance of a typical sub-transmission n/w in relation to grid integration of wind energy. 1. Effect of wind penetration using two type of generators variable speed synchronous gen (DDSG) and doubly fed induction generator (DFIG) is studied. For 20%, 30% and 40 % wind penetrations corresponding level of oscillation is visible. At the same level of penetration DFIG appeared to be impacting more adversely as compared to the DDSG. 2. System stability improves as point of integration shifts away from the conventional synchronous generator (In case of both technologies). 3. Voltage control can be achieved if AVR is included in the conventional generator.
2.	Impact of widespread photovoltaic generation on distribution systems, IET Renew. Power Gen. 2007(1), 33-40. By M. Thomson and D.G. Infield	Case studies of a very high penetration of PV within a typical UK urban distribution n/w (11 kV, 400 V and 230 V) are reported. 1. From the study it has been found that the maximum penetration of 30 % PV (30 % of the houses) is acceptable (considering +10%/-15% voltage change is acceptable, i.e. 253 V maximum for a 230 V system). 2. If the penetration is increased to 50 % the ten-minute mean voltage may exceed 253 V. 3. With PV penetration, the network losses are reduced. 4. At 50 % PV penetrations (nearly 2160 W_{peak}), there are more reverse power flows (in many cases reversal occurs only for few minutes). Also, for the system under consideration, it was observed that the for 50 % penetration, reversal occurs for 45 % of the installed cables including long line sections of 11 kV. 5. Reverse power flow in 11kV cable is associated with reverse power flow in some of distribution transformer. However the power flow through the primary substation transformers will correspond to sum of powers in all connected feeders. Even with 50 % penetration, reverse power through primary substation is unlikely. 6. If other forms of distributed generation e.g. combined heat and power (CHP) were also to be widely installed, reverse power flow through primary become strong possibility.
3.	**CASE STUDY** "Integration of photovoltaic power systems in high	This paper presents the results of international experiences on power quality analysis and the examination of grid stability of electric networks with high penetration of photovoltaic

S. No.	Reference	Key Findings
	penetration clusters for distribution network and mini grids", International Journal of Distributed Energy Resources, Volume 3 Number 3 July - September 2007 By Farid Katiraei, Konrad Mauch, Lisa Dignard-Bailey	systems. 1. *Clustered PV system in Japan (Gunma, commissioned by NEDO in 2002):* Projects include more than 500 houses with rooftop grid connected PV systems with overall capacity of 2.2 MWp of solar generation distributed in a 1-km^2 area. Groups of 5-15 PV integrated houses with an average of 4.1 KW PV generations per house are connected to an LV grid through LV transformer. The LV feeders are connected to medium voltage feeder which runs to a substation 7 km away. *Observations:* a. The increase in the daily global solar irradiation of above 5 kWh/m^2 causes up to 2% increase in the output voltage of individual PV-inverters. b. Load fluctuations, especially the difference between weekday household load and the load demand for weekends and national holidays (light loading) can shift up the voltage profile of a feeder that has an integrated PV system by 1.5% to 2% above the maximum limit. c. To mitigate the voltage rise, inverter with automatic voltage limiting based power factor control was used and o/p reduction by power tracking controller was used. Both options led to reduction in power output. 2. *PV settlement of "Schlierberg", Germany:* Overall capacity of this installation is 300 kWp. PV systems and buildings are distributed over two radial feeders supplied from 400 kVA transformer with short circuit level of 11 MVA at the point of common coupling (PCC). *Observations:* a. The measurements included a) real power flow of transformer, b) voltage variations at the PCC and at a house furthest away from the feeders. b. 2. Violations of maximum voltage were noticed during high solar irradiation intervals when high power penetration of PV system reversed the power flow. c. 3. Increase in phase voltage unbalance as a result of uneven distribution of inverters on different phases was also observed. 3. *Solar village at the Sydney Olympic Village, Australia:* It consists of 629 houses each with 1 KW rooftop PV system, and is connected to a voltage (240/415 V) underground distribution system.

S. No.	Reference	Key Findings
		Observations: examination was carried out to observe the harmonic distortion of grid voltage and it was found that THD was far below than the standard. The reasons for low THD are low grid impedance, short distance between houses and adequate cable size. 4. *PV suburb networks in Netherlands:* It consists of 500 houses with roof mounted PV. About 12 km2 of PV arrays with 1GWh annual generation is installed. *Observations:* a. It was observed that harmonic distortion was increases with high penetration of distributed PV sources which may violate Dutch limits. b. Some cases of inverter switch off were also observed which may be due to increase in harmonic interactions or feeder voltages.
4.	How do Wind and Solar Power Affect Grid Operations: The Western Wind and Solar Integration Study D.Lew and M. Miligan, 8th International Workshop on Large Scale Integration of Wind Power and on Transmission Networks for Offshore Wind Farms, Bremen, Germany October 14–15, 2009	1. This study examines the operational impact of up to 35% wind, photovoltaic and concentrating solar power on the West Connect grid in Arizona, Colorado, Nevada, New Mexico, and Wyoming. 2. Geographic diversity of renewable energy resources help in mitigating the variability. 3. Aggregation of wind and solar sites mitigates the relative impacts of the large ramps. 4. Drops in wind and solar combined with evening load rise drive extreme net load up-ramps in late afternoons during the late fall and winter. Extreme down-ramps are driven by summer/early fall evening load roll-off. 5. Operational Cost analysis done by GE is presented in this paper, Some of the conclusions are as i. Interestingly, no significant variations in operational results were found between the various scenarios. There was significant difference, however, in the different renewable energy penetration levels. ii. No significant operational issues were identified at penetrations up to 23% in the study footprint and 11% outside the study footprint. The impact is more severe at 35% inside the study footprint and 23% in the rest of WECC. iii. Displaced generation is mostly combined cycle and gas turbine units. At 35% renewables, coal units are also starting to be displaced. iv. At higher penetrations, it is essential that the load

S. No.	Reference	Key Findings
		be an active participant such as through interruptible load or demand response programs.
5.	Andrew Smith, "Quantifying Exports and Minimising Curtailment: From 20% to 50% Wind Penetration in Denmark", BIEE 2010.	1. For achieving 50% increase wind penetration in Denmark requires profound changes in power system architecture. 2. Sufficient reserves needs to be build up for balancing; Denmark cannot rely on international markets for this scenario. 3. Integration of all distributed players in the market, on both the supply side and demand side is required to meet the future balancing needs. 4. One such source of balancing is the country's extensive heat storage capacity in Banish district heating systems. 5. Along with the changes in power system architecture, demand side response management is also needed.
6.	Large-scale wind integration studies in United States: Preliminary Results, NREL, Miligan et.al, 8th International Workshop on Large Scale Integration of Wind Power and on Transmission Networks for Offshore Wind Farms Bremen, Germany October 14–15, 2009	1. Two studies a) Western wind and solar integration (WWSIS) and Eastern wind integration and transmission study (EWITS) are studied for 30% (of annual energy) penetration of wind energy. 2. The key objective of the study was to evaluate the wind integration cost. 3. 20 % wind penetration can be managed, but role of wind forecasting is important. 4. High penetrations of wind reduce the spot energy prices and production costs.
7.	M. Tsili, and S. Papathanassiou, "A review of grid code technical requirements for wind farms", IET Renewable Power Generation, 2009, 3 (3), 308-332.	1. Requirements imposed on wind farm differ considerably from one country to another. 2. Primary Frequency response requirements will be increased in a weakly interconnected systems, such as Ireland as compared to the strongly interconnected systems belonging to UCTE
8.	Operational Impacts of Wind Generation on California Power Systems, IEEE Transactions on Power Systems, Vol.24, No.2, May 2009. By Yuri V. Makarov et.al.	Impact of integrating 6700 MW wind generation on the regulation and load following requirements of the California Independent System Operator (CAISO) is studied. 1. Minute to minute variations and statistical interactions of the system parameters involved in these processes are depicted with sufficient details to provide a robust and accurate assessment of the additional capacity, ramping and ramp duration requirements that the CAISO regulation (AGC) and load following (ADS). 2. Significant increase in these requirements has been observed

S. No.	Reference	Key Findings
		from 2006 to 2010.
9.	Impact of wind power on the power system imbalances in Finland, IET Renewable Power Generation, 2010, 4(1), 75-84. By Helander, H, Holttinen, J. Paatero	In this work, the imbalance cost of wind power producers and the effect of wind power forecast error on net system imbalances in Finland are discussed. Link between the cost that wind power imbalances actually cause to power system and what is the cost allocation to wind power producers through balance settlement is studied. Two balance settlement rules for imbalance payment: one price and two price system are investigated. 1. Two price system for imbalances make the imbalance cost for producers higher than one price system, with lower wind power penetration when it doesn't affect the system imbalance significantly. 2. Increasing penetration level, increases wind prediction errors and they start to effect net system imbalance more. 3. According to comparison the increase in system cost because of wind power is lower than the imbalance payments for wind power producers.
10.	Supporting high penetrations of renewable generation via implementation of real-time electricity pricing and demand response, IET Renewable Power Generation, 2010, Vol. 4, Issue no. 4, pp. 369–382. By A.J. Roscoe G. Ault	This study instead examines the use of real-time pricing of electricity in the domestic sector to support high penetration of renewable energy. A simulation methodology for highlighting the potential effects of, and possible problems with, a national implementation of real-time pricing in the UK domestic electricity market is presented. This is done by disaggregating domestic load profiles and then simulating price-based elastic and load-shifting responses. Analysis of a future UK scenario with 15 GW wind penetration shows that during low-wind events, UK peak demand could be reduced by 8–11 GW. 1. The benefit can be used to justify the expense of installing and operating smart meters. 2. The case study concludes that many customers will perceive the real time pricing tariff as better value than fixed price tariff, because on real time pricing customers manages to use more energy but by spending less. 3. This study also tells three changes before implementation of real time pricing as a. More intelligent demand forecast algorithms are required. b. Price must be set appropriately. This is a fine balance between giving customers access to plentiful, cheap energy when it is available, but increasing prices just enough to reduce demand to meet the supply capacity when this capacity is limited. Increasing the price too far may penalize the

S. No.	Reference	Key Findings
		customers unnecessarily and demand may reduce more than is required. Hence, the load forecasting and price setting algorithm needs to be integrated. c. If automated energy display or smart meters are used within households to implement load shifting, then the possibility exists for all households to correlate their rescheduled loads to the same times giving rise to another demand spikes. 4. Such problems can be mitigated by a. Issuing different prices to different customers. A range of tariff could accomplish this. Prices can be location based to reduce nationally correlated demand spikes. This will assist power flow constraint management. b. Use of low end caps on real time prices, so that no single price period is the cheapest. c. Smart meters could, by law, be required to have some degree of randomization in timings and/or default parameter settings, so that without customer intervention, some diversity of response will occur.
11.	Power Quality and Integration of Wind Farms in Weak Grids in India, *Report by:* Risø National Laboratory, Roskilde, April 2000 by Poul Sørensen et.al.	This report is published as a part of joint Danish and Indian Project for investigating the integration of wind farms in weak grids. Two States Tamil Nadu and Gujarat wind farms are studied. *Tamil Nadu:* 1. Three substations dominated by certain type of wind farms are used for measurements. The measurements are done on 110 kV side, so the measurements are dominated by wind farms and are less effected by loads. 1. Measurement are taken in Muppandal at three substations Aralvai: 48 MVA, Radhapuram: 32 MVA and, Karunkulam: 42 MVA. *Gujarat:* 1. Two 66/11 kV substations are taken. Measurements are taken on both 66 kV and 11 kV sides. 2. Substations are: Dhank: 60 MVA where 36 MW wind turbine capacity installed and Lambha where 18 MW wind capacity turbine is connected. *Key Observations:* 1. Reactive power consumption of wind farms is significantly higher in Gujarat than in Tamil Nadu. As in Gujarat half of the capacitor banks in the wind turbines in Gujarat are defect. 2. 4-5 outages have been measured during 12 days of continuous logging on the 110 kV level in the wind farm substation Radhapuram in Tamil Nadu. 3. The measured voltage range on the 110 kV level in Muppandal is from +5% to –15 %, which exceeds the 12.5 % lower limit in IS 12360-1988 during peak load periods.

S. No.	Reference	Key Findings
		4. The measured frequency range is from 51 Hz to 48 Hz. Consequently, the lower limit is 4 % below the rated 50 Hz, which exceeds the ± 3 % frequency limit in IS 12360-1988. 5. A significant voltage distortion has been measured on the 110 kV level on the substation in Radhapuram. The frequency converters in the wind farm are most likely the source. 6. The voltage imbalance has been measured less than 2% in all substations. This may be because of the reason that measurements are done on dedicated feeders only not on the load sides.
12.	Grid Integration of Renewable Energy Systems, Renewable Energy, InTech, December 2009 By Athula et.al.	Integration of RE sources to electric grid poses different challenges when connected to transmission system and distribution system. *Integration of small scale generation into distribution grids (e.g. hydro, solar photovoltaic, biomass, small wind):* 1. Fault clearing, reclosing and inadvertent islanding operation are major protection related concerns. i) Radial systems are the most common form of distribution n/w configuration. They are usually protected by time graded over-current protection. Interconnection of DG may alter the coordination of the existing protection schemes, which may lead to malfunctioning of protection systems. ii) Short circuit level (SCL) is one of the main parameter used in selection of circuit breaker (CB) operation. SCL is characterized by equivalent impedance at the fault point and indicates the expected level of fault current. Time variation of fault current is influenced by the rotator machinery in the vicinity. Most of the distribution system is designed as passive n/w. However, with DG's equivalent impedance can decrease; result in an increase fault level. In case of fault, high current may exceed the interrupting capacity of existing breakers. High fault currents may also lead to CT saturation. Also, the coordination between relays may get disturbed. iii) Reverse Power Flow: In Radial distribution system, power flows are unidirectional. Connection of DG may lead to reverse power flow, which can also alter the relay coordination. iv) Lack of sustained fault current: In order for the protection relays to reliably detect and discriminate fault current from the normal load currents, the fault must cause a significant and sustained increase in the currents measured by the relays. However, DG's often employ induction generators, small synchronous generators and power electronic converters which can make only a limited contribution to fault currents.

