Discussion Paper

Gujarat

Enabling State Level Climate Mitigation Actions in the Power Sector

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1. Gujarat State Energy Profile

Electricity generation has been the single largest contributor in India's emissions portfolio. Coal consumption in the power sector is approximately 66 percent of total coal consumption in India. India's per capita emissions considering coal consumption only from the power sector in 2014-15 is 894.14 million tons of CO2, which is 61 percent of the total emission. Uttar Pradesh, the largest state by population size, generates the highest power followed by Maharashtra, Chattisgarh, Madhya Pradesh and Gujarat.

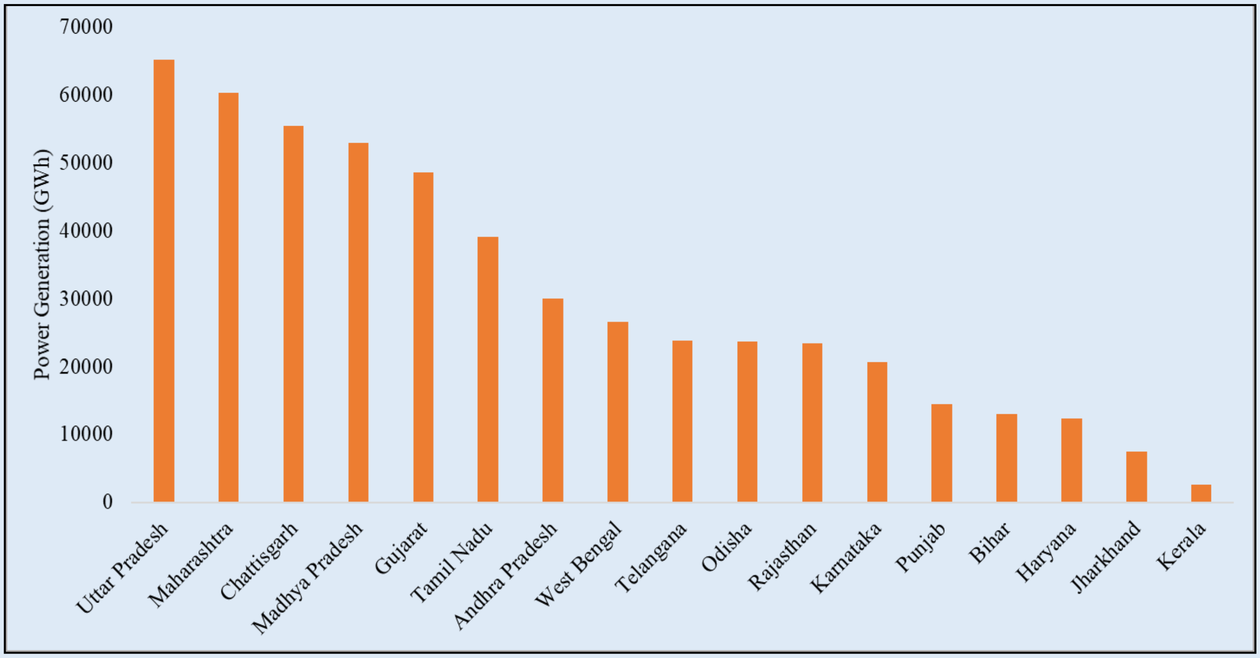


Figure 1: Power generation by major states in 2017-18

Himachal Pradesh is the biggest power generator in the Himalayan/North eastern group of states followed by Jammu and Kashmir and Uttarakhand respectively. However, not all these states are generating power from coal. Therefore, emission from power generation in these states are almost nil.

Under the National Action Plan on Climate Change in 2008, the government of India had identified the development of solar energy technologies in the country as a National Mission. The mission aims at the development and deployment of solar energy technologies in the country to achieve parity with grid power tariff by 2022. At that time the government had set a target for the deployment of 20 GW of solar power by 2022.

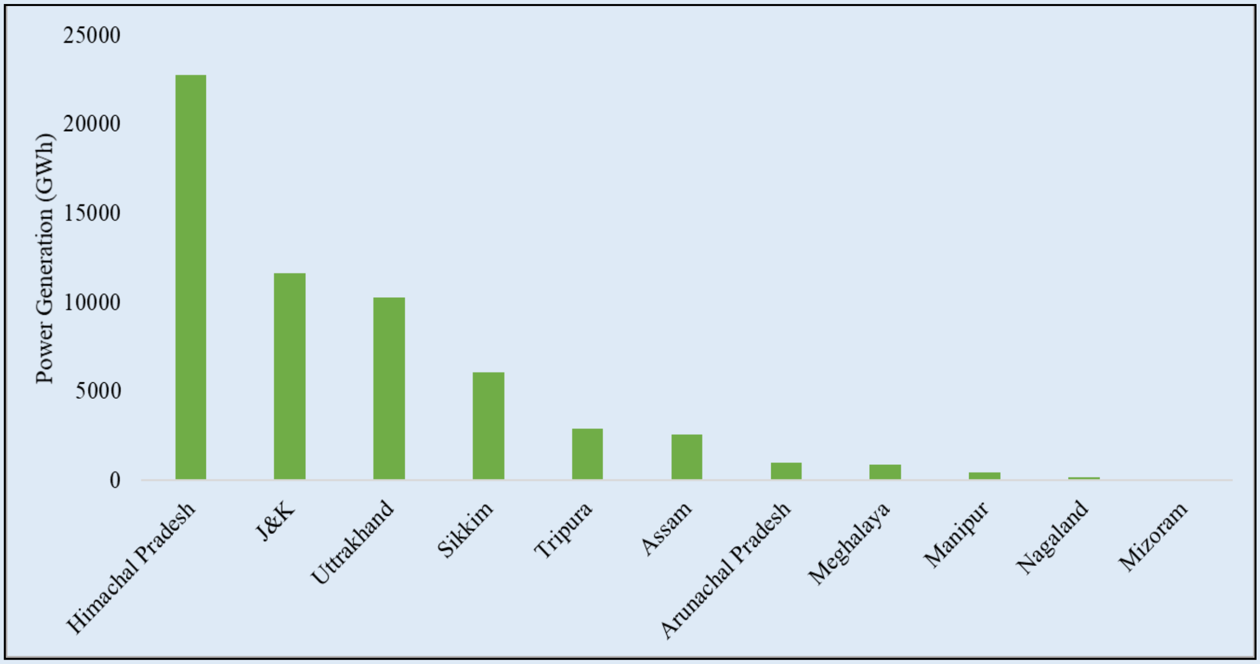


Figure 2: Power generation by Himalayan/north eastern states in 2017-18

However, later this target was revised substantially. The government had set a target to achieve 175 GW renewable deployment by 2022, which comprises 100 GW solar, 60 GW Wind, 5 GW Small hydropower and 10 GW biomass power. To achieve the national target, each region and further each state was given a target to achieve renewable deployment as shown in Figure 4. We have classified states based on their proposed renewable deployment targets by 2022 in 1) States having total deployment target above 4 GW- high potential states, 2) States having total deployment target above 1 GW and less than 4 GW - medium potential states, and 3) States having total deployment target below 1 GW -low potential states.

Gujarat accounts for 7.7% share to national GDP and the state's annual GDP growth from 2011-12 to 2017-18 at current prices has been more than 13% (Directorate of Economics and Statistics, 2019). This growth has been sustained by planned development of power and energy sector to meet the emerging demand from each sector. Power sector is one of the major emitting sector in Gujarat.

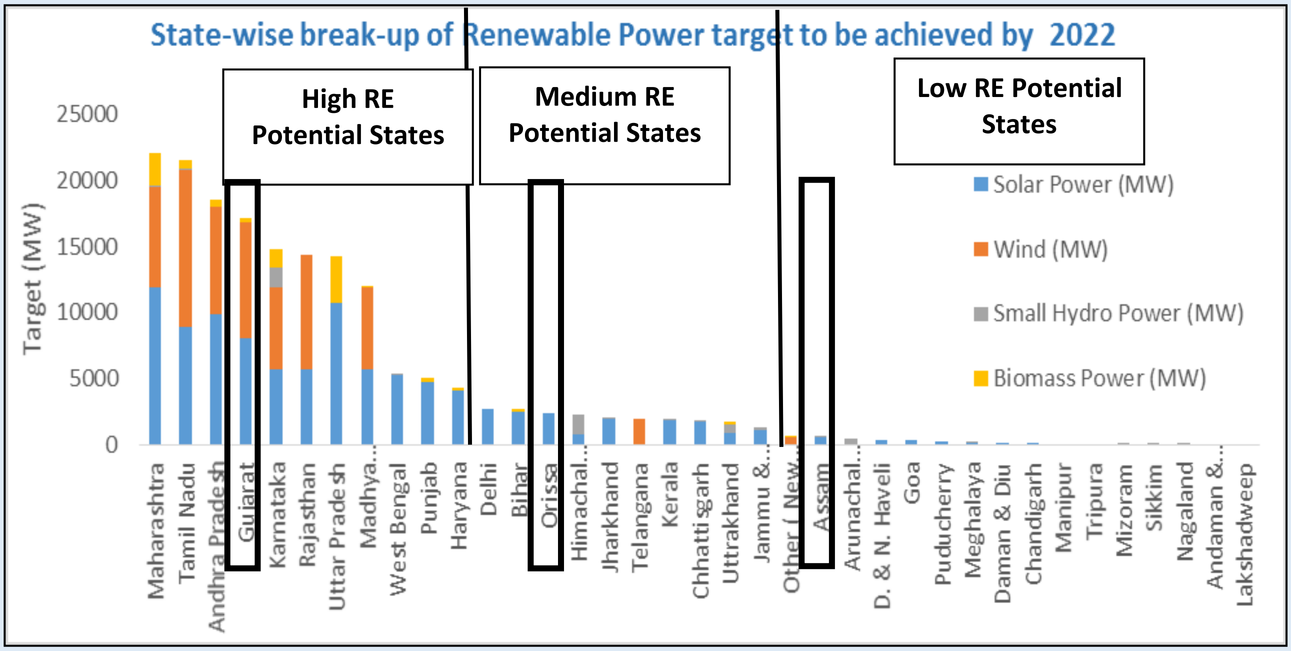


Figure 3: State-wise renewable power production capacity target to be achieved by 2022

Gujarat has multiple ports with required facilities to import energy resources to serve national demand. Department of Energy and Petrochemical of state government has huge responsibility that is managed by their subsidiaries. Gujarat Urja Vikas Nigam Ltd. (GUVNL) is the holding company and its subsidiary companies manage the generation, transmission and distribution of electricity in the state.

Gujarat state is self sufficient in its power generation requirements. The state electricity utility provides 24x7 hours of power in the state, not withstanding occasional breakdowns. Currently all the villages in the state of Gujarat are electrified. The state government has ensured availability of quality power to all consumers at reasonable rates, which is essential for sustained socio-economic growth. One important feature of State development is that state has diversified economic development in all districts of the state.