S. No.	Reference	Key Findings
		v) Islanding: islanding results in abnormal variations of frequency and voltage in the island. 2. Voltage limits, harmonics and flickers are other concerns. *Integration of large scale renewable generation:* 1. The nature and magnitude of fault current contribution from wind farm depends upon the type of wind turbine technology. A good understanding of this is required to design equipment ratings for protection and control strategy. 2. Application of appropriate FACTS based reactive power compensation may help in improving the performance of wind farm. 3. At large scale integration reserve requirements, reactive power requirements, and support during disturbances are major challenges.
13	Large-scale integration of wind power into the existing Chinese energy system, Wen Liu,Henrik Lund, Brian Vad Mathiesen,,Science Direct, June 2011	1. Allow about 26% of wind penetration to existing Chinese energy system 2. Occurrence of CEEP(Critical Excess Electricity Production) 3. Modeling using Energy PLAN tool
14	The Solar Transitions research on solar mini grids in India: Learning from local cases of innovative socio-technical systems, Kirsten Ulsrud, Tanja Winther, Debajit Palit, Harald Rohracher, Jonas Sandgren, Science Direct, July 2011	1. Implementation and use of solar mini grid systems in India 2. Use of photo voltaic technology in developing countries 3. Social and technical factors influencing the system
15	Power Quality and Integration of Wind farms in Weak Grids in India, Riso National Laboratory, Roskilde, April 2000	1. Critical power quality issues in weak grids in India 2. Power quality data of major wind sites in India like Muppandal in Tamilnadu, Lamba and Dhank in Gujarat 3. Power factor improvement schemes 4. Induction generator interaction with weak grid 5. Capacitor compensation in wind turbines 6. Requirement of shunt connected power capacitor
16	Indian Wind Energy Outlook 2011,April 2011	1. Deal with Repowering Potential and challenges in India 2. Technology development trends and utilization of hybrid systems 3. Fiscal barriers for higher growth 4. New initiatives of government in renewable energy sector 5. Technical challenges in Indian grid 6. Benefits of wind forecasting and scheduling 7. Challenges for smart grid in India

Annexure 7: Analysis of electricity demand, wind energy generation and solar energy generation variations in Gujarat

The solar energy generation variation from Charanka solar park are shown below

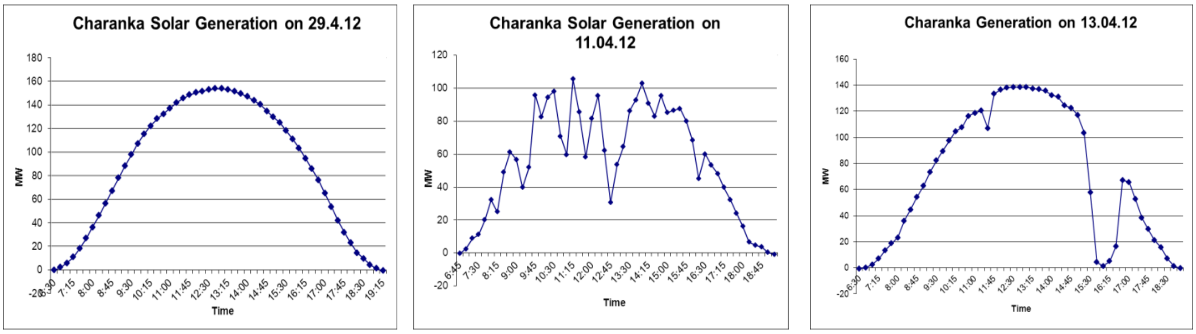


Figure A7.1: Solar energy injection pattern in Charanka

Source: GETCO

From Figure A7.1 of solar energy generation pattern it has been observed that generation from solar energy is higher during 10:00 hours to 15:00 hours in a normal sun-shine day. Like wind there is also reasonable varying output and sudden variation in case of solar. Days of variable output from solar is less as compare to wind.

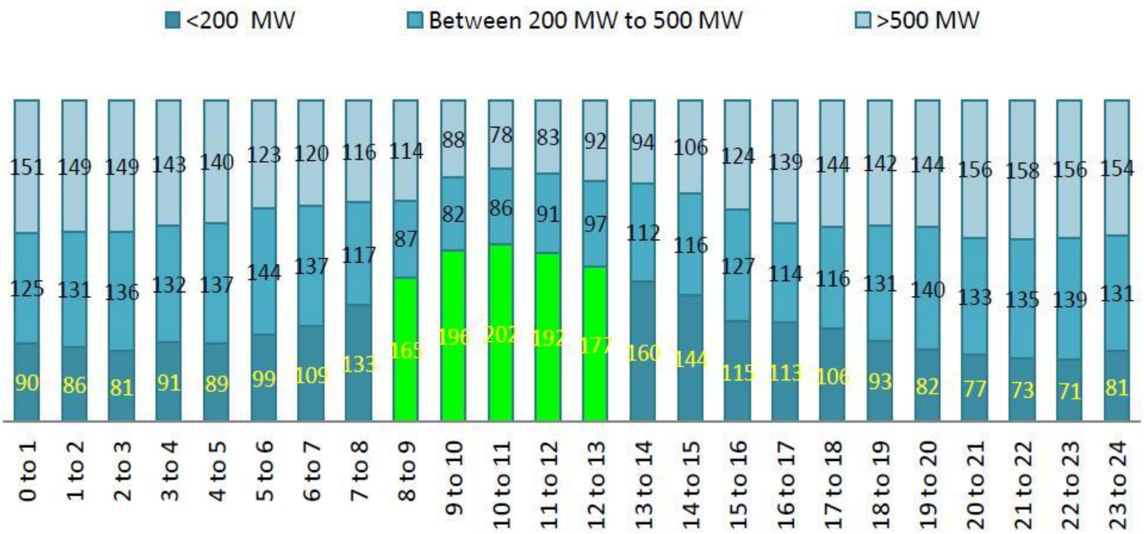


Figure A7.2: Hourly wind energy injection trends during the year 2011-12

Source: SLDC Gujarat annual report for year 2011-12

From Figure A7.2 it is observed that the wind energy injection between 8:00 hours to 13:00 hours during the year is quite less. There is a possibility of deficit in generation within mentioned time period in a day and can be met by adequate generation from solar energy. It has been observed that at the time of peak demand (Figure 3) in a day, generation from solar energy is higher and that from wind is lower. So, there is a possibility that significant generation from solar can fulfil the gap of low generation from wind and also meet the peak demand within 12:00 hours to 15:00 hours.