1.1 Energy Profile

Gujarat is located on the western coast of the Indian subcontinent with the largest coastline in the country. The state boasts to be the most industrialized state in India with a GSDP of Rs. 11.62 trillion (US $173.24 billion) during 2016-17. The state recorded a compound annual growth rate (CAGR) of 13.55% between 2011-12 to 2016-17 in its GSDP (India Brand Equity Foundation, 2019).

Energy sector in Gujarat has undergone major growth in the past few years, with significant reforms and capacity addition. The energy sector in Gujarat is primarily divided into Power, Oil and Gas sectors.

To support the rapid industrialization of the state, development of the Power sector of the state has been a priority. The state was first to achieve 100% electrification in India, providing 24*7 electricity access to its citizens.

1.2 Generation of Energy

Gujarat has a total installed capacity of about 32.6 GW (CEA, 2019) as of June 2019. Figure 4 presents the sector-wise installed capacity in Gujarat in 2019. There is a high proportion of private sector generating capacity in the total installed capacity of the state which indicates the conducive conditions for private sector investments.

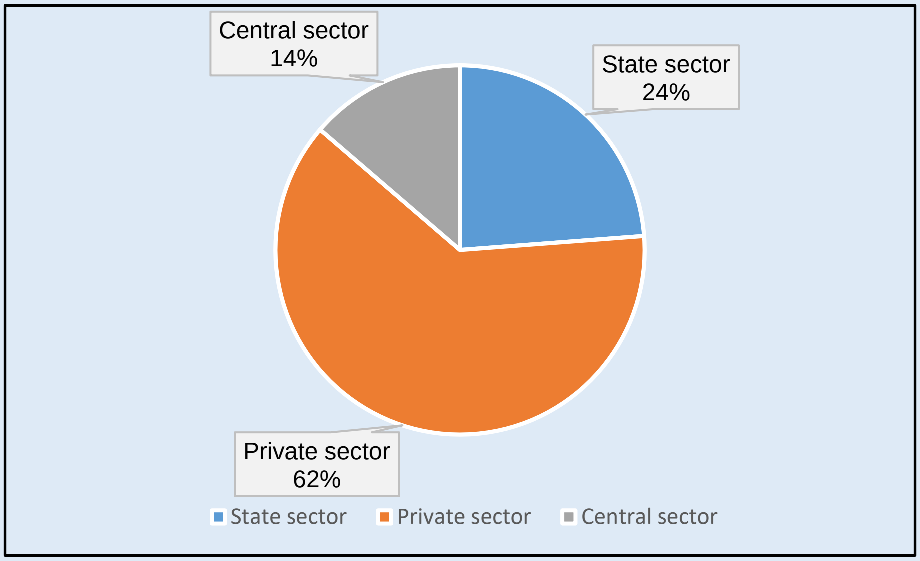
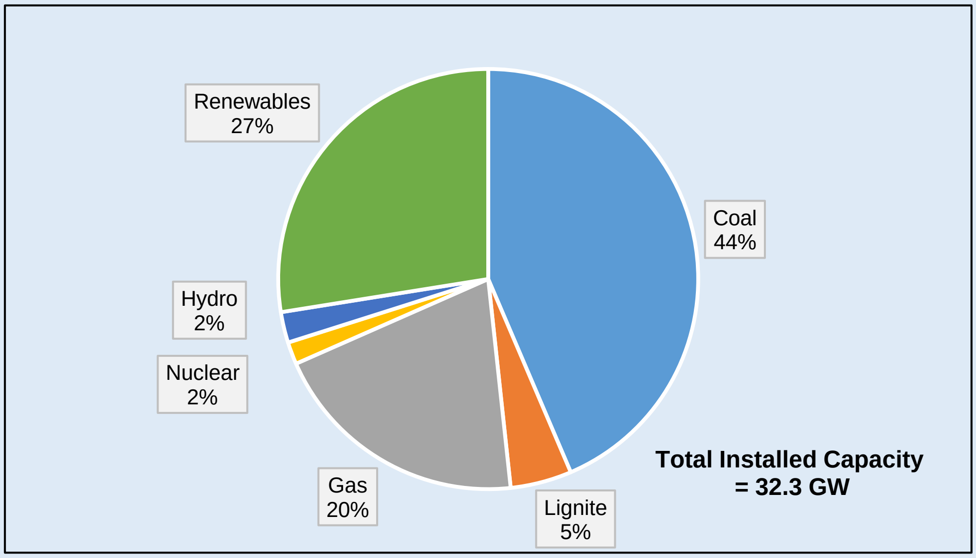


Figure 4: Sector-wise installed capacity in Gujarat in 2019
Source: CEA, 2019

The state has a high share of renewables in its generation installed capacity mix, i.e. 27%, as compared to the national average of 22% (CEA, 2019). Figure 6 depicts the source-wise installed capacity of Gujarat in 2019. However, coal's share in the installed capacity is still the highest at 44%. Fossil fuels in total had a share of 69% in the installed capacity mix of Gujarat in 2019.

Gujarat is one of the few states which not only provides sufficient power to its people but also exports power to other states. This may be attributed to the state's success in attracting private investments in the power generation sector and substantial addition of Renewable Energy (RE) in the mix.



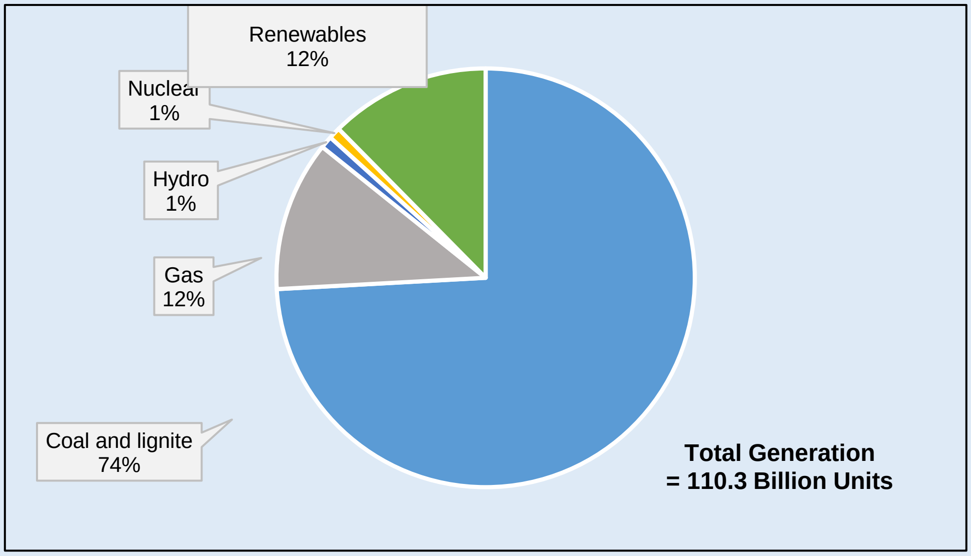
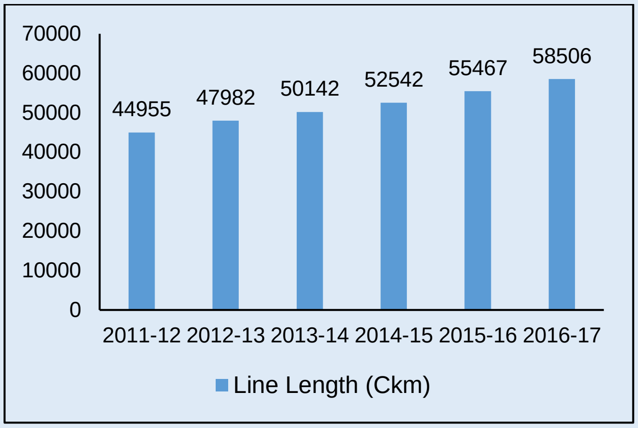


Figure 5: Source-wise installed capacity and generation of electricity in Gujarat in 2019
Source: CEA, 2019; SLDC Gujarat 2019

1.3 Transmission of Electricity

Transmission is that element of power sector value chain, which facilitates evacuation of power from generating stations to the load centers. Gujarat Energy Transmission Corporation Limited (GETCO) is the main entity responsible for construction, operation, and maintenance of the transmission network in the state.

GETCO focuses on transmission capacity addition and upgradation of transmission infrastructure, to facilitate reliable supply of power to the state. 101 substations were added in the year 2017-18, and the availability factor of substations in the year was 99.87%. Also, 2549 Ckm of transmission lines were added in 2017-18, with the availability factor of transmission lines being 99.58% (GETCO, 2019). Transmission losses of the company were 3.72% in 2017-18, which were below the prescribed 4% (GETCO, 2019). The losses have remained below 4% since 2013-14. Figure 7 depicts the growth of transmission infrastructure in Gujarat over the years.



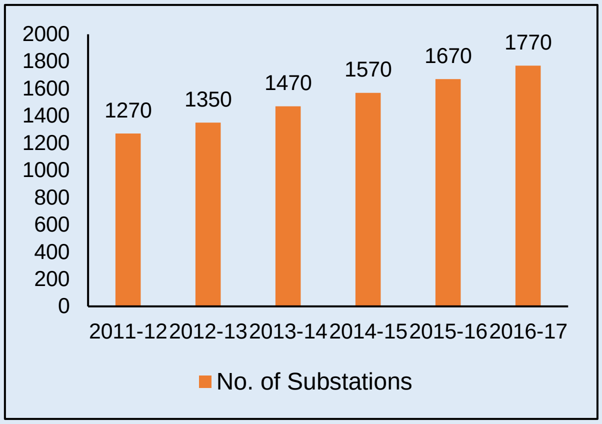


Figure 6: Growth of Transmission Infrastructure in Gujarat
Source: GETCO Annual Report 2016-17 and IRADe

1.4 Distribution of Electricity

Gujarat has been divided into four geographical regions and each region is run by separate Distribution Company (DISCOM). Northern part by Uttar Gujarat Vij Company Limited (UGVCL), western part by Paschim Gujarat Vij Company Limited (PGVCL), central part by Madhya Gujarat Vij Company Limited (MGVCL) and southern part by Dakshin Gujarat Vij Company Limited (DGVCL).

Apart from them, there are also private DISCOMs for Ahmedabad, Gandhinagar, Surat etc. The distribution sector of Gujarat has taken on various reforms in the past decade and is now one of the best in the country.