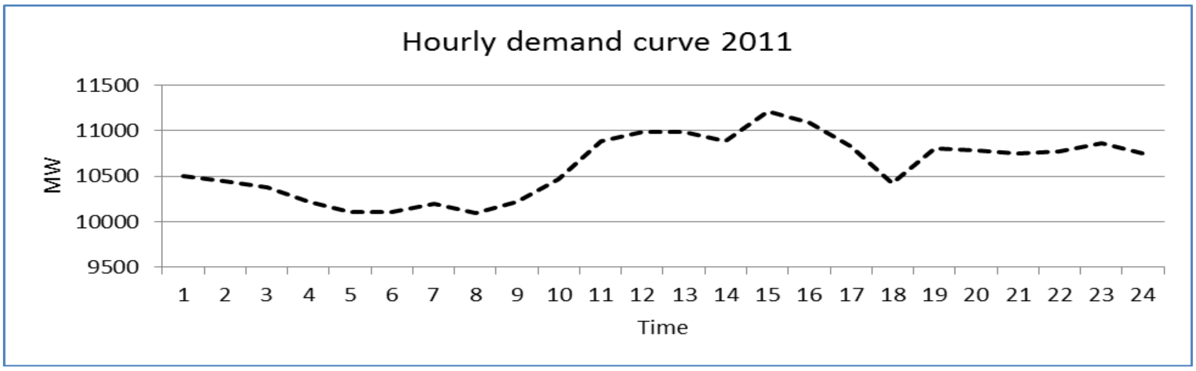


Figure A7.3: Hourly load curve of Gujarat for the year 2011

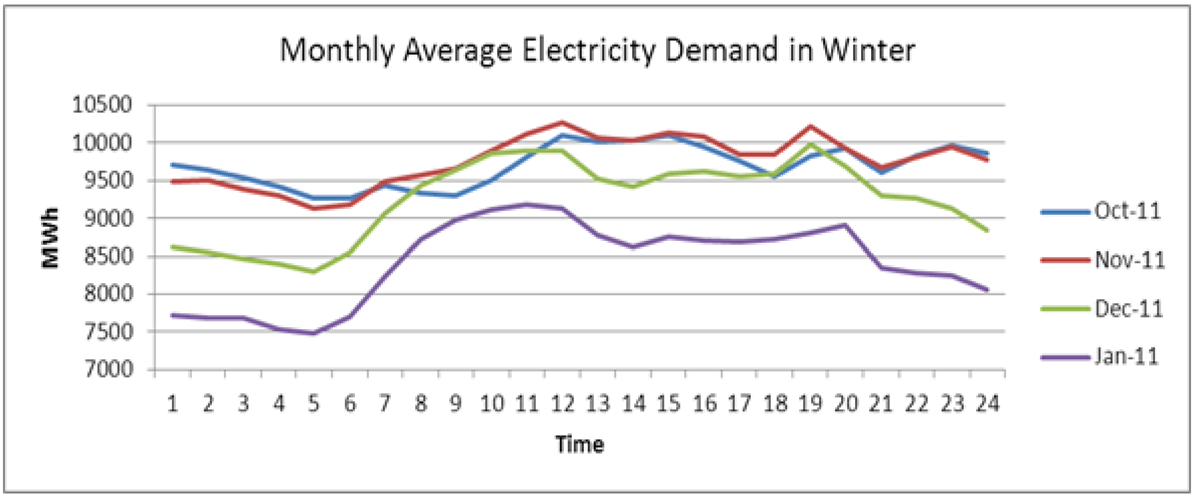


Figure A7.4: Monthly average electricity demand in winter

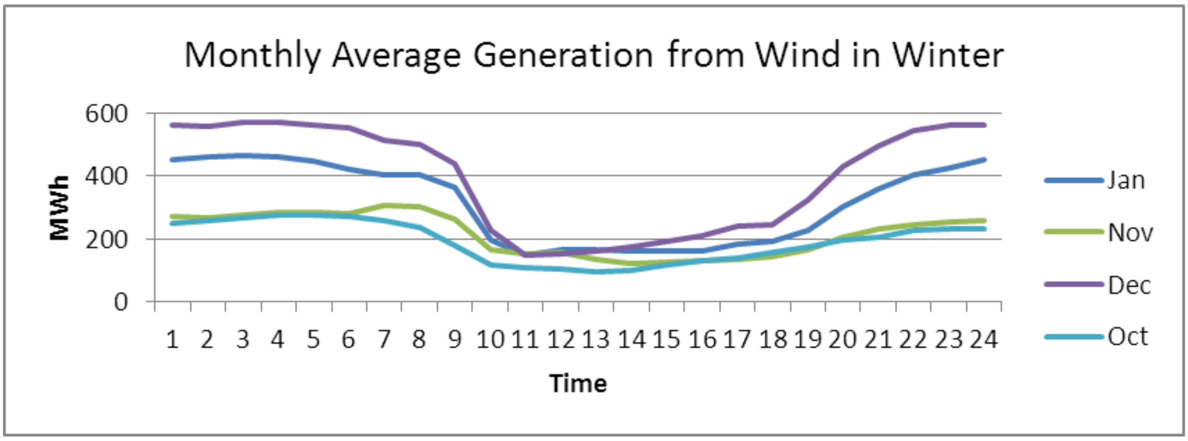


Figure A7.5: Monthly average generation from wind in winter

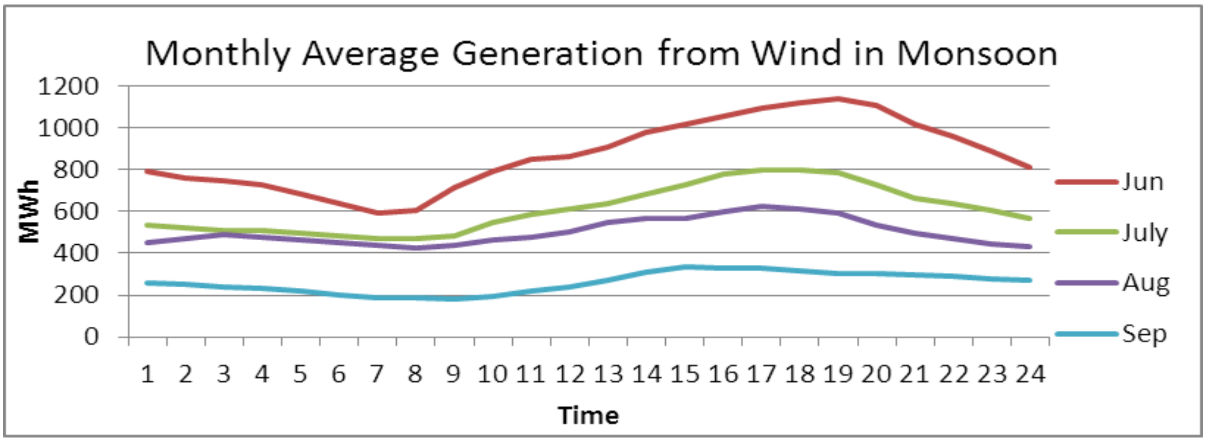


Figure A7.6: Monthly average generation from wind in monsoon

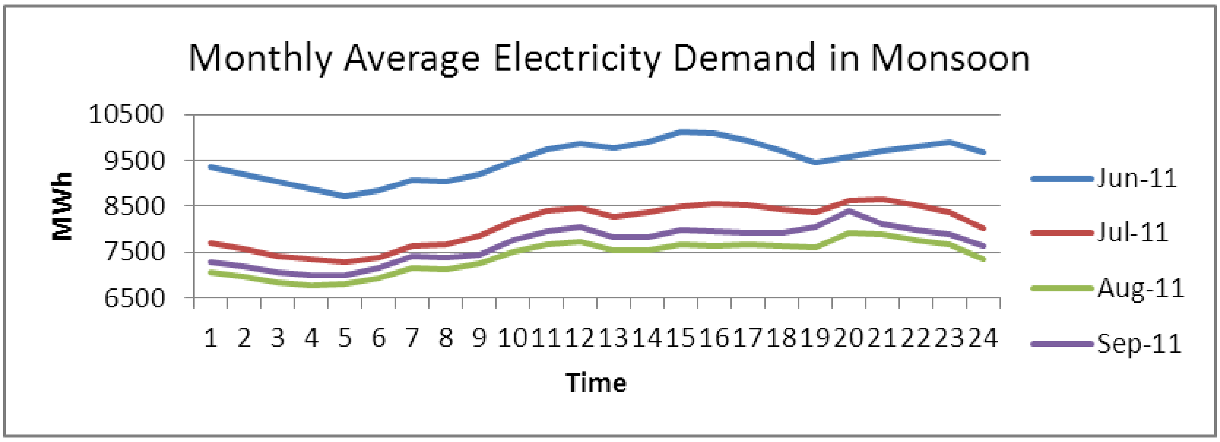


Figure A7.7: Monthly average electricity demand in monsoon

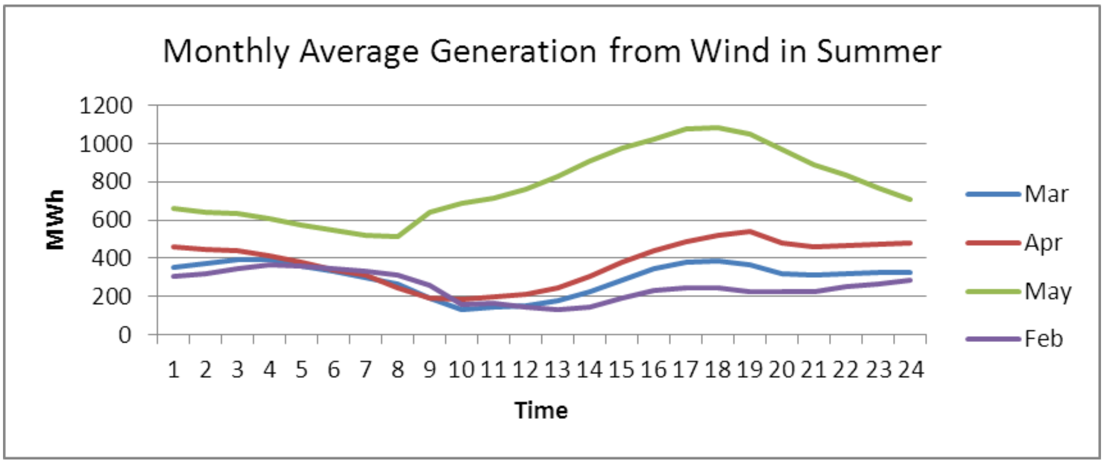


Figure A7.8: Monthly average generation from wind in summer

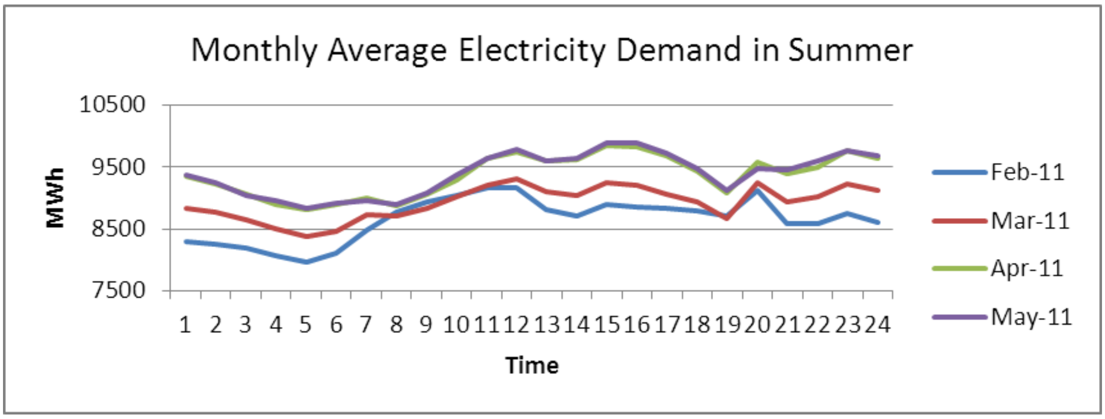


Figure A7.9: Monthly average electricty demand in summer

Annual hourly average electricity generation from wind is higher from 17:00 hours in the morning to 6:00 hours in the evening in a day. Thus, generation from wind can be utilised to meet high demands in the period of 15:00 hours to 23:00 hours. Within the period of 0:00 hours to 6:00 hours generation from wind can be utilized fully which may reduce the generation from fossil fuel based power plants.

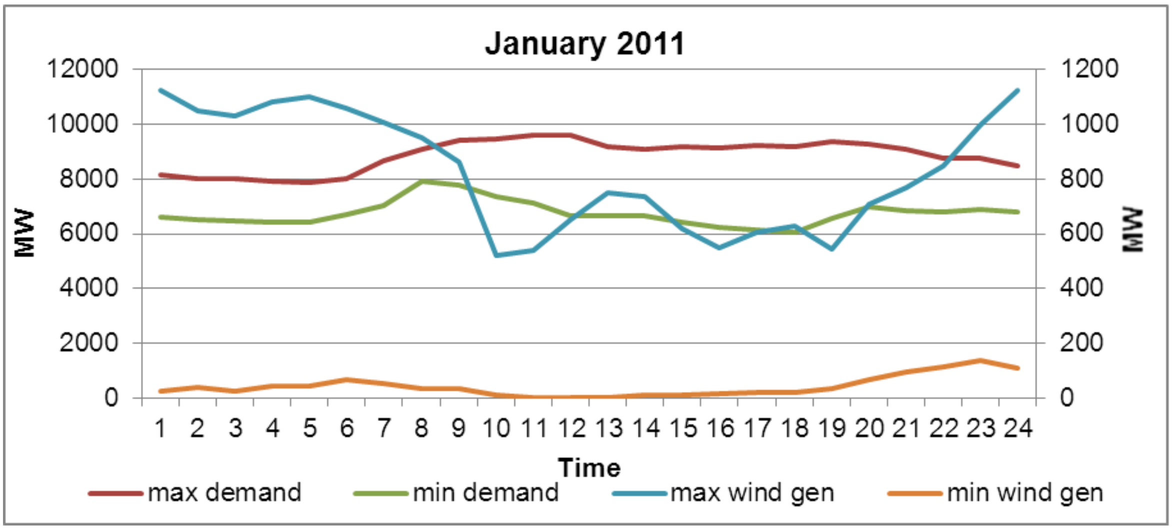


Figure A7.10: Electricity generation from wind in the month January 2011

1. Electricity generation from Wind in the month of January doesn't follow significantly the demand pattern.
2. More variability in the wind availability has been observed in the month of January.
3. High wind and high demand: Wind is capable of meeting around 5.5% - 13.8% of electricity demand.
4. Low wind and low demand: there is a case at 13:00 hour in a day of January wind is not capable of contributing any significant amount to 6662 MW of demand and at 6:00 hours wind is capable of meeting 1% of electricity demand.
5. High wind and low demand: there is a case that at 1:00 hour wind is meeting 17 % (1126 MW of wind is contributed to 6626 MW of demand) of electricity demand and also there is a case that at 10:00 hours wind is contributing 7% (521 MW of wind has contribution to 7343 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 1.6% towards electricity demand.
7. In the month of January the range of meeting electricity demand by wind varies from 0 to 17%.

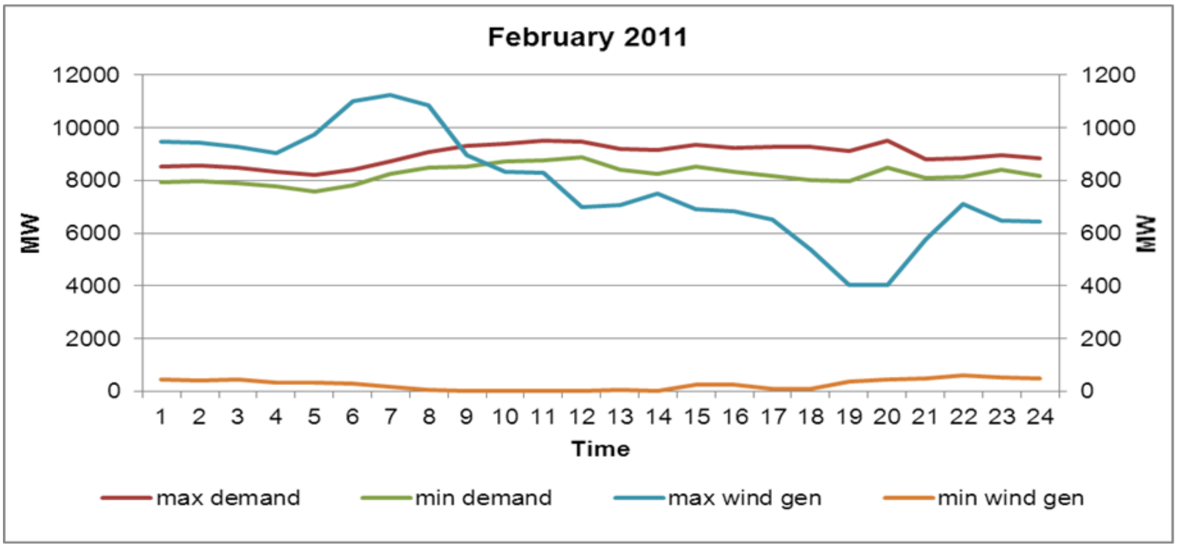


Figure A7.11: Electricity generation from wind in the month February 2011

1. Electricity generation from Wind in the month of February doesn't follow the demand properly.
2. More variability in the wind availability has been observed in the month of February.
3. High wind and high demand: Wind is capable of meeting around 4.2% - 12.9% of electricity demand.
4. Low wind and low demand: there is a case at 12:00 hours wind is not capable of contributing any significant amount to 8893 MW of demand and at 22:00 hours wind is capable of meeting 0.8% of electricity demand.
5. High wind and low demand: there is a case that at 7:00 hours wind is meeting 13.6 % (1126 MW of wind is contributed to 8261 MW of demand) of electricity demand and also there is a case that at 20:00 hours wind is contributing 4.8% (405 MW of wind has contribution to 8502 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 0.7% towards electricity demand.
7. In the month of February the range of meeting electricity demand by wind varies from 0 to 13.6%.

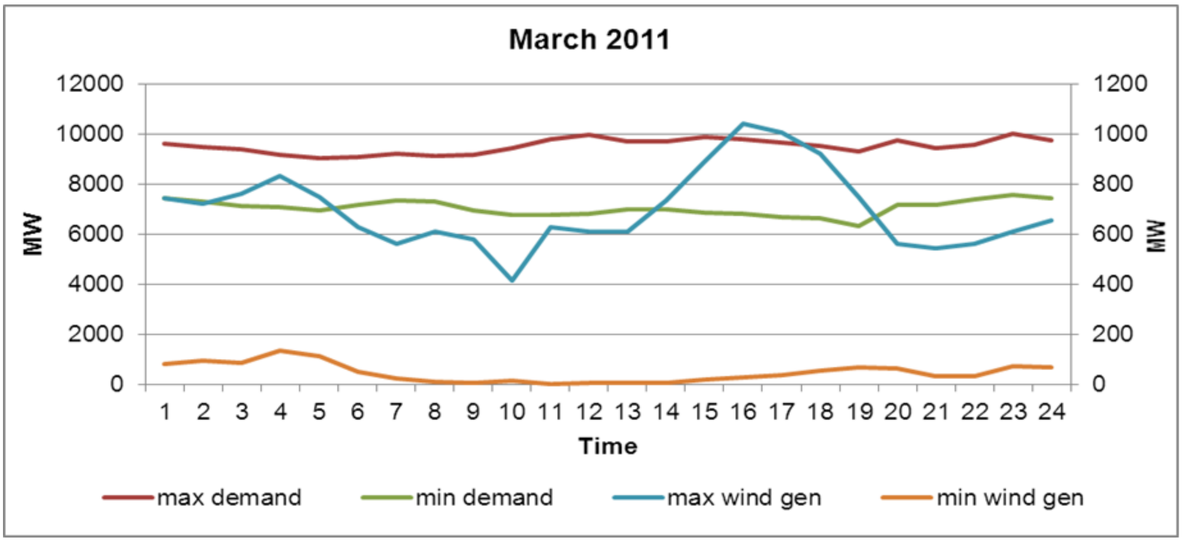


Figure A7.12: Electricity generation from wind in the month March 2011

1. Electricity generation from Wind in the month of March doesn't follow the demand properly.
2. More variability in the wind availability has been observed in the month of March.
3. High wind and high demand: Wind is capable of meeting around 4.4% - 10.6% of electricity demand.
4. Low wind and low demand: there is a case at 11:00 hours wind is not capable of contributing any significant amount to 6797 MW of demand and at 4:00 hours wind is capable of meeting 1.9% of electricity demand.
5. High wind and low demand: there is a case that at 16:00 hours wind is meeting 15.3 % (1040 MW of wind is contributed to 6815 MW of demand) of electricity demand and also there is a case that at 10:00 hours wind is contributing 6.1% (414 MW of wind has contribution to 6757 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 1.5% towards electricity demand.
7. In the month of March the range of meeting electricity demand by wind varies from 0 to 15.3%.