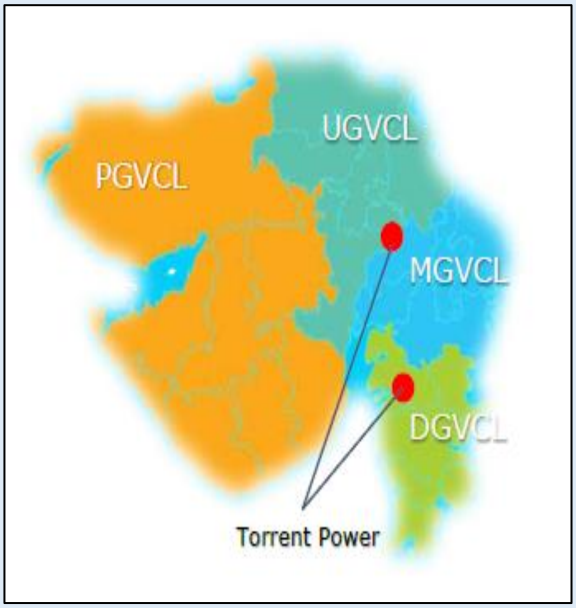


Figure 7: Gujarat State DISCOMs
Source: Energy Sector in Gujarat, Vibrant Gujarat Summit 2017

The average Aggregate Technical and Commercial (AT&C) losses of the state were found to be 12.59% (Uday Dashboard, 2019)[1], which were much lower than the national average of 20.4%. AT&C losses of state DISCOMs of Gujarat are given in Figure 9.

[1] As on 20/08/2019

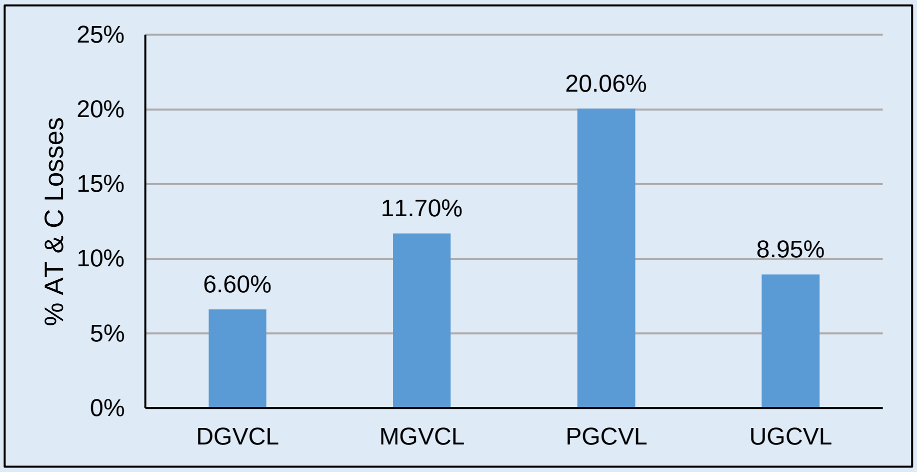


Figure 8: AT&C losses of individual DISCOMs in Gujarat in FY 2018
Source: Seventh Annual Integrated Ratings

1.5 Electricity Consumption

Gujarat is one of the largest consumer of electricity in India with total energy consumption of around 122 BU in the FY 2018-19 (WRLDC, 2019), second only to the state of Maharashtra. The state has a per-capita electricity consumption of 2018 kWh (WRLDC, 2019), much higher than the national average of 1181 kWh2 (CEA, 2019b) in 2018-19. Industry sector is the largest consumer of electricity in Gujarat.

Figure 9: Category wise Energy supplied by state utilities in **Gujarat** gives the category-wise energy supplied by state DISCOMS in Gujarat.

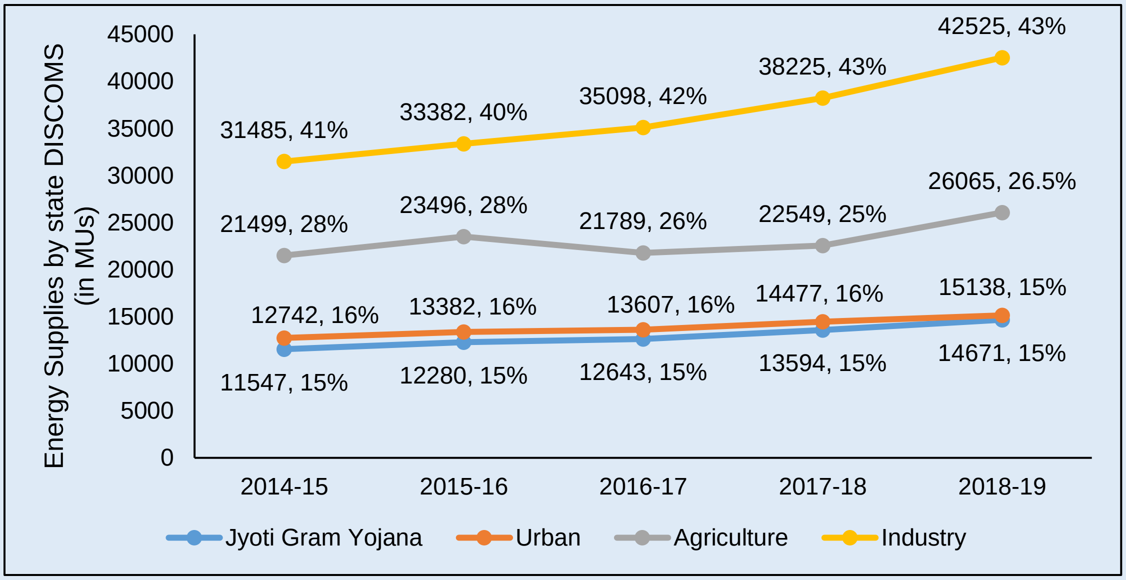


Figure 9: Category wise Energy supplied by state utilities in Gujarat
Source: SLDC Gujarat, 2019

[2] Provisional figure, CEA

1.6 Energy Sector Policies

Electricity production is one of the major consumers of the fossil fuel resources such as coal and gas and hence abundantly adds to the state emissions. Various policies and schemes have been launched by the central government and the state government for the efficient utilization of these resources in order to limit emissions. These policies provide a necessary push to renewable sources of energy.

1.6.1 Central Government Policies

A comparative table of national policies in the Indian power sector having impact on NDC Goal 3 have been provided in Table 1.

Table 1: National Level Power Sector Policies for Achieving India's NDC Goal 3

S. No.	Policy/Schemes	Description	Nodal Agency
1	175 GW Renewable Energy by 2022	To increase the total capacity of RE to 175 GW by 2022	Ministry of New and Renewable Energy (MNRE)
2	Unnat Jyoti by Affordable LEDs for All (UJALA)	Promote replacing of ordinary bulbs with energy efficient LED bulbs	Energy Efficiency Services Limited (EESL) and Discoms of participating state
3	Perform Achieve Trade (PAT)	Reduction in Specific Energy Consumption (SEC) of energy intensive industries	Bureau of Energy Efficiency (BEE)
4	Clean Coal Technology (Super-critical Power Plants)	No new Sub-critical power plant addition after 2017	Central Electricity Authority (CEA)
5	Renovation and Modernization of Thermal Power Plants	Increasing energy efficiency of old power plants	CEA
6	Integrated Power Development Scheme	AT&C Loss reduction and strengthening of distribution networks.	Power Finance Corporation Limited (PFC)
7	National Smart Grid Mission	Accelerate smart grid deployment in India	Ministry of Power

8	Ujjwal Discom Assurance Yojana (UDAY)	Operational and financial turnaround of state-owned discoms through revival package	Ministry of Power
9	Bachat Lamp Yojana	Promote replacing of incandescent bulbs with efficient CFLs.	BEE
10	Street Light National Program	Replacement of conventional street lights with LEDs.	EESL
11	Smart Meter National Program	Replacement of conventional meters with advanced metering infrastructure (smart grids)	EESL
12	Municipal Energy Efficient Program	Retrofitting inefficient municipality pump sets	EESL
13	Renovation & Modernisation, Uprating and Life Extension (RMU&LE) of Hydro power plants	Increasing energy efficiency of old hydel power projects	CEA
14	Nation Wind-Solar Hybrid Policy	Promotion of large grid connected wind - solar PV hybrid systems foe effective utilization of land and transmission infrastructure	MNRE
15	National Off-shore Wind Energy Policy	Explore and Promote deployment of offshore wind farms in the Exclusive Economic Zones (EEZ) of the country	National Institute of Wind Energy (NIWE)

1.6.2 State Government Policies

Table 2 provides a brief overview of the policies in the power sector by the Government of Gujarat.

Table 2: State Level Power Sector Policies for Achieving India's NDC Goal 3

S. No.	Policy/Schemes	Description	Nodal Agency	Useful Links (accessed on 20 Sep 2019)
1	Gujarat Solar Power Policy 2015	Scale up the solar power generation in a sustainable manner	Gujarat Energy Development Agency (GEDA)	https://guj-epd.gujarat.gov.in/uploads/Gujarat_Solar_Power_Policy_2015.pdf
2	Gujarat Waste to Energy Policy 2016	Promotion of Municipal Solid Waste (MSW) utilization as a renewable resource for generation of electricity	GEDA	https://guj-epd.gujarat.gov.in/uploads/Waste-to-Energy-Policy-2016.pdf
3	Gujarat Wind Power Policy 2016	Promotion of power generation through wind energy	GEDA	https://guj-epd.gujarat.gov.in/uploads/guj-wind-Power-Policy-2016.pdf
4	Gujarat Wind-Solar Hybrid Power Policy 2018	Promotion of large grid connected wind-solar PV hybrid systems for effective utilization of land and transmission infrastructure	GEDA	https://guj-epd.gujarat.gov.in/uploads/Gujarat_Wind-Solar_Hybrid_Power_Policy-2018.pdf
5	Gujarat Small Hydel Policy 2016	Promotion, facilitation and incentivizing investments in small hydel projects	GEDA	https://guj-epd.gujarat.gov.in/uploads/GUJARAT-SMALL-HYDEL-POLICY-2016.pdf
6	Gujarat Repowering of the Wind Projects Policy 2018	Promotion of optimum utilization of wind energy resources by creating facilitative framework for repowering.	GEDA	https://guj-epd.gujarat.gov.in/uploads/Repowering_of_the_Wind_Projects_Policy.pdf

The Gujarat power sector is regarded as one of the most progressive in the country. The state has achieved 100% electrification long back and is power surplus. The state realized early on, its vast potential for RE and drafted policies to exploit this potential. The Gujarat Solar Power Policy

2009 was first solar policy to be announced in India. The state government notified its revised Solar Policy in 2015.

The state also took into account solid waste as a potential source of energy and developed the Gujarat Waste to Energy Policy 2016 to promote utilization of MSW (Municipal Solid Waste) as a renewable source of energy. With advancements in the RE technologies, the government updated its policies from time to time. Gujarat Repowering of Wind Projects Policy 2018 is one such policy, which aims to incentivize repowering of older wind projects below 1 MW that were installed at sites having high wind potential. The aim is to increase the power output from wind projects installed under Wind Power Policy – 1993, 2002 and 2007, by increasing the capacity or modernizing them. Further, Gujarat Wind Solar Hybrid Power Policy was notified in 2018. The policy, if successful, would not only promote effective utilization of land and transmission infrastructure but also decrease the variability in power generation.

1.7 Emissions Level

Electricity production accounted for 23.2% of the total emissions of Gujarat in 2013, the second highest sectoral polluter in the state after Industries (GHG Platform India, 2017 series).

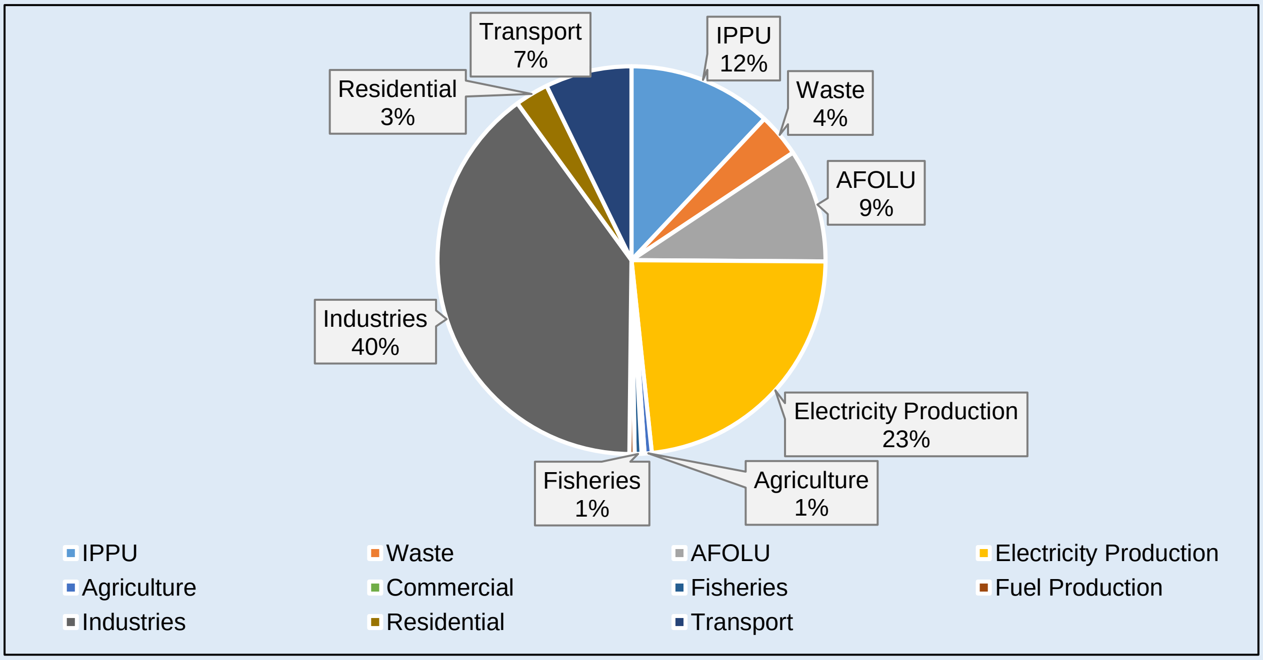


Figure 10: Total emissions from various sectors of Gujarat[3]
Source: GHG Platform India, 2017 series

[3] IPPU includes emissions from Industrial Processing and Product Use, AFOLU includes emissions from Agriculture, Forestry and Other Land Use

1.8 State Action Plan on Climate Change, 2014 (SAPCC) – Gujarat Power sector snapshot[4]

Gujarat's SAPCC imparts major focus on energy efficiency and renewable energy for decarbonizing its power sector. Major focus areas of the state in power sector are:

- To promote renewable energy in the state, the state had set an ambitious RPO target of 10% for 2017. The state has further increased the target to 17% for 2022 in a phased manner.
- Promotion of private investments and research & development in the sector.
- Development of Gandhinagar as a model, energy efficient, clean energy powered city. A pilot project to install smart meters in the state's capital Gandhinagar was launched. The city is to be developed as a model Solar City. The target was 12% reduction in projected demand of conventional energy in the period of 2011 to 2015.
- Promotion of energy audits in government buildings, SMEs, power plants, etc.
- Increasing the knowledge base of the citizens especially regarding decentralized renewable technologies.

1.9 GHG Impact of Power Sector Policies in Gujarat

Table 3: GHG Impact of Power sector policies in Gujarat

Policy	Time Duration	CO_2 Abatement ($Mt\ CO_2e$)
Solar Power Policy – 2009, 2015	2009-2015	4.4
Wind Power Policy – 2007, 2009, 2013	2007-2015	28.2
Subsidy Scheme for Residential Solar Rooftop Plants	2015	0.1
UDAY Scheme, R – APDRP	2005-2015	7.5
PAT Scheme for Thermal Power Plants	2012-2015	5.7
UJALA Scheme	2007-2015	2.0

[4] State Targets and Status have been revised post release of this document

Standards and Labelling Programme	2007-2015	6.7
Potential Abatement from Policies		
30 GW State RE Target by 2022 - Wind	2022	15.3
30 GW State RE Target by 2022 - Solar	2022	13.3

Source: GHG Platform India, 2019 and IRADe

Note: Of the 30 GW Target, abatement is calculated for 20 GW capacity as 10 GW is planned to be sold outside of the state. Also, 20 GW is distributed equally between wind and solar i.e. 10 GW each. PLF is taken (as per the National Electricity Plan, 2018).

2. Renewables in Energy Mix – Gujarat

2.1 Evolution of Renewables – Gujarat

Gujarat has been one of the pioneers of the RE revolution in the country. High potential for wind and solar energy deployment and good policy support has helped the state to become one of the top RE producers in the country. As pointed out earlier, the state was the first to launch a solar power policy in the country, in 2009 itself. Decentralized RE technologies such as solar rooftop are also being promoted by the state. Recently, a subsidy of 40% for a capacity of upto 3 kW and 20% for a capacity of upto 10 kW was also announced by the Government of Gujarat (GoG) for promoting solar rooftop in the region under the aegis of Solar Rooftop Yojana (GoG, 2019).

In terms of infrastructure, the country's first solar park was established in Gujarat in 2012. Gujarat also holds some of the best sites for wind energy production. In fact, country's first offshore wind park is planned to be set up in the state of Gujarat (Recharge news, 2019).

As of now, Gujarat has fourth highest installed RE capacity among all states in India. The state has 11% of total installed RE capacity of the country (CEA, 2019a). The state also has an ambitious target of 17% RPO for its Obligated Entities by FY 2021-22. Further, according to the Institute of Energy Economics and Financial Analysis, a target of 30

The succession of policy release in the power sector of Gujarat highlights the approach of the state towards easing out the reservations of all the stakeholders.

The Solar Power Policy 2009 provided a foundation for development of solar power market in the state and was seen by many as benchmark for the whole country at that time. The Solar Power Policy 2015 is the current policy for solar development in Gujarat.

As the prices of RE, especially solar, came down, the age of large solar parks with big developers came. With this, concerns over lack of decentralized systems such as rooftop solar systems came up. Thus subsidies for rooftop solar systems was announced. But, a cap of 50% of connected load was also imposed on installation. The cap was not supported by many and thus an amendment to remove the cap was introduced.

With entry of large developers, it was felt that small RE developers were at a competitive disadvantage (Sareen and Kale, 2018) and small scale RE development was not being given its due. Thus, a new Solar Rooftop Yojana and a Policy for development of Small Scale Solar PV Power Projects - 2019 was announced.

GW of installed capacity of renewable energy by 2022 has been announced in the Gujarat state budget for FY 2019-20 (IIEFA, 2019).

2.2 Opportunities & Potential of RE in the future

The state has an installed capacity of Renewable energy of around 9.8 GW as on September, 2019 but has a potential to scale further high. Current status of source-wise installed capacity5, MNRE target of installed RE capacity by 2022 and potential of RE in Gujarat is given in Table 4.

Table 4: Current status of Source-wise installed capacity, Target by 2022 and potential of RE in Gujarat

Source	Installed Capacity (GW) as on 31.03.2019	Target of Installed RE Capacity by 2022 (GW)	Total Potential (GW)
Solar	2.44	8.02	85
Wind	6.07	8.8	85
Small Hydro	0.06	0.025	0.25
Biomass	0.07	0.28	0.9
Others	-	-	1.1

Source: Vibrant Gujarat document and MNRE

Currently, only 3% of the solar potential, and 8% of the wind potential of the state has been tapped. Even on completion of the 2022 MNRE target, only 9% and 10% of solar and wind energy potential respectively will be utilized.

Only 6% of the of the total renewable potential has been tapped in the state of Gujarat

Gujarat does not have a coal resource of its own and has to buy it from the coal mines located in the other states of the country or import it. The state has to pay high amounts in the form of transportation charges to source the coal. Although, source rationalization of coal transport was done in the country leading to monetary savings, transportation cost of coal is still quite high. Thus, increasing the share of RE can be viewed as an instrument to reduce the coal transportation charge.

Furthermore, due to limited domestic gas availability, and high cost of Liquefied Natural Gas (LNG), the plant utilization factor of gas-based power plants is quite low. The PLF of gas based power plants of Gujarat was found to be 22% in FY 2017-18. Thus RE presents itself as an attractive opportunity especially for Gujarat. The state not only has a very high potential for wind energy but

[5] As on 30.09.2019 (MNRE)

also receives higher solar radiation than more other states in the country. Falling prices of RE, especially solar PV, in the recent years, has given a further push to RE in the state. Figure 11: Cost of solar power per unit over the years in India shows the per unit cost of solar power over the years in India.

With the announcement of the state Government in September 2019 not to set up any new thermal power plants in the future (The Indian Express, 2019) and meeting the increasing electricity demand through increase in RE capacity, the growth of renewable energy is inevitable.