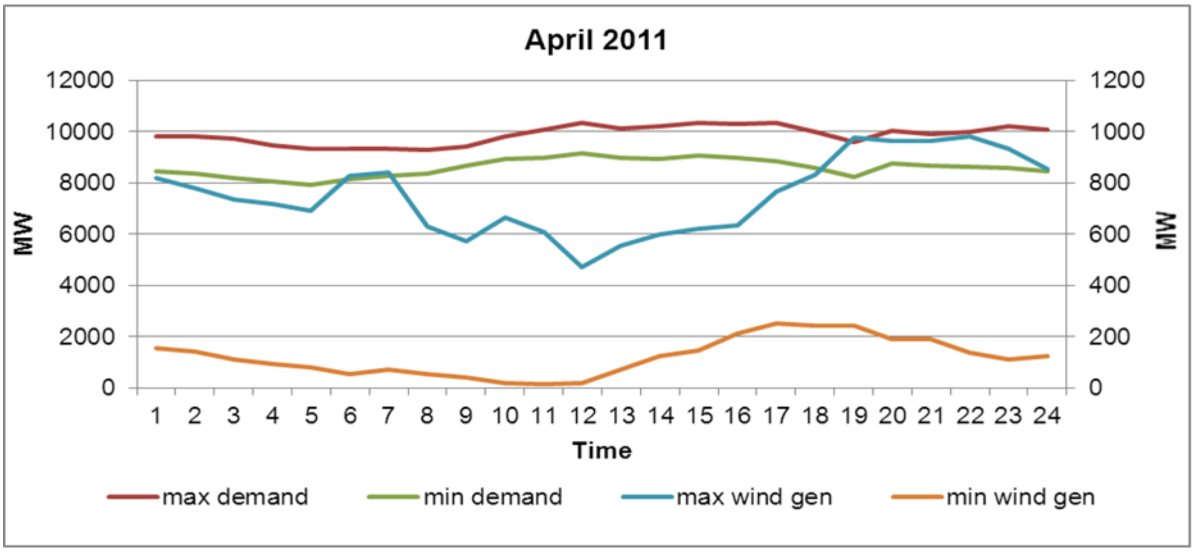


Figure A7.13: Electricity generation from wind in the month April 2011

1. Electricity generation from Wind in the month of April doesn't follow the demand properly.
2. More variability in the wind availability has been observed in the month of April.
3. High wind and high demand: Wind is capable of meeting around 4.6% - 10.1% of electricity demand.
4. Low wind and low demand: there is a case at 11:00 hours wind is not capable of contributing any significant amount to 8994 MW of demand and at 17:00 hours wind is capable of meeting 2.9% of electricity demand.
5. High wind and low demand: there is a case that at 19:00 hours wind is meeting 11.8 % (975 MW of wind is contributed to 8241 MW of demand) of electricity demand and also there is a case that at 12:00 hours wind is contributing 5.2% (474 MW of wind has contribution to 9151 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 2.4% towards electricity demand.
7. In the month of April the range of meeting electricity demand by wind varies from almost 0 to 11.8%.

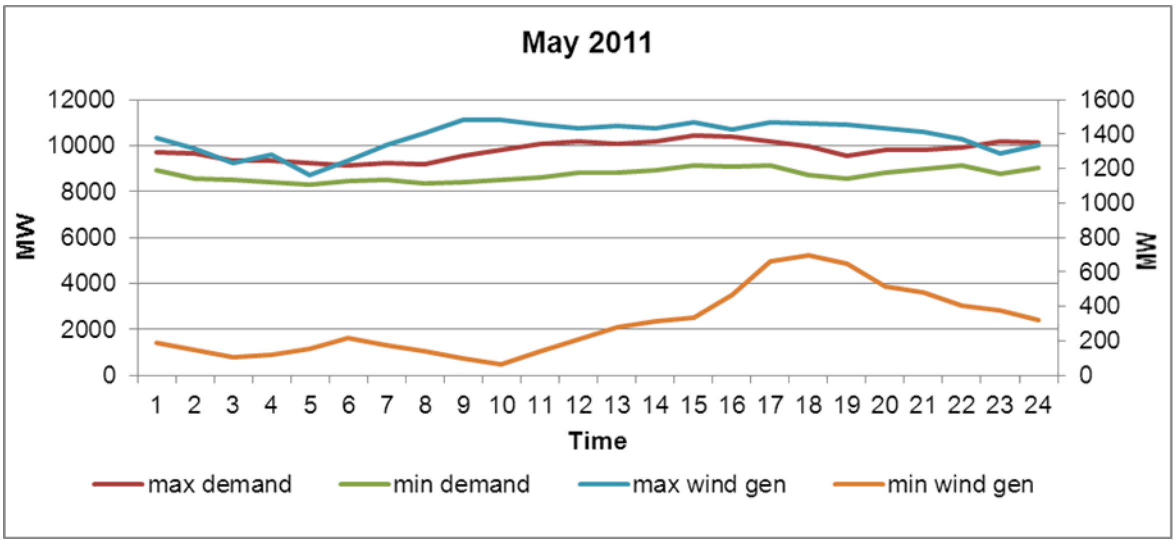


Figure A7.14: Electricity generation from wind in the month May 2011

1. Electricity generation from Wind in the month of May doesn't follow the demand properly.
2. High wind and high demand: Wind is capable of meeting around 12.6% - 15.5% of electricity demand.
3. Low wind and low demand: there is a case at 10:00 hours wind is capable of contributing only 0.8% of 8994 MW of electricity demand and at 18:00 hours wind is capable of meeting 8% of electricity demand.
4. High wind and low demand: there is a case that at 9:00 hours wind is meeting 17.7% (1482 MW of wind is contributed to 8378 MW of demand) of electricity demand and also there is a case that at 5:00 hours wind is contributing 14% (1163 MW of wind has contribution to 8315 MW of electricity demand) of electricity demand.
5. Low wind and high demand: wind contributes maximum of 7% towards electricity demand.
6. In the month of April the range of meeting electricity demand by wind varies from 0.7% to 17.7%.

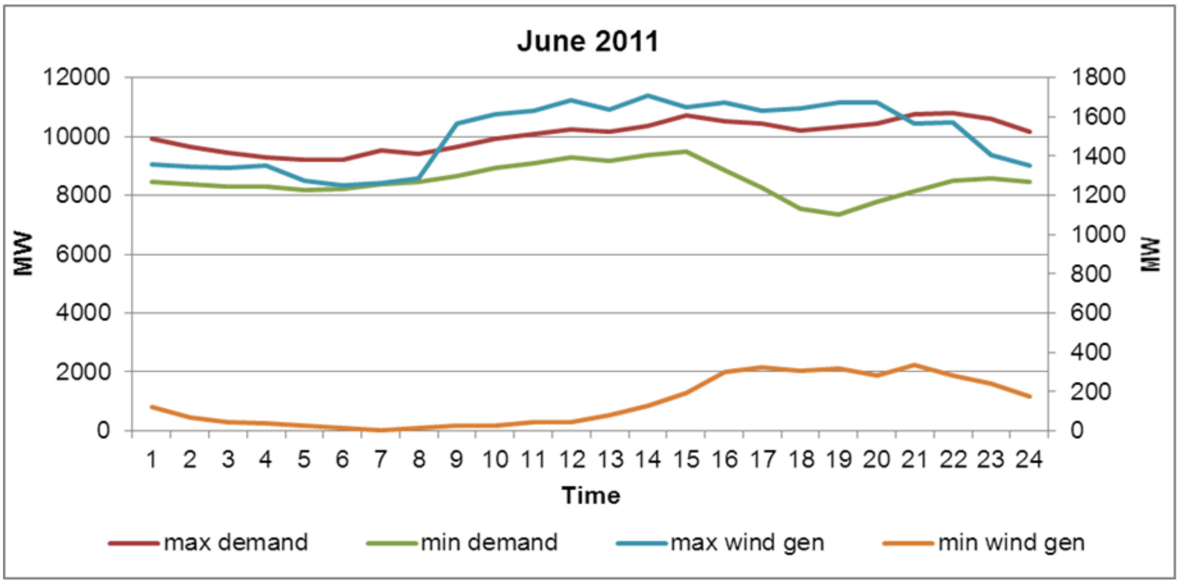


Figure A7.15: Electricity generation from wind in the month May 2011

1. Electricity generation from Wind in the month of June follows demand pattern.
2. High wind and high demand: Wind is capable of meeting around 13% of electricity demand.
3. Low wind and low demand: there is a case at 7:00 hour wind is not capable of contributing any significant amount to 8386 MW of demand and at 19:00 hours wind is capable of meeting 4% of electricity demand.
4. High wind and low demand: there is a case that at 19:00 hour wind is meeting 23% (1672 MW of wind is contributed to 7360 MW of demand) of electricity demand.
5. Low wind and high demand: wind contributes maximum of 3% towards electricity demand.
6. In the month of June the range of meeting electricity demand by wind varies from almost 0 to 23%.

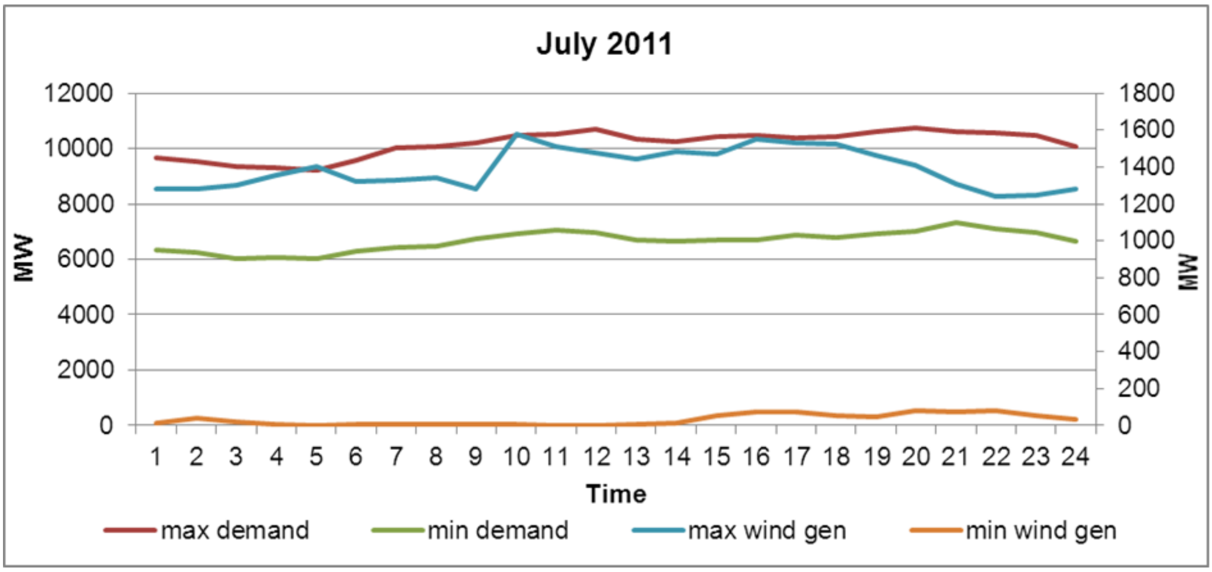


Figure A7.16: Electricity generation from wind in the month July 2011

1. Electricity generation from Wind in the month of July follows demand pattern.
2. High wind and high demand: Wind is capable of meeting around 12% - 15% of electricity demand.
3. Low wind and low demand: there is a case at 5:00 hour wind is not capable of contributing any significant amount to 6013 MW of demand and at 17:00 hours wind is capable of meeting 1% of electricity demand.
4. High wind and low demand: there is a case that at 18:00 hour wind is meeting 22.5% (1526 MW of wind is contributed to 6788 MW of demand) of electricity demand.
5. Low wind and high demand: wind contributes maximum of 1% towards electricity demand.
6. In the month of July the range of meeting electricity demand by wind varies from almost 0 to 22.5%.

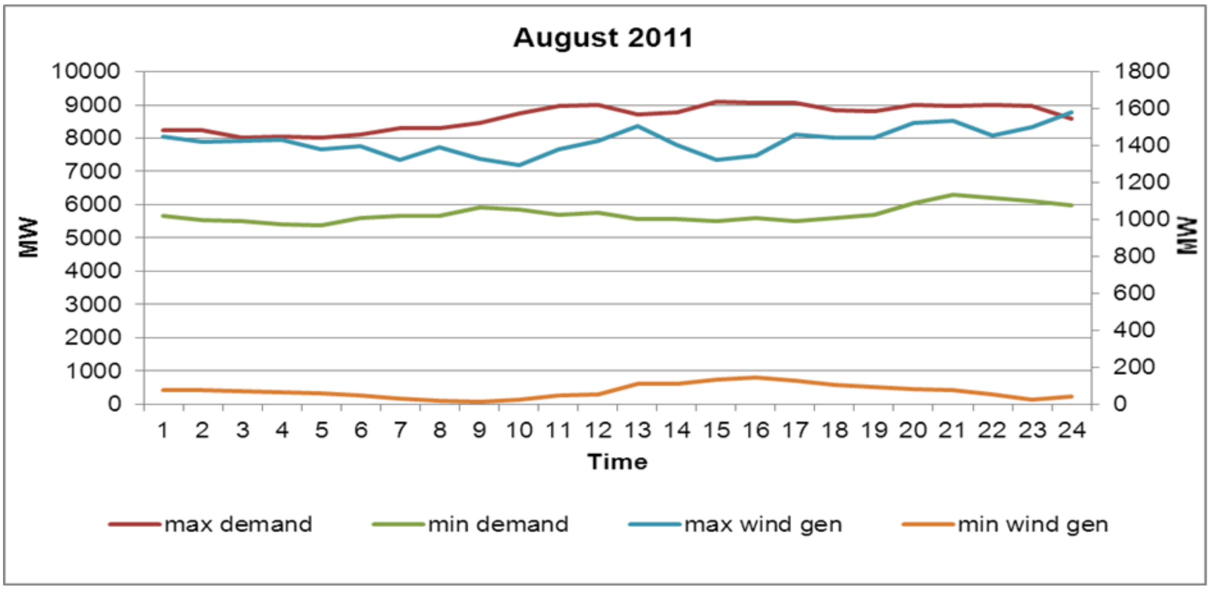


Figure A7.17: Electricity generation from wind in the month August 2011

1. Electricity generation from Wind in the month of August follows demand pattern.
2. High wind and high demand: Wind is capable of meeting around 15% - 17% of electricity demand.
3. Low wind and low demand: there is a case at 9:00 hour wind is not capable of contributing any significant amount to 5915 MW of demand and at 16:00 hours wind is capable of meeting 2.6% of electricity demand.
4. High wind and low demand: there is a case that at 24:00 hour wind is meeting 26.4% (1578 MW of wind is contributed to 5978 MW of demand) of electricity demand.
5. Low wind and high demand: wind contributes maximum of 1.6% towards electricity demand.
6. In the month of August the range of meeting electricity demand by wind varies from almost 0 to 26.4%.

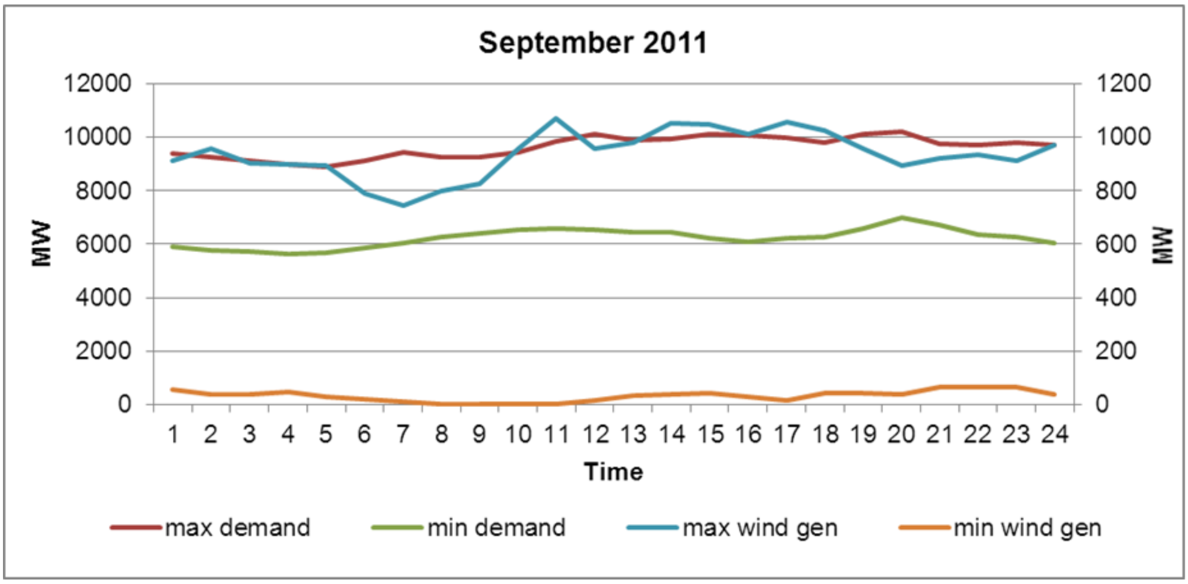


Figure A7.18: Electricity generation from wind in the month September 2011

1. Electricity generation from Wind in the month of September follows demand pattern.
2. High wind and high demand: Wind is capable of meeting around 8% - 11% of electricity demand.
3. Low wind and low demand: there is a case at 9:00 hour wind is not capable of contributing any significant amount to 6423 MW of demand and at 16:00 hours wind is capable of meeting 1% of electricity demand.
4. High wind and low demand: there is a case that at 2:00 hour wind is meeting 16.6% (956 MW of wind is contributed to 5751 MW of demand) of electricity demand.
5. Low wind and high demand: wind contributes maximum of 1% towards electricity demand.
6. In the month of September the range of meeting electricity demand by wind varies from almost 0 to 16.6%.

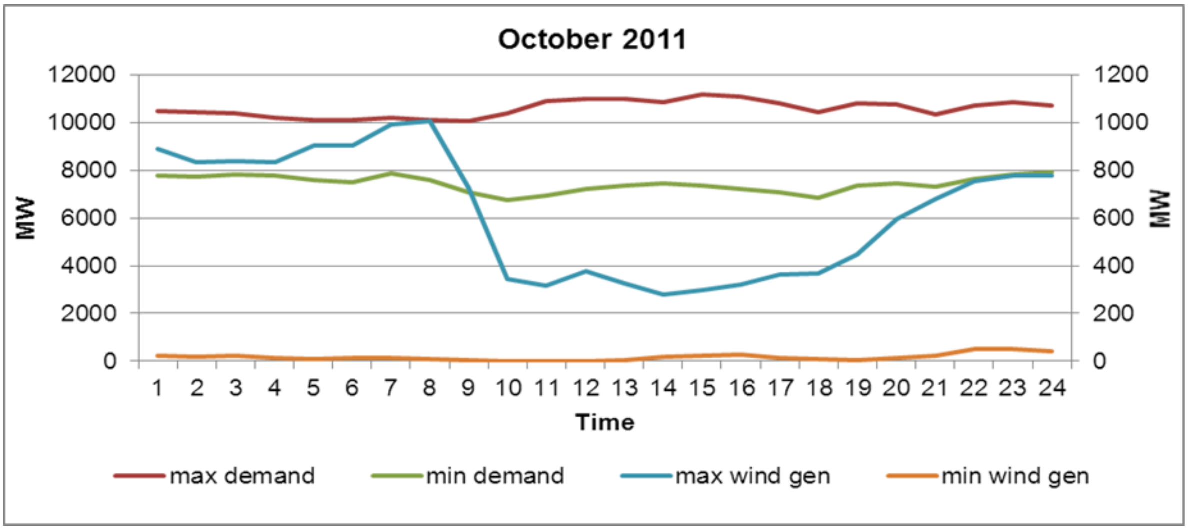


Figure A7.19: Electricity generation from wind in the month October 2011

1. Electricity generation from Wind in the month of October doesn't follow significantly the demand pattern.
2. More variability in the wind availability has been observed in the month of October.
3. High wind and high demand: Wind is capable of meeting around 2.6% - 10% of electricity demand.
4. Low wind and low demand: there is a case at 10:00 hours wind is not capable of contributing any amount to 6771 MW of demand and at 23:00 hours wind is capable of meeting 0.7% of electricity demand.
5. High wind and low demand: there is a case that at 8:00 hours wind is meeting 13.2% (1006 MW of wind is contributed to 7615 MW of demand) of electricity demand and also there is a case that at 14:00 hours wind is contributing 3.7% (279 MW of wind has contribution to 7463 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 0.5% towards electricity demand.
7. In the month of October the range of meeting electricity demand by wind varies from almost 0 to 13.2%.

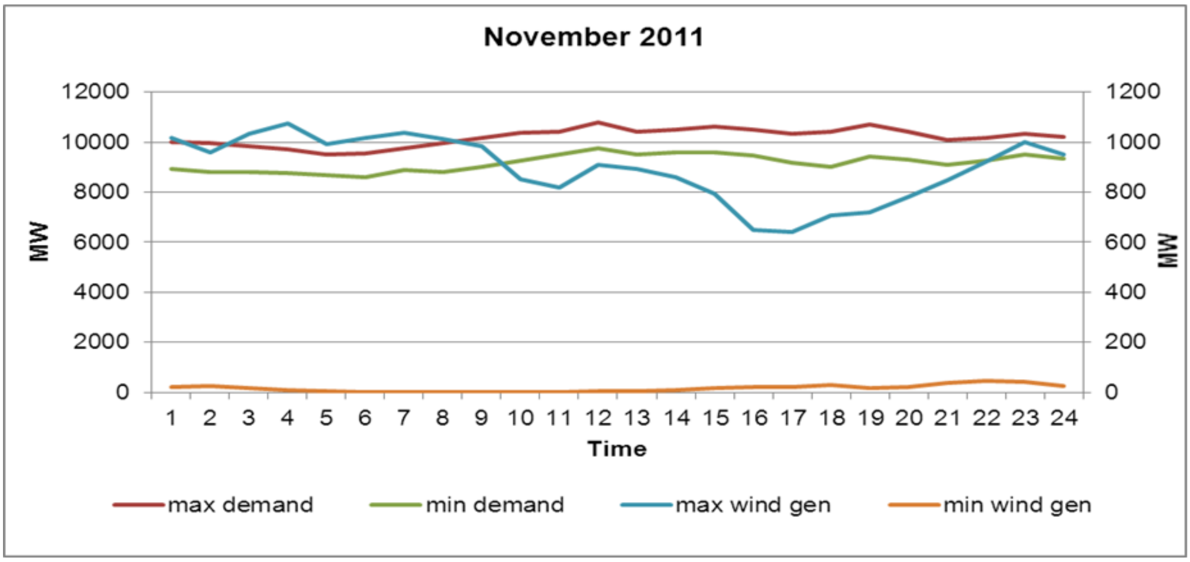


Figure A7.20: Electricity generation from wind in the month November 2011

1. Electricity generation from Wind in the month of November doesn't follow significantly the demand pattern.
2. More variability in the wind availability has been observed in the month of November.
3. High wind and high demand: Wind is capable of meeting around 6.2% - 11% of electricity demand.
4. Low wind and low demand: there is a case at 7:00 hours wind is not capable of contributing any amount to 8880 MW of demand and at 23:00 hours wind is capable of meeting 0.4% of electricity demand.
5. High wind and low demand: there is a case that at 4:00 hours wind is meeting 12.3% (1074 MW of wind is contributed to 8760 MW of demand) of electricity demand and also there is a case that at 17:00 hours wind is contributing 7% (641 MW of wind has contribution to 9164 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 0.5% towards electricity demand.
7. In the month of November the range of meeting electricity demand by wind varies from almost 0 to 12.3%.

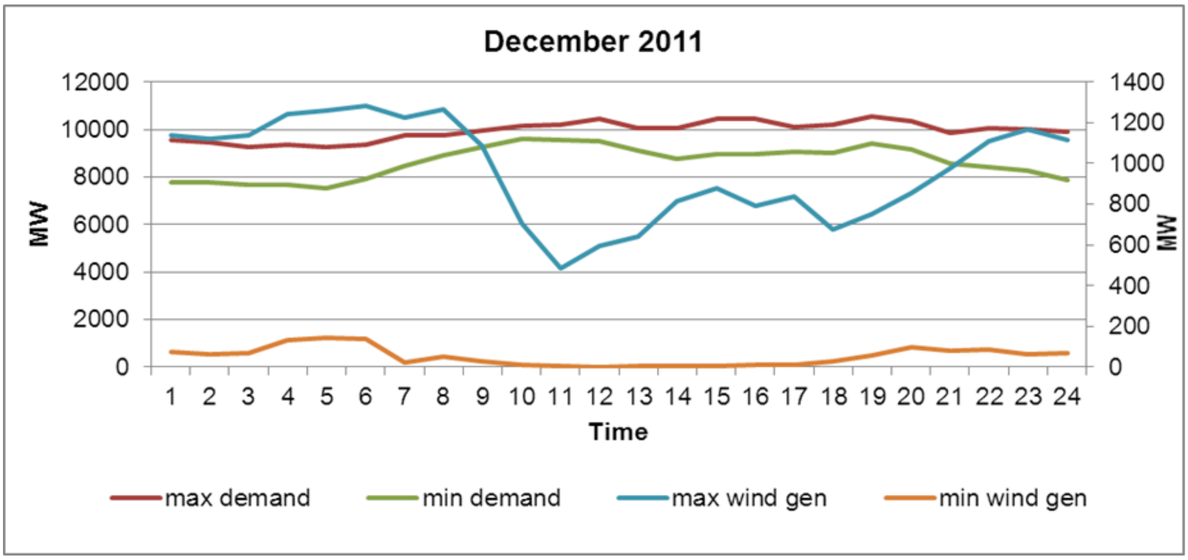


Figure A7.21: Electricity generation from wind in the month December 2011

1. Electricity generation from Wind in the month of December doesn't follow significantly the demand pattern.
2. More variability in the wind availability has been observed in the month of December.
3. High wind and high demand: Wind is capable of meeting around 4.8% - 13.7% of electricity demand.
4. Low wind and low demand: there is a case at 12:00 hours wind is not capable of contributing any significant amount to 9495 MW of demand and at 5:00 hours wind is capable of meeting 1.9% of electricity demand.
5. High wind and low demand: there is a case that at 6:00 hours wind is meeting 16.2% (1283 MW of wind is contributed to 7909 MW of demand) of electricity demand and also there is a case that at 11:00 hours wind is contributing 5% (487 MW of wind has contribution to 9562 MW of electricity demand) of electricity demand. Thus there is a large variability.
6. Low wind and high demand: wind contributes maximum of 1.5% towards electricity demand.
7. In the month of December the range of meeting electricity demand by wind varies from almost 0 to 16.2%.