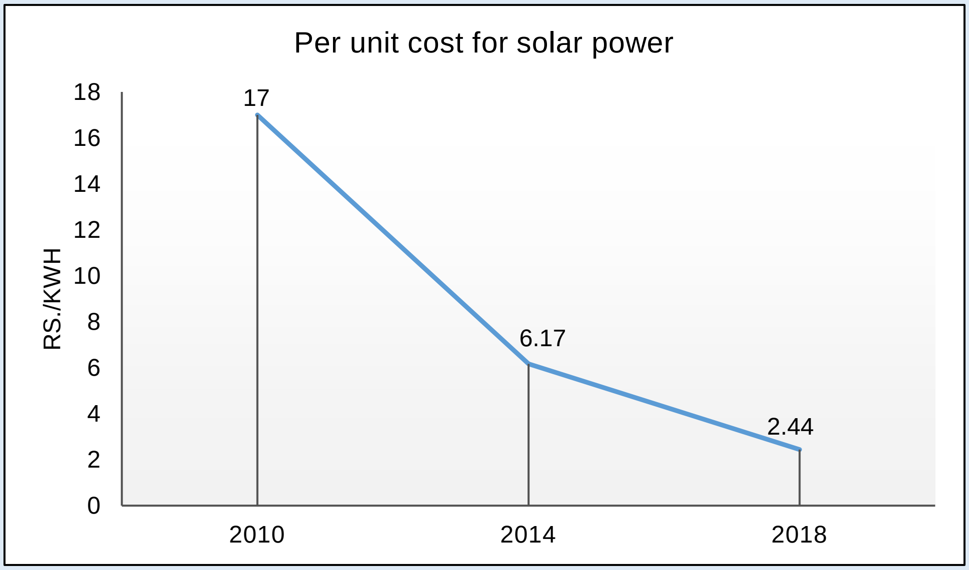


Figure 11: Cost of solar power per unit over the years in India
Source: MNRE 4-Year Achievement Booklet, 2018

Growth of RE in the state, while being hailed as a model of sustainable energy for future, comes with its own set of challenges. One very prominent among others is the intermittent nature of RE power. Due to this, it becomes a challenge for the grid operator to balance the load requirement with the available generation, including the intermittently available generation. Thus, there is now an indispensable need to forecast and schedule the RE power with increased accuracy to have minimum disturbance in the system. As shared by the state grid operator, If the GoI target of 175 GW of RE is to be achieved in true sense, demand forecasting, weather forecasting, solar forecasting as well as wind forecasting needs to be embraced for Integrated Energy Solution. However, even if the solar and wind forecasting becomes very accurate, there will still be a need for balancing of the intermittent generation. The cost of balancing this intermittency, as calculated for Gujarat by CEA in its Report (CEA, 2017a), was Rs. 1.45 per unit of energy consumed, considering historical renewable energy contracts of about Rs. 4 per unit. If these historical contracts are not considered, the balancing cost will be more in the range of about Rs. 1 per unit as per the Report. But even if Re. 1 is added to the levellized cost of renewable energy at Rs. 2.50 per unit, the total cost would still come to Rs. 3.50 per unit, including the balancing cost, which is lower than the new levellized cost of a new pit-head coal plant at about Rs. 4 per unit. Therefore, going for renewable energy for future electricity needs makes sense.

2.3 Promoting Renewable Power: Renewable Purchase Obligation (RPO)

Renewable Purchase Obligation (RPO) mechanism was first envisaged under Section 86 (1) (e) of Electricity Act 2003.DISCOM Renewable Purchase Obligation (RPO) is imposed on the obligated entities[6] to ensure that a fixed portion of energy as specified by the State Electricity Regulatory Commission, be procured from a RE generating station. Separate obligations are prescribed for procurement of solar and non-solar (wind) power.

Gujarat has been a pioneer in the power sector and has always set benchmarks for the country to follow. However, lately Gujarat is yet to match the ambitious targets prescribed by the Ministry of Power (MoP) in terms of RPO targets. In FY 19-20, Gujarat has a total RPO (as prescribed by GERC) of 14.5% which is less than the targets prescribed by comparable states viz. Maharashtra (15%), Rajasthan (15%) and Karnataka (18.5% average of all DISCOMs). The graphs below compare the targets identified by Gujarat and the ones prescribed by MoP, both for solar RPO and non-solar RPO.

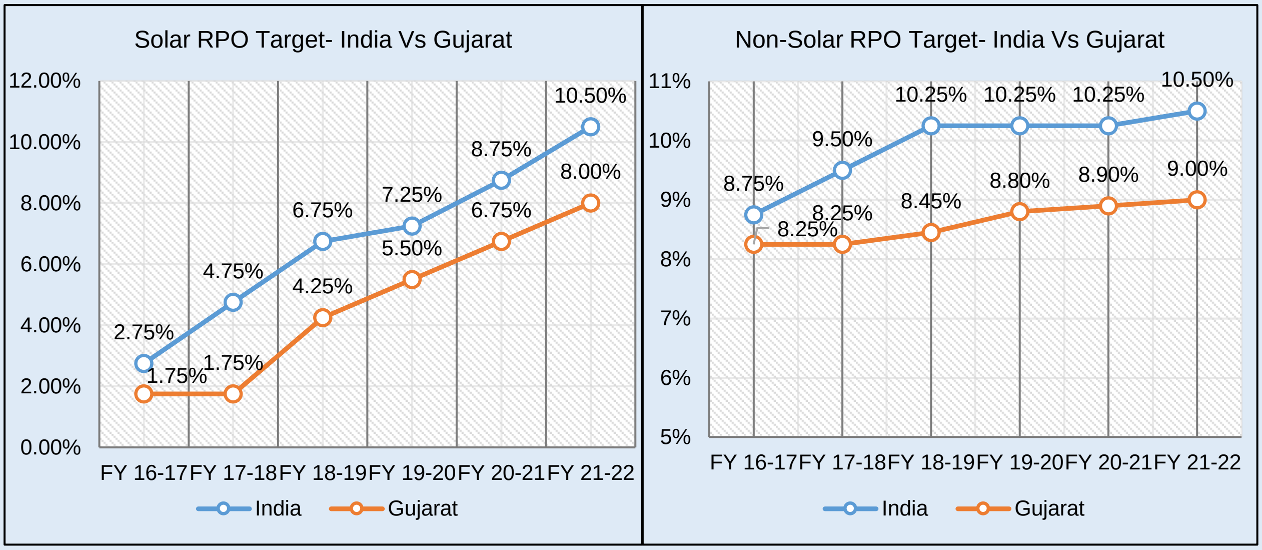


Figure 12: (a): Solar RPO Target – India Vs Gujarat
(b) Non – Solar RPO Target- India Vs Gujarat

[6] Obligated Entities- Entities who are obliged to have a portion of their electricity consumption generated from RE based generators- Distribution Companies, Consumers consuming electricity from its conventional Captive Generating plant of 5 MW and above capacity, consumers procuring electricity from conventional generation through open access and third party sale

As shown in Figure 12 given above, Gujarat targets are consistently trailing the ones prescribed by MoP. RPO Compliance of four public DISCOMs under Gujarat Urja Vidyut Nigam Ltd. (GUVNL) , namely Uttar Gujarat Vij Company Ltd. (UGVCL), Paschim Gujarat Vij Company Ltd. (PGVCL), Madhya Gujarat Vij Company Ltd. (MGVCL) and Dakshin Gujarat Vij Company Ltd. (DGVCL) and two private DISCOMs, Torrent Power Limited (TPL) – Ahmedabad & Surat and TPL – Dahej are shown below in **Error! Reference source not found.**.

Table 5: Year-wise RPO Target &Category; achieved and shortfall in procuring RE power on the part of DISCOMs

Year	RPO Category	RPO Target	Gujarat Urja Vikas Nigam Limited		Torrent Power Ltd., Ahmedabad & Surat		Torrent Power Ltd., Dahej		MPSEZ Ltd.		Source
			Achieved	Shortfall in %	Achieved	Shortfall in %	Achieved	Shortfall in %	Achieved	Shortfall in %	
FY 2013-14	Wind	5.04%	5.13%	-0.09%	4.55%	0.49%	4.63%	0.41%	0.00%	5.04%	GERC Order in Suo Moto Petition No. 1442/2014 dated 02.01.2019
	Solar	1.00%	2.18%	-1.18%	0.07%	0.93%	0.62%	0.38%	0.00%	1.00%	
	Others	0.11%	0.12%	-0.01%	0.00%	0.11%	0.00%	0.11%	0.00%	0.11%	
	Total	6.15%	7.44%	-1.29%	4.62%	1.53%	5.25%	0.90%	0.00%	6.15%	
FY 2014-15	Non-Solar	6.75%	5.39%	1.36%	6.73%	0.02%	6.67%	0.08%	0.00%	6.75%	As per Commission's order in petition no. 1533/2015 dated 31.12.2016
	Solar	1.25%	2.02%	-0.77%	0.68%	0.57%	1.24%	0.01%	0.00%	1.25%	
	Total	8.00%	7.41%	0.59%	7.41%	0.59%	7.91%	0.09%	0.00%	8.00%	
FY 2015-16	Non-Solar	8.25%									[7]
	Solar	1.75%									

[7] Not available as of yet

	Total	10.00%									
FY 2016-17	Non-Solar	8.25%	6.73%	1.52%	5.79%	2.46%	6.50%	1.75%	8.25%	0.00%	As per GERC interim order dated 4 April 2018 in Suo-Motu Petition No. 1713/2018
	Solar	1.75%	1.88%	-0.13%	2.46%	-0.71%	1.77%	-0.02%	1.75%	0.00%	
	Total	10.00%	8.61%	1.39%	8.25%	1.75%	8.27%	1.73%	10.00%	0.00%	
FY 2017-18	Non-Solar	8.25%	7.97%	0.28%	8.24%	0.01%	8.80%	-0.55%	8.24%	0.01%	GEDA Website
	Solar	**1.75%**	2.06%	-0.31%	2.59%	-0.84%	3.22%	-1.47%	0.81%	0.94%	
	Total	10.00%	10.03%	-0.03%	10.83%	-0.83%	12.02%	-2.02%	9.05%	0.95%	
FY 2018-19	Non-Solar	8.45%	9.62%	-1.17%	8.29%	0.16%	6.56%	1.89%	8.05%	0.40%	GEDA Website
	Solar	4.25%	2.23%	2.02%	5.22%	-0.97%	2.82%	1.43%	4.12%	0.13%	
	Total	12.70%	11.85%	0.85%	13.51%	-0.81%	9.38%	3.32%	12.17%	0.53%	

As seen in the table above, there has been a shortfall on part of DISCOMs in procuring RE power. The graphs below show the representation of the above data of RPO vs Actual achievement for Gujarat State owned Distribution companies as a whole (GUVNL) and the privately owned distribution company as a whole (Torrent Power Limited, TPL).

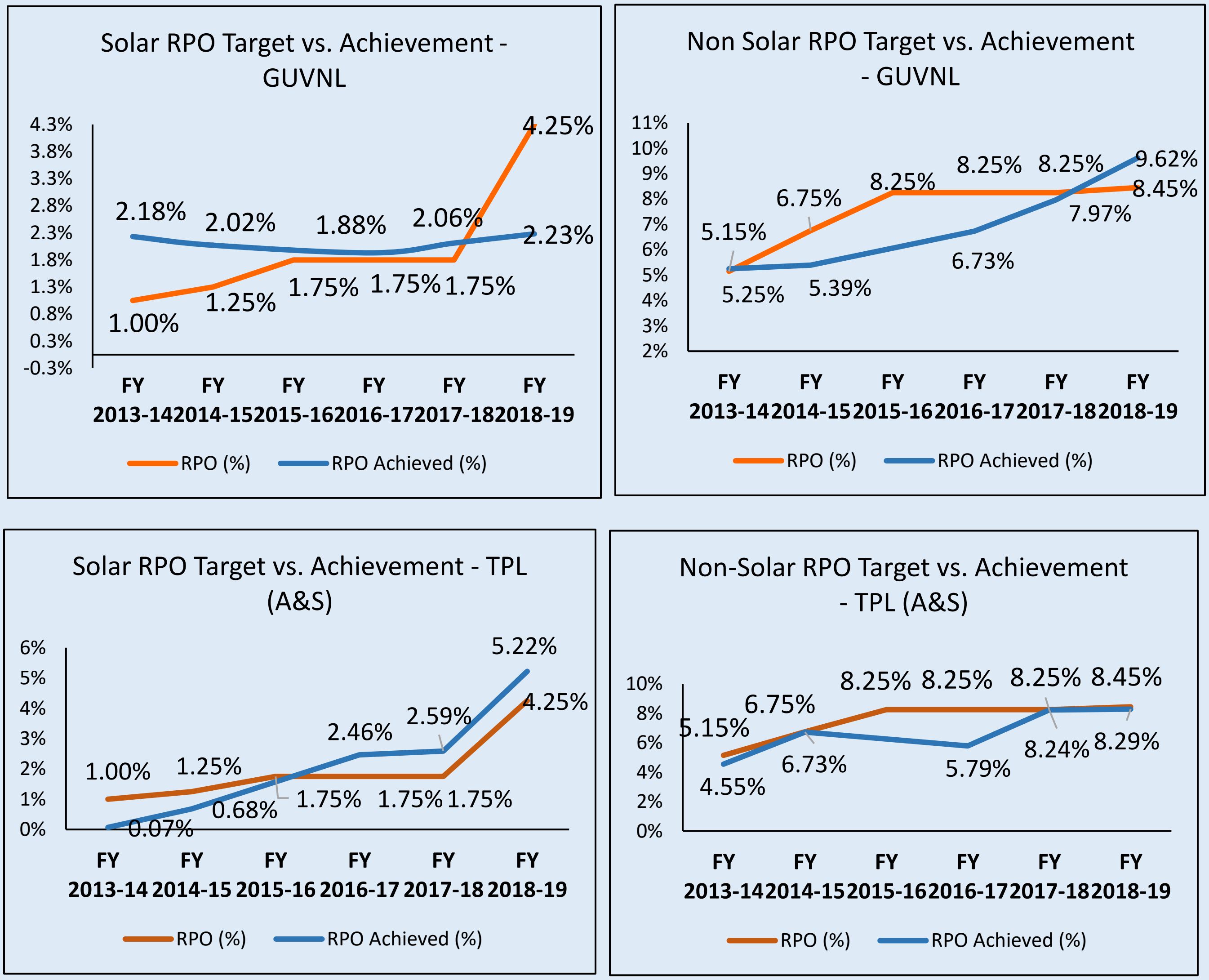


Figure 13: (a) Solar RPO Target vs. Achievement – GUVNL (b) Non- Solar RPO Target vs. Achievement – GUVNL (c) Solar RPO Target vs. Achievement – TPL (A&S) (d) Non- Solar RPO Target vs. Achievement – TPL (A&S)

Source: GERC Orders, GEDA (The Compliance data of FY 2015-16 is not available)

A reason that can possibly be attributed to shortfall in compliance by DISCOMs is the opportunity cost of renewable power. DISCOMs have existing Power Purchase Agreements (PPA), under which they must purchase a fixed quantum of power from conventional power sources, failing which they will still have to pay for the capacity charges for the purchase quantum agreed upon. Thus, if the difference between the demand and PPA commitments from conventional power plants is less than the RPO obligations, the opportunity cost of purchasing more renewables is price of renewables plus the capacity charges of the PPA that is not honored.

If the total RPO Compliance of the state is considered, there has been over-compliance in Non-Solar RPO targets of FY 2018-19 but there has also been shortfall of Solar RPO Compliance during the same period. Table 6: shows the data only for FY 2018-19 (provisional) for all DISCOMs in Gujarat.

Table 6: Summary of RPO Compliance of Gujarat DISCOMs (FY 2018-19) – Provisional

Distribution Licensee/Holding Company	Solar RPO Target (%)	Non-Solar RPO Target (%)	Energy Consumption (MU)	Solar RPO Compliance (% Points)	Non-Solar RPO Compliance (% Points)
GUVNL	**4.25%**	**8.45%**	22195	2.23%	9.62%
TPL – Ahmedabad & Surat			3632	5.22%	8.29%
TPL- Dahej			102	2.82%	6.56%
MPSEZ			76	4.12%	8.05%
Total			**26,004**	**2.66%**	**9.42%**

Source: GEDA

A lot of other obligated entities viz. the consumers procuring electricity from conventional captive power plants or through open access from conventional thermal power stations are yet to comply with the Renewable Purchase Obligation, not only for the current year but also for the past few years. To fulfill the RPO, the following needs to be done

a) When RPO obligations increase faster than the demand for electricity, the old PPAs become an obstacle. RPO trajectory should be announced few years in advance so that a state may not get into long term PPAs that will increase the opportunity cost of absorption of renewable power.

b) Since the differences in prices between the two major sources of RE, i.e. solar and wind, have come down, separate RPOs need not be prescribed. One RPO for total RE should be adequate.

Floor Price of Solar and Non-Solar RECs both is INR 1000/MWhr while the forbearance price is INR 2400/ MWhr and INR 3000/MWhr respectively. Approximately 1.8 million Renewable Energy Certificates are available in the market of which around a lakh are from solar projects. Hence, it can be assumed that the market is currently available with sufficient RECs for any obligated entity to purchase, for its RPO compliance.

2.4 Challenges & Bottlenecks for Increasing the share of RE

The Renewable Energy sector in the state (as well as in India) has gone through rapid changes in past few years. With the promulgation and acceptance of reverse bidding as a preferred mode of procurement of power by state utilities, new lows in tariff has been discovered. This has the potential to benefit the end consumers and alleviate the burgeoning pressure of power purchase cost in the total cost for the DISCOMs. While the discovery of low tariff has brought joy to many stakeholders, it has also brought the question of feasibility of such low tariffs in the long run. There is a certain section of stakeholders, who contest that until and unless the projects are successfully commissioned and run at least for a few years, it can't be said that the reverse bidding has been successful in its objective. There are also thoughts that floor price for RE bidding should be mandated to ensure quality of the system proposed. Some stakeholders also feel that there has been advent of non-serious players in the market, which may prove detrimental to the sector in the long run. There are also some obstacles in installation of new renewable capacity. Some of these are:

- **Land Allotment issues for central sector bids:** It has been alleged that the RE developers who have won the central (SECI[8]) bid to develop RE projects in Gujarat have faced delays in land allotment by the state government. While this is an issue highlighted by multiple developers, it has been suggested that the land allotment has not been done as the power generated by these stations are supposed to be sold outside Gujarat.

- **Regulatory Uncertainty:** Regulatory challenge is considered by many developers/investors as a major deterrent in decision making.

[8] SECI – Solar Energy Corporation of India Limited

a. It is alleged that despite allowing certain tariff/incentive for a definite control period, there were inhibitions in adhering to said decision, in the wake of certain developments in the sector.
b. In 2018-19, Gujarat cancelled 1200 MW bids for RE, due to the perception that the tariffs were on the higher side. This is believed to have slowed down the pace of RE deployment in the state (The Economic Times, 2019).

- **Forecasting & Scheduling/ Variability difficulties:** Stakeholders have highlighted that the forecasting and scheduling of the RE generation plant, as mandated by central and state regulations is a welcome step and while acknowledging that it is for the good of the grid, there has been massive variations in the wind speed during the day, leading to penalty provisions being invoked for the proponents involved. There have been variations of wind generation of more than 2000 MW in only nine-hour time span (CEA, 2017b) due to variable wind speed, thus leading to variability difficulties.

  It has also been highlighted by RE generators that in Gujarat, the aggregation of more than one pooling stations or individual generating station connected to a substation is not permitted while doing forecasting and scheduling. This is leading to heavy penalties as individual generator's Forecasting & Scheduling is very difficult owing to variability in wind speeds.

- **Ecological Issues:** Experts believe that there is a linkage between massive RE scale up (especially wind energy) and negative ecological impact especially on avifauna. The impacts include mortality from collision, barotrauma, electrocution etc. and disturbance in migratory paths due to habitat changes (WWF India and GEER Foundation, 2016; Kumar et al., 2019). Thus, these need to be duly considered beforehand.

- **Balancing Power Requirement:** Infirm nature of RE generation pose a challenge for grid stability especially when the portion of RE in the total energy mix is very high. It has been suggested that Gujarat has stopped using central government Gas Subsidy scheme for gas power plants due to restrictive conditions such as previous year PLF, maintaining designed heat rates, etc. All these conditions made the use of gas power plant impractical for balancing.

- **RPO Compliance:** The state utilities have missed their RPO targets in 2018-19 and hence would have to get more RE PPAs in place (support the deployment of renewables) or else would need to procure RECs from the market.

- **<u>Focus on Alternate Sources of Energy:</u>** Biomass based and Waste to Energy (WtE) power generation is at a very nascent stage in Gujarat (and also in India) and despite some Power Purchase Agreements being signed[9], has not been able to take off as a business model for many stakeholders. Policy push for WtE and Biomass based energy generation is required and will go a long way in mitigating GHG emissions and tackling the ever growing waste disposal in many cities across Gujarat (and India).

- **<u>No uptake on Repowering Wind Generator Scheme:</u>** Gujarat came up with its repowering policy in mid-2018 but there has not been any uptake of the policy by any Wind Energy Generator(WEG). While it makes sense to replace an existing low CUF wind turbine with a new one yielding far higher CUF, especially at high wind energy potential sites, there have been multiple barriers cited by developers. One of the major barrier that has been cited is that the developers are wary of is disruption of continuous flow of revenue source from existing PPAs. Because of the regulatory uncertainty the sector is in, no wind developer is willing to jeopardize their existent flow of income. Also, if any wind generator agrees for repowering of its turbines, it will not only have to forego the revenue for substantial period of months due to the works involved but also have to heavily invest in the infrastructure pertinent to new set of turbines. These additional infrastructure costs would have to be apportioned to only the additional power[10] that may be generated from the wind farm as the existing PPA will not allow additional cost in it. Thus, the additional power generated from the wind power may have high tariff and subjecting it to competitive bidding (as laid out in repowering policy) additionally puts stress on the developer as to whether or not the generated power will find any takers. These conditions coupled with no obligation for DISCOM to buy the generated power makes repowering far risky proposition for a WEG.

- **<u>Ambitious target:</u>** Gujarat's current total RE installed capacity is 9.8 GW[11], but the state's 2022 target for installed RE capacity is now revised from 17 GW to 30 GW as has been reported in the press (Mercom India, 2019) and confirmed by state officials. Thus the state has to deploy roughly 7 GW of RE capacity each year to achieve the target, which seems to be highly ambitious.