Annexure 8: Analysis of grid codes and grid connectivity standards with recommendations for Gujarat state Grid code

Current grid connectivity status and guidelines for renewable energy in Gujarat

In Gujarat wind firms are connected at 66 kV, 132 kV and 220 kV substations. Most of the solar power plants are connected to 66 kV substations where power plants at Charanka solar park are connected to 66 kV, 220 kV and 400 kV substations. Existing Grid connectivity Standards applicable to the Generating Units in Gujarat are[1];

1. The excitation system for every generating unit:-

    a. shall have state of the art excitation system;

    b. shall have Automatic Voltage Regulator (AVR). Generators of 100MW rating and above shall have Automatic voltage Regulator with digital control and two separate channels having independent inputs and automatic changeover; and the AVR of generator of 100 MW and above shall include power system stabilizer (PSS).

2. The short-circuit ratio (SCR) for generators shall be as per IEC-34.

3. The generator transformer windings shall have delta connection on low voltage side and star connection on high voltage side. Star point of high voltage side shall be effectively (solidly) earthed so as to achieve the Earth fault factor of 1.4 or less.

4. All generating machines irrespective of capacity shall have electronically controlled governing system with State speed/load characteristics to regulate frequency. The governors of thermal generating units shall have a drop of 3 to 6%.

5. The project of the M/s COMPANY shall not cause voltage and current harmonics on the grid which exceed the limits specified in Institute of Electrical and Electronics Engineers (IEEE) standard 519.

6. Generating units located near load centre, shall be capable of operating at rated output for power factor varying between 0.85 lagging (over-excited) to 0.95 leading (under-excited) and Generating Units located far from load centers shall be capable of operating at rated output for power factor varying between 0.9 lagging (over-excited) to 0.95 leading (under-excited). The above performance shall also be achieved with voltage variation of $\pm$ 5% of nominal frequency variation of +3% and -5% and combined voltage and frequency variation of $\pm$ 5%. However, for gas turbines, the above performance shall be achieved for voltage variation of $\pm$ 5%.

[1] www.getcogujarat.com/getco/.../File/Connection%20Agreement.doc

7. The coal and lignite based thermal generating units shall be capable of generating up to 105% of Maximum continuous Rating (subject to maximum load capability under valve wide open condition) for short duration to provide the frequency response.

8. Every generating unit shall have standard protections to project the units not only from faults within the units and within the station but also from faults in transmission lines. For generating units having rated capacity greater than 100 MW, two independent sets of protections acting on two independent sets of trip coils fed from independent Direct Current (DC) supplies shall be provided. The protections shall include but not be limited to the local Breaker Back-up (LBB) protection.

9. Bus bar protection shall be provided at the switchyard of all generating station.

The station auxiliary power requirement, including voltage and reactive requirements, shall not impose operating restrictions on the grid beyond those specified in the Grid code or state Grid code as the case may be.

Fault ride-through capability

By dynamic grid support, voltage stability during voltage drops in the overlaying high-voltage grid is meant and often referred to as Fault-Ride-Through (FRT) requirements and they are described by a voltage against time characteristic. Due to an increasing penetration of renewable energies in the grid, it is necessary to include these plants in dynamic grid support. This means generating plants should have following capabilities:

- stay connected during a fault,
- support the voltage by providing reactive power during the fault
- withstand voltage dips down to a certain percentage of the nominal voltage (0% in some cases) and
- consume the same or less reactive power after the fault clearance

Wind generating stations and Solar Generating stations should have fault ride through capability so that grid is not destabilized. The fault ride through characteristics should be estimated based on the local grid characteristics by undertaking the system study. In the draft of CEA technical standards of grid connectivity, it has been mentioned that the wind turbines should remain connected at least for 300 ms up to voltage drop of 15 % of the nominal. (Maximum fault clearance time is 300 ms).

International experiences

Table A8.1: Characteristics of FRT curve in various Grid Codes [6]

Grid code of	Fault duration (milli second)	Minimum voltage level (% of Vnominal)	Voltage restoration (second)
Germany	150	0	1.5
UK	140	0	1.2
Ireland	625	15	3.0
Nordel	250	0	0.75
Denmark (<100kV)	140	25	0.75
Denmark (>100kV)	100	0	1.0
Belgium	200	0	0.7
Canada	150	0	1.0
USA	625	15	3.0
Spain	500	20	1.0
Italy	500	20	0.8
Sweden (<100MW)	250	25	0.25
Sweden (>100MW)	250	0	0.8
New Zealand	200	0	1.0

For example in Spain, in the case of a fault in the grid (voltage sag) a power plant can be forced to shut down. This behaviour increases the fault of the grid. Therefore, an incentive is given to wind power plant operators to provide fault ride-through capability so that the plant is not shut down in case of a fault. In the case that the wind power plant provides fault ride-through capability, a bonus of 3.8 €/MWh is paid. This is applied if the wind power plant has been installed before January 1st, 2008 and will be applied for 5 years [5].

Active power and frequency control

- The generating plant must be able to reduce its power output. The following cases allow the network operator to temporarily limit the feed-in power or disconnect the plant;
  - unsafe system operation,
  - bottlenecks and congestion in the network,
  - unwanted islanding,
  - static or dynamic grid instability,
  - instable system due to frequency increase,
  - carry out repairs or construction,
  - in the context of production management, feed-in management, and network security management
- The plant must be capable of power output reduction steps of 10% (or smaller) of the agreed rated output power. A set point given by the network operator must be reachable from any operation point in any operation mode.
- These requirements refer to the ability of wind farms to regulate their power output to a defined level (active power curtailment); either by disconnecting wind turbines or by pitch control action. In addition, it is required from wind farms to provide frequency response that is to regulate their active output power according to the frequency deviations.

- The grid codes of the following countries demand the wind farms to have the ability of active power curtailment:
    - Germany, with a ramp rate 10% of grid connection capacity per minute
    - Ireland, with a ramp rate 1 – 30 MW/min
    - Nordic grid code, with a ramp rate 10% of rated power per minute
    - Denmark, with a ramp rate 10 – 100% of rated power per minute
- In German Grid code it is recommended that all generating units have to reduce their power output above a system frequency of 50.2 Hz. The power has to be reduced with a gradient of 40%/Hz of the instantaneously available power. The output power is only allowed to increase again as soon as the frequency is below 50.05 Hz. above 51.5 Hz and below 47.5 Hz the plant has to disconnect from the grid. Similar analysis should be carried out for Indian Grid by performing exhaustive studies.

Reactive power supply

In Spain an incentive to supply reactive power a bonus or penalty is calculated as a percentage of reference tariff (78.441 €/MWh in 2008). The percentage rates are shown in table below.

Table A8.2: Bonus or penalty for reactive power as percentage of reference tariff; source: (Rodriguez 2008) [5]

Power factor		Bonus (+) or penalty (-) as percentage of reference tariff		
		Peak load	Intermediate load	Off-peak load
Inductive power	< 0.95	-4%	-4%	+8%
	0.95 - 0.96	-3%	0%	+6%
	0.96 – 0.97	-2%	0%	+4%
	0.97 – 0.98	-1%	0%	+2%
	0.98 – 1.00	0%	+2%	0%
	1	0%	+4%	0%
Capacitive power	1.00 – 0.98	0%	+2%	0%
	0.98 – 0.97	+2%	0%	-1%
	0.97 – 0.96	+4%	0%	-2%
	0.96 – 0.95	+6%	0%	-3%
	<0.95	+8%	-4%	-4%

During peak load, there is an incentive to supply capacitive power; during off-peak load there is an incentive to supply inductive power.

Voltage stability in the medium voltage grid under normal operation is meant by static grid support. Slow changes in voltage have to be kept in acceptable limits. In case of operation requirements and on demand of the system operator generating plants have to supply static grid support. The generating plant should be able to provide reactive power in every operating point.

Most of the PV systems are designed to produce active power only. Reactive power is avoided due to losses in the inverter, lines and transformers. To meet the requirements of the grid code, the inverter of a PV system has to be designed bigger. Overall, an increase of system costs has to be expected. The reactive power set point can be either fixed or adjustable by a signal from the network operator. The set point value is either

- a fixed displacement factor cos or
- a variable displacement factor depending on the active power cos or
- a fixed reactive power value in MVar or
- a variable reactive power depending on the voltage

The function range to meet the requirements of the grid code is new ground for PV systems and thus a big challenge for the manufacturers of PV systems. The size of inverters, transformers and lines may increase due to required reactive power supply. Otherwise there is no major impact on the design of the inverter, only the control system has to be adapted.

Reactive power control is an important issue for wind farms, because not all wind turbine technologies have the same capabilities, whereas wind farms are often installed in remote areas and therefore reactive power has to be transported over long distance resulting in power losses. Wind farms should support the grid by generating reactive power during a network fault, to support and restore fast the grid voltage.

According to German grid code; wind farms should support grid voltage with additional reactive current during a voltage dip. The voltage control must take place within 20 ms (one cycle) after fault recognition by providing additional reactive current on the low-voltage side of the wind turbine transformer, amounting to at least 2% of the rated current for each per cent of the voltage dip. A reactive power output of at least 100% of the rated current must be possible if necessary. The above applies a +/- 10% dead band around nominal voltage. Wind farms may function in lagging or leading power factor in case of over voltages.

According to the Spanish grid code, the wind power plants are required to stop drawing reactive power within 100 ms (five cycles) of a drop voltage and to be able to inject reactive power within 150 ms (7.5 cycles) of grid recovery.

Great Britain and Ireland specify in their grid codes that wind farms must produce their maximum reactive current during a voltage dip caused by a network fault. According to the British code, power plants must be able to provide their full reactive power at voltages +/- 5% around the nominal, for voltage levels 400 and 275 kV.

Reactive power planning as ancillary service

Ancillary services include the services that support the provision of energy to support power system reliability. Federal Energy Regulatory Commission (FERC) in US [1], defines the following services as ancillary services in the following framework,

1. Scheduling, system control and dispatch: This is the service that the Independent System Operator (ISO) or Regional Transmission Organization (RTO) provides.
2. Reactive supply and voltage control from generation service: Reactive power supply and voltage control is generally supplied as a cost-based service.
3. Regulation and frequency response service: Today, regulation is typically supplied and priced by dynamic markets in ISO/RTO regions. It is used to assist in controlling frequency. However, frequency response, as defined by the droop response of governors immediately in response to frequency is generally not included in any dynamic markets nor is it given cost-based rates.

4. Energy imbalance service: Energy imbalance is usually the service of the real-time markets balancing out the imbalance from the forward markets and therefore is priced by the real-time energy markets.
5. Operating reserve – synchronized reserve service: This service is typically supplied and priced by dynamic markets in ISO/RTO regions.
6. Operating reserve – supplemental reserve service: This service is typically supplied and priced by dynamic markets in ISO/RTO regions.

With the introduction of renewable energy sources the ancillary service should be tuned to tackle the large variability. The reserve requirements in these cases can't be static, they should be dynamic. The predicted RE (e.g. wind) will impact the need for reserve on the system. By having a requirement that changes each hour based on predicted conditions, market participants would have to plan ahead to understand what the ancillary services demand might be, similar to how they anticipate the load demand. The reserve demand may change between day-ahead and real-time markets, similar to how load demand does today. Also, it stated in this paper that introduction of more RE sources may require development of more ancillary services to achieve a stale grid operation e.g. load following, inertial response etc.

Medina et.al. [2] proposed to use ancillary service of reactive power support provided by DGs, specifically Wind Turbine Generators (WTGs), with high level of impact on transmission systems. The main objective in the paper is to Price this service by determining the costs in which a DG incurs when it loses sales opportunity of active power, i.e., by determining the Loss of Opportunity Costs (LOC). DFIG wind generator and synchronous based generators has a capability to produce reactive power. LOC occur when more reactive power is required than available, and the active power generation has to be reduced in order to increase the reactive power capacity. The proposed optimization algorithm determining the optimal controls for best cost solution is developed from the standpoint of the Transmission System Operator (TSO) in a centralized approach. The DGs provide information about their generation capacity and receive set points from the TSO. The TSO price the reactive power support by determining the LOC of each DG according to the parameters and topology of the network. Three objectives are considered: active power generation costs of DGs, a Voltage Stability Index (VSI) associated to the VSM of the system, and losses in the lines of the network.