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[9] As mentioned by GEDA
[10] 'Additional Power' means the quantum of power generated over and above the power that was already being generated by the Wind Energy Generator (The generation corresponding to existing capacity prior to repowering shall be average of last three years prior to repowering of wind mill)
[11] As on 30/09/2019, MNRE

- **RE Induced Issues:**

    - **Deviation Charges:** It has been suggested by the state utilities that Gujarat absorbs a lot of RE power in its system and RE being infirm power causes major fluctuation in supply. This fluctuation causes deviation in the actual drawl of power from the grid against the schedule, for which the state is penalized. It is felt that despite helping the grid absorb more of RE generated power helping it become more green, penalties instead of incentives are imposed upon Gujarat. It is suggested that states like Gujarat which absorbs so much RE in the system, should be given an extra margin to operate its deviation, before a penalty is levied. There is an additional margin given for renewable rich states in the CERC Regulations for Deviation Settlement Mechanism, which should be increased.

    - **Transmission Cost:** RE generators have lower CUF, as compared to its conventional counterparts, due to which the transmission costs are higher for a dedicated RE corridor and hence it is felt that there should be support from central government when the same is built.

2.5 Way Ahead

For sustainable development of the state, de-carbonization of the power sector is of utmost importance. India's NDC promises to have 40% of its installed capacity through non-fossil fuel based energy sources by 2030. Currently, 31% of the installed capacity in Gujarat is non-fossil fuel based and rest 69% is fossil fuel based capacity. Although, the state is on course to achieve the 40% of non-fossil fuel installed capacity, the need of the hour for a RE blessed state like Gujarat is to contribute more to the cause by maximizing the RE in the energy mix while ensuring the grid stability through **Balancing Power**.

As per the 19th Electricity Power Survey Report, to cater to the electricity demand of Gujarat in 2030, the state would have to add around 25.5 GW of RE along with storage options in the coming years. This is assuming that no new fossil fuel based or hydro power plant is commissioned in

Additional 25.5 GW of RE is required to be installed in Gujarat by 2030 to suffice the electricity demand in case no new fossil fuel based or hydro power plant is commissioned by 2030.

the given time period, except those already under construction (See detailed calculations in **Appendix 1**).

On deployment of this additional 25.5 GW of RE along with the storage options by 2030, the share of non-fossil fuel energy based installed capacity will reach around 61% of the total installed capacity. This will exceed the 40% non-fossil fuel based installed target by a considerable margin.

As stated earlier, and also according to the views of the state grid operator, when the infirm power of such a huge quantum is injected into the grid, there will be a need for substantial balancing power to accommodate the intermittent generation in the system. Hence, for a healthy and un-interrupted power supply, it is necessary that reserve power which can be ramped up or down in a very short interval *viz. Gas Power Stations, Pumped Hydroelectric Stations,* etc. are available. Thus, efforts need to be made (on operational and policy level) such that these balancing power plants (at times also used as peaking power plants) are available by the time the RE mix in whole energy portfolio of the state is substantially higher. Pumped Storage Hydro Plants (PSPs) are being seen as one of the most promising options for balancing of grid (CEA, 2018; Srikanth, 2018). The technology makes even more sense in states with high RE penetration such as Gujarat. CEA in its National Electricity Plan has recognized PSPs as *“Best friends of Electricity Grid”.* It has also been suggested by state grid operator that MoP should undertake operationalization of more than 4000 MW idle Pump Mode hydro stations, which are not being operated due to administrative / minor technical issues, on high priority. A special task force may be deployed for the same. Further, avenues exploring technological modifications for using normal hydro-electric plant in pumped hydro mode should also be discussed. Advocacy of all upcoming hydroelectric power plants to indispensably be designed as pumped hydro plants through policy push, has also been put forward by few stakeholders.

Gujarat currently uses the flexibility in its existing thermal power stations to accommodate infirm power in the system and balances the system in the best way possible, using existing resources. At present, the practiced technical minimum of thermal power stations is around 60-65% of its rated capacity (without secondary fuel support). This is higher than the technical minimum norms of 55% prescribed by CERC[12] for Central Generating Stations and Inter-State Generating Stations. It has been suggested that technical modification, if required, may be carried out by the machine manufacturers to achieve the prescribed norms which will give more flexibility to the grid operator in managing infirm power in the system.

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[12] As per CERC IEGC 4th Amendment Regulations 2016

Increasing the flexibility of thermal power plants can aid the transitioning of the grid to a more renewable friendly system. However, this also means an incremental cost for the power plant, as these plants are designed to run at base load. Thus, revision of tariff structure for flexible operations of plants may be needed to support them (CEA, 2019c).

Decreased technical minimum of thermal power stations allows them to run even when there is high generation of RE. In case the generation from RE drops, they can be quickly ramped up as opposed to starting up the plant after complete shutdown. Start-up of a power plant is not only slow but also costly. Thus, reducing the technical minimum of a thermal power station also results in monetary savings. (National Renewable Energy Laboratory, 2019).

Forecasting and Scheduling (F&S) of RE generating stations has been the Achilles' heel for the RE sector and while everyone agrees that it is an indispensable necessity for a stable grid, accuracy of the same has always been an issue till now. Appointment of Qualified Coordinating Agency (QCA) for carrying out the forecasting and scheduling by RE generator themselves have seen its own challenges. Penalties of very huge quantum are being levied consistently ever since the regulations have been implemented owing to deviation from the allowed variation. It has been suggested by RE developers that appointment of an agency to do the F&S activity by the grid operator itself (SLDC may levy fees on RE developers) will bring uniformity in carrying out the generation forecast and it might also reduce the penalty burden on the developer. Pilot projects are being taken up by Western Region Load Dispatch Center (WRLDC) for forecasting of RE rich constituents (WRLDC, 2019). In regard to aggregation of more than one pooling stations or generators, it has been suggested by some developers that the same should be allowed in Gujarat such that the penalty burden on them is eased.

There have been suggestions to exploit the expertise of Indian Meteorological Department (IMD) in the forecasting and scheduling of Wind Energy Generators. IMD can predict the weather conditions to not only forecast the wind generation but also help in predicting the load fluctuations. Power System Development Fund can be used to create a sub-group of dedicated professionals which specifically caters to the cause.

With regard to the land allotment to RE developers who have won central bids, there have been suggestions that the projects who are to supply power outside the state should pay some royalty to the state which can be used for RE sector development in the state. The applicability of such a suggestion will mean an extra tariff burden on the developer which again has ramifications for developers' financial viability, as they would not have embedded such cost while bidding for the project.

It has been highlighted by many stakeholders that the PSDF and NCEF funds need to be used more proactively for the RE development activities of the state, including creation of RE dedicated transmission lines, infrastructure for energy banking as well as RE F&S activities.

It is felt that Gujarat Repowering Policy needs to be revisited by the policy makers and appropriate changes may be made to make it more appealing to existing wind energy generators.

3. Energy Efficiency in Gujarat Power System-Overall Health

3.1 Generation of Power

Gujarat has a total thermal power capacity of around 23 GW, majority of which is coal based (63%), followed by 33% of gas based and 4% of lignite based capacity. The state is power surplus and has invested in varied power projects to suffice its needs.

Figure 14 depicts various thermal power stations present in the state with their capacities. It can be seen from the graph that although coal power plants have a larger share in capacity, the number of gas power stations is highest.

The plants with highest capacities in the state (and also in the country) are Mundra UMPP (Ultra Mega Power Project) and Mundra TPP (Thermal Power Plant). These plants have multiple supercritical units that are inherently more efficient than the units with smaller (sub-critical) capacities. The government sector is currently investing in setting up new more efficient units at the location of older power plants.[13]

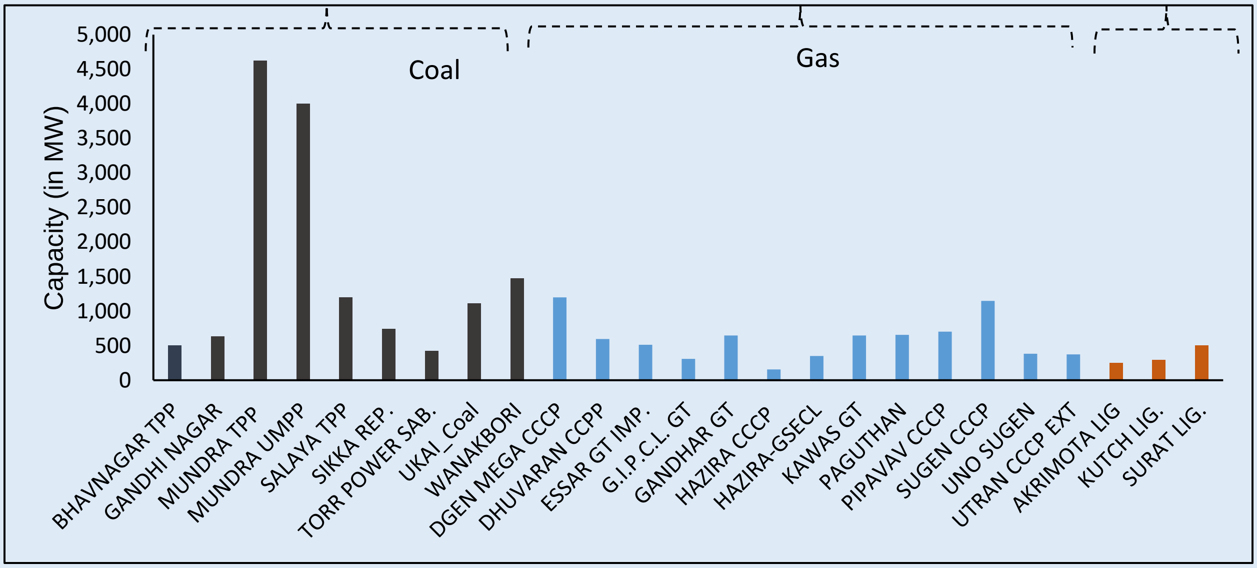


Figure 14: Thermal power stations present in the state of Gujarat with their capacities
Source: Central Electricity Authority

[13] A new unit of 800 MW has been constructed but is awaiting COD at Wanakbori TPS (As on 30th September, 2019).

3.1.1 Current Scenario

I. Coal Power Plants

Power sector is one of the major carbon emitting sector in Gujarat. Gujarat's major share of electricity comes from coal power stations.

Specific emission of a coal power plant is dependent on many factors such as the type of coal, design technology of the power station and its operational efficiency etc. Figure **15** shows the Fuel-wise specific emissions of power stations of Gujarat.