Vizoso et. al. [3], deals with grid-connected Photo Voltaic (PV) power plants for supplying ancillary services to the distribution grid. It is demonstrated in this paper that the power converter, interfacing the photovoltaic system with the grid, can be controlled (using a control strategy) in order to achieve both the primary goal of maximum power generation and as well as the voltage regulation of the grid and to the suppression of the current harmonics absorbed by loads close to the system.

Alvarado et. al. [4], discusses about the concept of reactive power as an ancillary service with its own compensation and charges with a main purpose to find for Alberta whether there is merit in creating a separate unbundled tariff mechanism for the revenue and cost allocation of reactive power as an identifiable Ancillary Service.

Margaris et. al. [5], illustrate the basic control scheme regarding the capability of the Doubly Fed Induction Generator (DFIG) wind turbine configuration to fulfil the basic technical requirements set by the system operators and contribute to power system security (by providing the reactive power support).

Renewable energy forecasting

Forecasting is the integral factor for maintaining grid stability while integrating renewables. Accuracy level helps the grid operator to maintain any contingencies in voltage as well as frequency with the help of ancillary market.

Indian RE sector should follow multiple forecasts including one at developer level and other at SLDC/NLDC level. In order to attain more accuracy multiple forecasting models or tools can be used for same data set.

Forecasting of renewable energy in Germany and Spain;

Germany- The forecast horizon is 96hrs and beyond that it's updated twice a day. The information is combined using a weighted sum. Dispatchers use the information to develop an operational forecast.

Spain - SIPREOLICO is a wind prediction tool for the Spanish peninsular power system. Three different agents provide SIPREOLICO with wind power forecasts updated each hour: (i) AEOLIS: Up to 2.8days horizon (ii) IIC: Up to 6.5 days horizon and (iii) METEOLOGICA: Up to 10 days horizon.

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Annexure 9: International case studies: China, Germany and USA

Grid integration of Renewables: International experiences

China

Chinese RE overview

China's renewable energy industry has experienced a rapid growth over the last decade. .China added an estimated 29 GW of grid connected renewable capacity, for a total of 263GW.Renewables accounted for about 26% of china's total installed capacity, 18% of generation and more than 9% of final energy consumption in 2010[2]. China's total renewable power capacity was 103GW in 2010, with wind (43GW), small hydroelectric (56GW), biomass power (5GW) and solar PV (less than1GW) driving the renewables market [8].

The installed capacity of wind power has doubled for five years successively between 2006 and 2010. The original goal of 5.0 GW by 2010 was achieved 3 years earlier in 2007. In 2010, China surpassed the United States and ranked the first in terms of cumulative installed capacity of wind power reaching 43 GW. This amounted to about 5% of total generation capacity. The reality is evolving so fast that the Chinese government has put forth new objectives for 2020 at 150 GW instead of the original 30 GW [1].

In 2010, China's PV module output rose to 10GW, accounting for 45% of world production, and maintaining its lead as the world's biggest producer of PV modules for four straight years. By 2010, China's total installed PV capacity reached 900MW. In 12th Five-Year Plan of Renewable Energy Development, the National Energy Administration suggested that by 2015, China's installed solar power capacity will reach 10GW. [3].

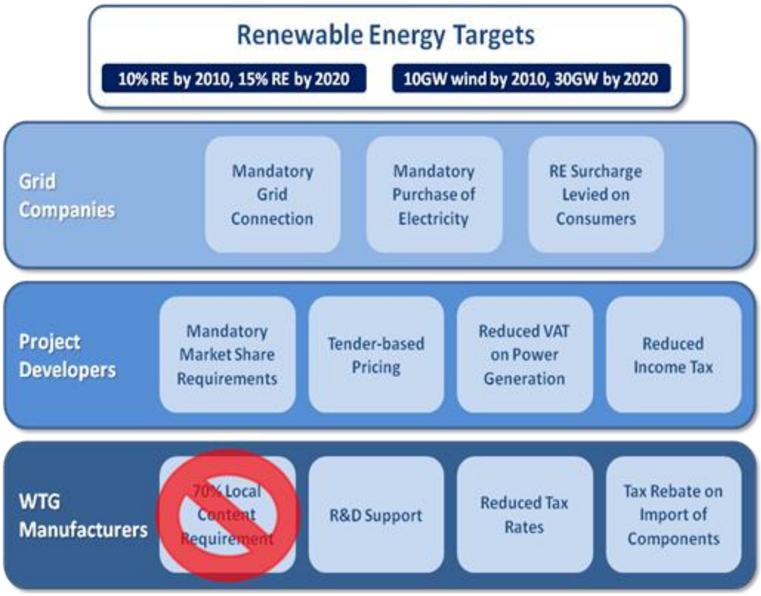

Figure A9.1: Renewable energy targets of China

Source: Chinese wind power Centre

As the Chinese renewable energy sector had crossed the targets projected by Chinese wind power centre the following problems incurred in Chinese power system

Problems in large scale grid integration of renewable energy

While the total installed capacity of wind power has expanded greatly, the level of wind power generation remains rather low. According to the statistics released by the China Electricity Council, in 2010 wind power generated 49.4 billion kWh of electricity, accounting for only 1.17% of the nation's total electricity production. The bottlenecks preventing the dispatch of renewable power onto the transmission network are due to: (1) grid safety and balancing power (2) lack of suitable national technical codes for wind power integration; (3) Critical excess electricity production (CEEP) and (4) insufficient economic incentives for grid enterprises [6] & [1].

Interventions for large scale grid integration of renewable energy

Technical interventions:

Grid safety and balancing power:

Grid strengthening which include implementation of ultra-high voltage transmission system is adopted by Chinese authorities to maintain grid stability and safety. For balancing power china make use of secondary reserve capacities like hydro power as they possess a total exploitable potential of 542GW.They also make use of long term reserve capacities like natural gas power system, nuclear power systems and coal based systems for balancing power[7].

Another option in renewable energy integration is the application of **energy storage systems**. There are two types of energy storage systems currently available at in china. First, physical energy storage systems such as wind powered pumped hydro storage systems and compressed-airsystems are used. By the end of 2007, there have been 18 pumped hydro storage plants operated in China. Another 11 plants are under construction. In addition, a number of electrochemical energy storage systems are available, such as lead-acid battery energy storage systems, redox flow cell energy storage systems and sodium sulphur battery energy storage system [7].

Wind power grid code

In 2005, the Technical Rules for Connecting Wind Farms to Power System (GB/Z19963-2005) drafted by the State Grid, a state-owned grid company, took effect. It provides a clear idea regarding active power control, reactive power regulations, LVRT requirements, wind farm voltage regulation and operating frequency [5].

Critical Excess electricity Production

Critical excess electricity production during high wind seasons are managed with the help of CHP plants. (CHP) combined heat and power plants in the northern part of China are important because they provide both electricity and heat to the end-users in winter. A significantly higher proportion of the CHP plants are found in northern China. Since the strongest wind also blows in winter, power system operators have to curtail the wind power outputs during the light load period in order to provide sufficient heat supply. Thus, it is naturally hard to make the combination of wind power with those possible options match each other well in reality [6] & [7].

Policy interventions

China's government encourages the use of renewable power resources for generating electricity, in a bid to reduce greenhouse gas emissions. Currently, China's Renewable Energy (RE) law encourages entry into the renewable energy market for electricity generation by making it mandatory for power grid operators to buy all electricity produced by renewable energy generators. Currently, China's government has a combination of laws, the Feed-in Tariff mechanism, programs and policies like the tariff for uploading electricity to the power grid be determined through a nationwide concession bidding process, taking into consideration the power generation costs, loan repayments and a reasonable profit; (2) that the gap between the wind electricity tariff and the average electricity tariff be shared across the whole power grid, through collecting a levy on each kilowatt-hour of electricity sold to the end users

Insufficient economic incentives for grid enterprises:

According to Renewable energy law, National Development and Reform Commission (NDRC) requires the grid enterprises be responsible for constructing transmission lines on time to connect the wind farms to the nearest grid as well as to purchase all the electricity generated by the wind farms .The National Development and Reform Commission put forth the subsidy standards for grid connection expenses in 2007, i.e. the grid connection expenses incurred for renewable energy power generating projects. The grid-connection expenses standards are formulated according to the route length and appropriate incentives are provided to grid enterprises [9].

Policy path way of China in renewable energy addition is mentioned below.

Table A 9.1: Policy path way of China in renewable energy addition

Policy name	Main contents
2008.12 Notice of Ministry of Finance and State Administration of Taxation on the Cessation of Tax Rebate Policy of Foreign Investment Enterprises to Purchase Domestic Equipment (Finance and Taxation No. [2008] 176)	Since January 1, 2009, the policy of full VAT refund for foreign invested enterprises to purchase domestic equipment within the total investment was stopped. Other relevant documents and articles were also repealed
2009.07 Notice on Improving Pricing Policies of Grid-Connected Wind Power	Introduced benchmark pricing according to four types of wind resource The pricing level is more reasonable and profitable for investors
2009.08 Notice on the Adjustment of Import Tax Policies of Major Technologies and Equipment	The policy on equipment and raw materials that meet the requirements is changed from a refund after collection to a direct tax-free allocation
2009.09 Opinions on the Inhibition of Overcapacity and Duplication in Some Industries, and Guiding the Healthy Development of Industry	Encouraged independent innovation by enterprises and prevents low-level repetitive construction
2009.11 Notice on Abolishing the Localization Rate Requirement for Equipment Procurement in Wind Power Projects by National Development and Reform Commission	Abolished the procurement requirement for a localization (domestic manufacture) rate of 70%
2009.12 Decision on Amending the Renewable Energy Act of People's Republic of China by National People's Congress	Ensured the acquisition of renewable energy and established the renewable energy development fund
2010.02 Interim Measures for the Administration of	Made provisions for requirements on planning,

Policy name	Main contents
Development and Construction of Offshore Wind Power	project approval, sea areas for construction and environmental protection during the development of offshore wind power projects
2010.04 Notice on the List of the Interim Provisions on Adjustment of Import Tax Policies for Major Technical Equipment	In relation to key components and raw materials imported for wind turbines with a single-machine capacity not less than 1.5 MW, these are exempted from customs duties and import VAT Importing of wind turbines with a single rated power 3 MW shall not be exempt from taxes

Source: China wind power outlook 2010

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Germany

Renewable energy status in Germany

Germany met 11% of its total final energy consumption with renewable sources, which accounted for 16.8% of electricity consumption, 9.8% of heat production (mostly from biomass), and 5.8% of transport fuel consumption. Wind power accounted for nearly 36% of renewable generation, followed by biomass, hydropower, and solar photovoltaic (PV). Germany added more PV (7.4GW) in 2010 than the entire world did the previous year, ending 2010 with 17.3 GW of existing capacity. During the first quarter of 2011, Germany generated 2.75TWh of electricity with PV, an increase of 87% over the same period in 2010. Germany shares 44% of total solar PV capacity of 17 GW worldwide in 2010[1].

Table A9.2: Increase in renewable energy share in total electricity generation from 2005 to 2011 [2]

Year	Installed capacity [MW]	Hydro power [GWh]	Wind energy [GWh]	Biomass [GWh]	Biogenic share of waste [GWh]	Photo-voltaics [GWh]	Geothermal energy [GWh]	Total electricity generation [GWh]	Share of gross electricity consumption [%]
2005	27,735	19,576	27,229	10,978	3,047	1,282	0.2	62,112	10.1
2006	31,431	20,042	30,710	14,841	3,844	2,220	0.4	71,657	11.6
2007	35,300	21,169	39,713	19,760	4,521	3,075	0.4	88,238	14.3
2008	39,497	20,446	40,574	22,872	4,659	4,420	17.6	92,989	15.1
2009	45,845	19,036	38,639	25,989	4,352	6,583	18.8	94,618	16.4
2010	55,578	20,956	37,793	29,085	4,781	11,683	27.7	104,326	17.1
2011	65,483	19,500	46,500	31,920	5,000	19,000	18.8	121,939	20.1

In June 2011 on the basis of the Energy Concept, the German government confirmed an extensive reorientation of its energy policy: It is to undertake a speedy phase-out of nuclear energy and at the same time move into the age of renewable energy. The German government also regards its decisions as a milestone in Germany's economic and social development. The cornerstones are [2]:

1. Use of nuclear power to cease not later than the end of 2022,
2. Dynamic expansion of renewable energies in all sectors,
3. Rapid expansion and modernisation of electricity grids,
4. Improvements in energy efficiency, especially through energy-saving building refurbishment and use of modern technologies to minimise electricity consumption.

The German government's Energy Concept will ensure that energy supply remains reliable; nobody finds energy costs unaffordable, Germany's position as an industrial location is strengthened, and the climate objectives are rigorously implemented. To support dynamic expansion of renewable energies, Germany has different renewable energy support policies [1];

1. Regulatory policies
   a. Feed-in tariff (incl. premium payment)
   b. Biofuels obligation/mandate
   c. Heat obligation/mandate
2. Fiscal incentives
   a. Capital subsidy, grant, or rebate
   b. Investment or production tax credits
   c. Reductions in sales, energy, CO_2, VAT, or other taxes
3. Public financing
   a. Public investment, loans, or grants

Expansion of power grids

Rapid expansion and modernization of electricity grid in Germany has been started to ensure that it is better equipped for transporting electricity from renewable energies. Against this background, the German government has approved plans to amend the Energy Management Act so that, for the first time, it facilitates coordinated nationwide planning of grid expansion. Through strong public involvement, the proposed rules will ensure a large measure of transparency, making it possible to generate great acceptance for grid expansion. In addition, the proposed "Act concerning measures to speed up the expansion of power grids" is to make it possible to ensure faster construction of very-high-voltage transmission lines. The electricity grids are also due to be modernised, for instance through "Smart Grids".

Experience of grid operators worldwide shows that besides several other factors integrating a significant amount of wind largely depends on the accuracy of the wind power forecast. Varieties of challenging operating conditions for successful management of wind energy integration in the grid by transmission system operator are;

1. Overload on control area internal power lines but also lines that interconnect with the neighbouring control areas
2. Overloads of transformers linking the transmission level with the distribution level
3. Problems with local voltage stability
4. Problems with frequency stability/ system balance

All technical problems arise due to grid integration of wind energy has been addressed in Germany by respective transmission system operators. Some of the key issues are [3];

1. *Excess power produce from wind:* When the actual wind power in feed exceeded the demand such as during low load conditions, the excess wind capacity has to be transported to neighbouring TSOs (Transmission System Operators) where the electrical demand is much higher.
2. *Wind power forecasting:* 50Hertz, a transmission system operator in Germany uses three different forecast tools. It receives wind power forecast data from four different forecast service providers. The forecast horizon is 96 hours and beyond that it's updated twice a day. The information is combined using a weighted sum. Dispatchers use the information to develop an operational forecast.
3. *Power congestion:* During periods of congestion in the grid, 50 Hertz, Germany redispatches power plants to manage overloads. European Commission Renewable Electricity Directive requires that wind generators are guaranteed priority dispatch, except for those conditions that affect the stability of electricity grid. To ensure a reliable and secure electricity supply, the directive states that wind production can be curtailed if the grid is endangered. As part of the process, the curtailment orders are determined using information about generators that have the most impact on the congestion at that time. However, this curtailment only occurs during heavy flow of power. As a last measure, 50 Hertz manually curtails winds by informing the respective distribution system operators about the required amount of power to be curtailed and for how long.

New German grid Codes for connecting PV systems to the medium voltage power grid:

The penetration of renewable energies in the power grids has been increasing in the last couple of years due to successful regulations like the Renewable Energy Law in Germany and comparable regulations in Spain and elsewhere. This expansion of renewable energies, especially PV systems, can only happen due to an unlimited access to the power grid. A high penetration of renewable energies harbours the risk of grid instability in case the generating plants are not able to support the grid. On this background, the German Association of Energy and Water Industries introduced in 2008 the new grid codes for connecting power plants to the medium voltage power grid [4].

Dynamic grid support:

By dynamic grid support, voltage stability during voltage drops in the overlying high-voltage grid is meant and often referred to as Fault-Ride-Through (FRT). Due to an increasing penetration of decentralized generating plants in the medium-voltage grid, it is necessary to include these plants in dynamic grid support. This means generating plants have to be able:

- To stay connected during a fault,
- To support the voltage by providing reactive power during the fault, and
- To consume the same or less reactive power after the fault clearance.

Short circuit:

The short circuit current of the network in the area of the grid connection point is increased by the short circuit current of the generating plant and can thus exceed the limits of the power grid. Thus it is essential to take the short circuit into account when connecting a generating plant to the grid. The short circuit of a synchronous generator is typically eightfold the rated current, whereas generators with converter like PV have typically the same short circuit current as rated current. Thus there is no necessity for PV to limit the short circuit current by e.g. an external current limiter.

Active power control:

The generating plant must be able to reduce its power output. The following cases allow the network operator to temporarily limit the feed-in power or disconnect the plant:

- Risk of unsafe system operation,
- Risk of bottlenecks and congestion in the network,
- Risk of unwanted islanding,
- Risk of static or dynamic grid instability,
- Risk of instable system due to frequency increase,
- Carry out repairs or construction,
- In the context of production management, feed-in management, and network security management.

The plant must be capable of power output reduction steps of 10% (or smaller) of the agreed rated output power. A set point given by the network operator must be reachable from any operation point in any operation mode. Commonly used set points at present time are 100%, 60%, 30%, and 0%. The network operator does not interfere in the control of generating plant, but only gives a signal for the set point.

Static grid support by reactive power control:

By static grid support voltage stability in the medium voltage grid under normal operation is meant. Slow changes in voltage have to be kept in acceptable limits. In case of operation requirements and on demand of the system operator generating plants have to supply static grid support. The generating plant has to be able to provide reactive power in every operating point according to the following displacement factor at the grid connection point:

$$\cos\varphi = 0.95_{underexcited} to 0.95_{overexcited}$$

Today PV systems are designed to produce active power only. Reactive power is avoided due to losses in the inverter, lines and transformers. To meet the requirements of the grid codes, the inverter of a PV system has to be designed bigger. A 500 kVA inverter will then be designed for a rated active power of 475 kW. Overall, an increase of system costs has to be expected. Reactive power has only to be provided during feed-in operation, so there is no need to provide reactive power during the night.

The reactive power set point can be either fixed or adjustable by a signal from the network operator. The set point value is either

- A fixed displacement factor *cos φ* or
- A variable displacement factor depending on the active power *cos φ* or
- A fixed reactive power value in MVAr or
- A variable reactive power depending on the voltage Q

The generating plant must be able to traverse the agreed area of reactive power within a few minutes and as often as required. If the network operator provides a characteristic, each value resulting from this has to be automatically set within 10 seconds.

Energy and Climate Fund

To finance the accelerated energy revolution, the German government has established a special

"Energy and Climate Fund". This resource will be used to fund, among other things, CO_2 building refurbishment and research and development on energies and storage technologies.

With effect from 2012, all revenue from the auctioning of emission allowances will be paid into the fund, which will have 3 billion EUR per annum at its disposal from 2013 onwards [2].

Revision of the Renewable Energy Sources Act (EEG)

Under the Energy Concept, renewable energies will be the mainstay of the future energy supply system. Their share of electricity supply is to more than double by 2020 (at least 35 % by 2020 at the latest). To make this possible, a revised version of the Renewable Energy Sources

Act (EEG), adopted in mid-2011, and is to come into force on 1.1.2012. This tried and tested regulation will enable electricity generation from renewables to continue to rise steadily and improve the integration of renewables into the market and the energy system. The principles – priority purchase of renewable electricity and fixed feed-in payments – will remain unchanged.

Thus, as before, the EEG is not a form of subsidy. Furthermore, the system of payment is to be simplified and made more transparent. An optional market bonus is also to be introduced as an incentive to market-oriented operation of installations for the use of renewable energy sources. The EEG is anchored in EU Directive 2009/28/EC on the promotion of the use of renewable energy [2].

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USA

US renewable energy accounted for 14.3% of the domestically produced electricity in first six months of 2011. In 2009, the U.S. was the world's largest producer of electricity from geothermal, solar and wind power and it trailed only China in the total production of renewable energy.

A 2012 report by the National Renewable Energy Laboratory evaluates the potential energy resources for each state of the United States

		Total Technical Potential	
Type	**Resource**	**Capacity (GW)**	**Potential (TWH)**
Solar	Urban utility-scale PV	1,200	2,200
	Rural utility-scale PV Solar	153,000	280,600
	Rooftop PV	664	800
	Concentrating solar power	38,000	116,100
	Total	**192,922**	**399,810**
Wind	Onshore wind power	11,000	32,700
	Offshore wind power	4,200	17,000
	Total	**15,178**	**49,760**
Bioenergy	Biomass/biofuel/methane	62	488
	Total	**62**	**488**
Geothermal	Hydrothermal power systems	38	300
	Enhanced geothermal systems	3,976	31,300
	Total	**4,014**	**31,653**
Hydro	Hydropower	60	259
	Total	**60**	**259**
	Total	**212,236**	**481,970**

Electricity Production by Renewables in 2010						
Power Source	**Units in Operation**	**Power Capacity (GW)**	**% of total Capacity**	**Capacity factor**	**Annual Energy (billion kWh)**	**% of annual production**
Hydro	4,171	98.7	8.7	0.295	255	6.1
Wind	689	39.5	3.5	0.27	95	2.3
Wood	346	7.9	0.7	0.53	37	0.9
Biomass	1,574	5	0.4	0.43	19	0.45
Geo Thermal	225	3.5	0.3	0.49	15	0.36
Solar	180	0.9	0.07	0.13	1.2	0.02
Total	7,185	155.5	13.7	0.31	422	10.1

A. To encourage the use of Renewable energy in US Renewable Portfolio Standard (RPO) are enforced [2]

Three ways to encourage the same;

An RPS creates market demand for renewable and clean energy supplies. Currently, states with RPS requirements mandate that between 4 and 30 % of electricity be generated from renewable sources by a specified date. While RPS requirements differ across states, there are generally three ways that electricity suppliers can comply with the RPS:

1. Owning a renewable energy facility and its output generation.
2. Purchasing Renewable Energy Certificates (RECs).
3. Purchasing electricity from a renewable facility inclusive of all renewable attributes (sometimes called "bundled renewable electricity")

In March 2009, 33 states plus the District of Columbia. More than 2,300 megawatts (MW) of new renewable energy capacity through 2003 was attributable to RPS programs. According to 2009 data, the Union of Concerned Scientists projects that state standards will provide support for 76,750 megawatts (MW) of new renewable power by 2025—an increase of 570% over total 1997 U.S. levels (excluding hydro). Each state has given its own RPS design to fulfil their goals and objectives.

The structure of an RPS can influence investor confidence, the ability of markets to develop, and opportunities for project developers and investors to recover capital investments. The critical structural elements include:

- Method of accounting for renewable energy (e.g., energy production versus installed capacity requirements; RECs or bundled energy only).
- Time horizons for compliance periods.
- Mandatory or voluntary participation.
- Flexible compliance mechanisms to guard against high prices or the lack of supply of renewable energy (e.g., credit for early compliance, forward compliance banking, deficit banking, establishment of true-up periods, alternative compliance payments).
- Coordination with other energy policies at the federal level (e.g., Federal Production Tax Credit) and state level (e.g., system benefit charges, interconnection standards).
- Cost recovery mechanisms for utilities.
- Enforcement mechanisms for noncompliance.
- The incorporation

B. Feed-in tariffs (FIT) According to NREL report of year 2009, the FIT policies are being experimented with in the United States, though at a smaller scale and less comprehensively than in a number of European countries.

The state level and utility based FIT structure is utilized. The US state FIT differs from the European tariff structure. Examples of some of the states are represented here, more details for other states can be found in [3].

Gainesville, Florida

2009, the board of directors at the Gainesville City Commission approved Gainesville Regional Utilities' (GRU) proposal for a FIT policy tailored to solar PV. This particular policy is unique in the United States as it is the first FIT to be based on the levelized cost of generating electricity from RE sources, with an estimated rate of return, thereby making it close in design to FIT policies in Europe. GRU expects that smaller developers will be able to obtain roughly a 5% rate of return on their investment, which is expected to make solar PV a financially viable investment.

This policy was implemented at utility level rather than state level.

Similarity with European FIT policy

- **Degression** meaning that the annual payment awarded to solar developers for the electricity generated declines by a certain percentage (in this case, 5%) every year. This is done to both track and encourage cost reductions in the technology while fostering greater efficiencies and innovation.
- FIT payments are differentiated by project size. A higher tariff rate is offered for projects less than 25 kW than the rate offered to projects greater than 25 kW.
- Contract length is structured over 20 years.

Differences with European FIT policy

Solely for solar PV rather than being extended to a wider variety of RE technologies.

Wisconsin

Wisconsin's FIT policies are utility-based and include all three kinds of FITs: fixed-price incentives, avoided cost FITs and one loosely based on RE project costs. These are developed for solar PV, biogas, and wind plants.

Wisconsin's FIT policies have not been accurately based on the levelized cost of RE generation. Because they are utility-based FIT policies, utilities are not allowed to participate. Also, because the programs include a number of caps on the individual project size, as well as on the total program size, these FIT policies are limited in their ability to drive large-scale RE deployment.

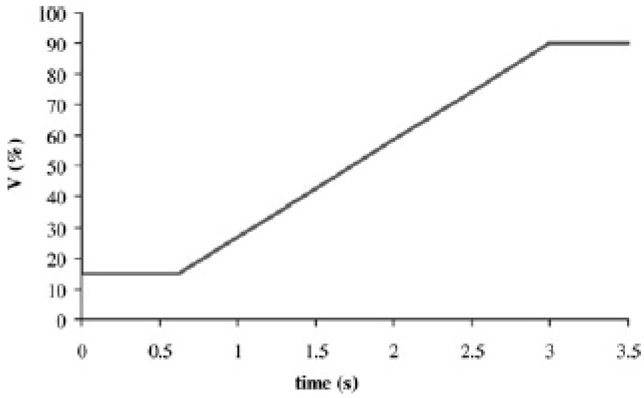
California

The tariff payment level was determined according to the market price referent (MPR) at the time of commercial operation of the plant; it is fixed at this level over a period of 10, 15, or 20 years.

The FIT policy has had little impact in California so far. This is largely due to the fact that the suite of rebates and up-front subsidies is not available to certain technologies state of California.

USA

According to the current FERC rule, issued in June 2005, after the petitions for rulemaking issued by the American Wind Energy Association the wind power plants 'shall be able to remain online during voltage disturbances up to the time periods and associated voltage levels' shown in below (former E.ON requirement). Also, the 'wind generating plant must be able to operate continuously at 90% of the rated line voltage, measured at the high-voltage side of the wind plant substation transformer.



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