As is evident from the figure, a comparison of specific emissions of the coal power plants showed that Gujarat has some plants with very good performance such as Mundra Ultra Mega Power Project (Mundra UMPP), while others are exceeding the national average of specific emissions. The plants with consistently high specific emissions are Wanakbori Thermal Power Station (Wanakbori TPS), Gandhinagar Thermal Power Station (Gandhinagar TPS) and Ukai Thermal Power Station (Ukai TPS).

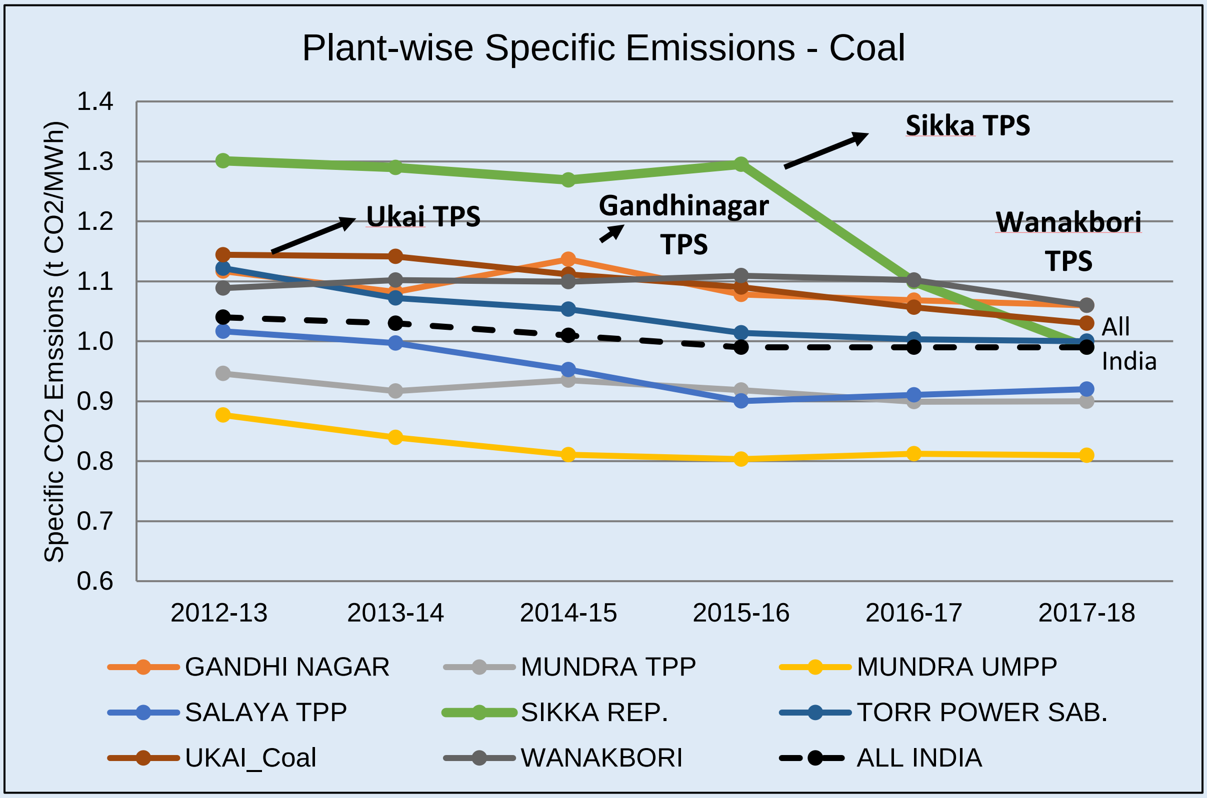


Figure 15: Plant-wise Specific Emissions of Gujarat - Coal
Source: Central Electricity Authority and IRADe

It is to be noted that although Sikka TPS also had consistently high specific emissions, they dropped in FY 2017-18 due to retirement of the two older units of the power station.

A closer look at the auxiliary consumption of the coal power plants in Gujarat as shown in Figure 16 shows that Wanakbori TPS, Gandhinagar TPS and Ukai TPS's auxiliary consumption are also on the higher side. Higher auxiliary consumption of a plant is associated with reduction in the amount of effective electricity available to the grid, thus leading to lower efficiency and higher specific emissions.

A low Plant Load Factor (PLF) is associated with decreased operational efficiency of a plant. A low PLF translates to increased heat rates and thus total efficiency of the plants, which in turn affects the specific emissions of a plant. A PLF in the range of 75 to 85% leads to an increase in the station heat rate by 2.25% in the sub-critical coal/lignite units as compared to the units running on a PLF of more than 85%. A further drop in PLF to 65 to 75% leads to an increase in station heat rate by 4%[14].

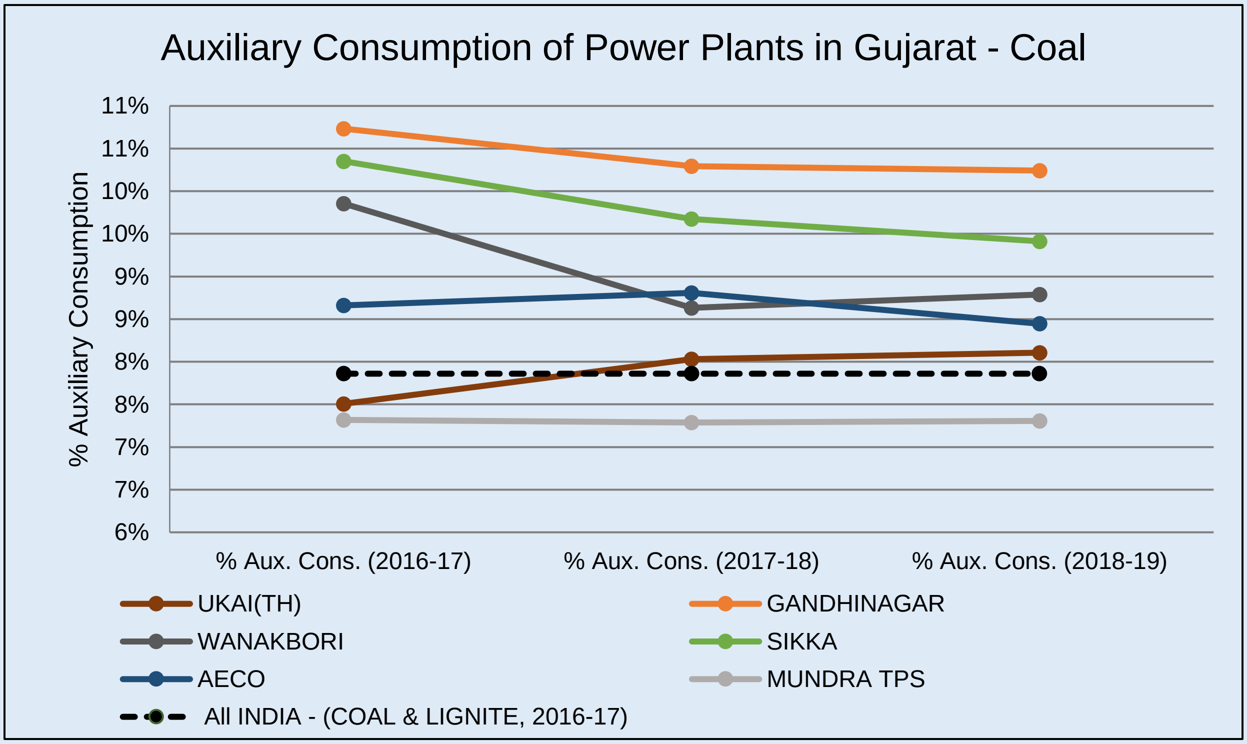


Figure 16: Auxiliary Consumption of Power Plants in Gujarat - Coal
Source: Gujarat SLDC and IRADe analysis

[14] As per CERC IEGC 4th Amendment Regulations 2016

On observing the PLF data of the coal power plants (Figure 17), it was seen that PLF for the aforementioned plants have increased in FY 2017-18. However, specific emissions of the plants have not been significantly affected by this increase in the PLF.

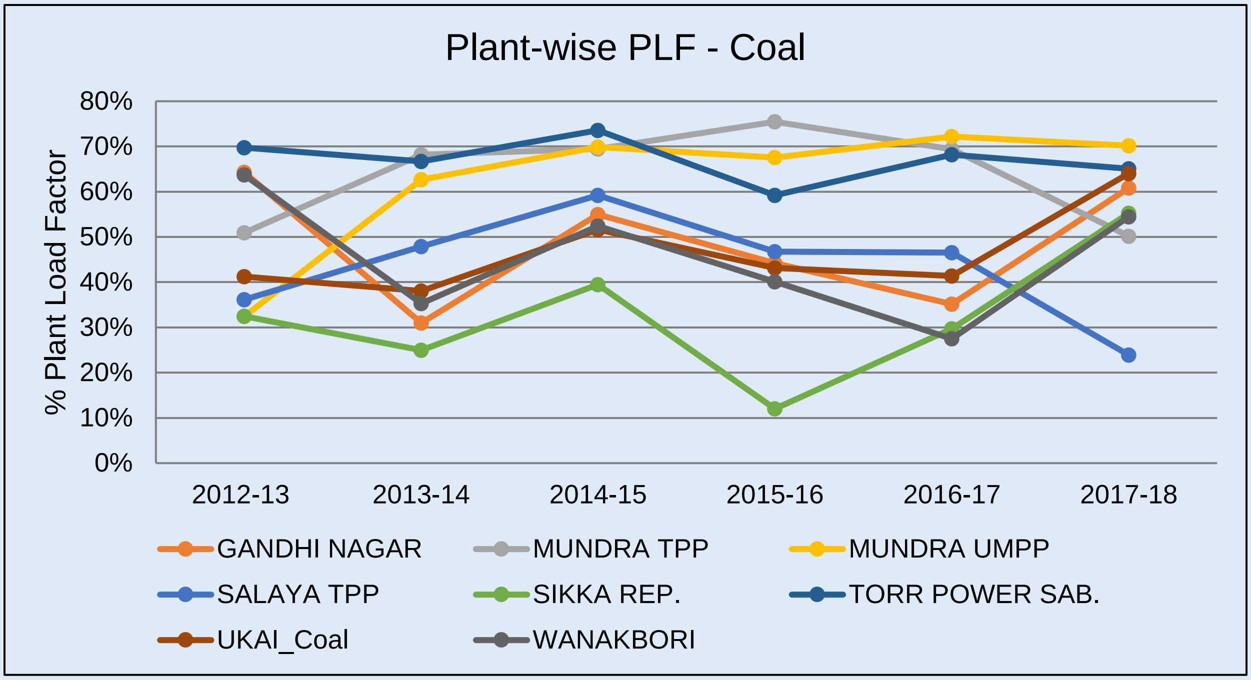


Figure 17: PLF of Power Plants in Gujarat - Coal
Source: Central Electricity Authority and IRADe analysis

It was however seen from the month-wise PLF data shown in Figure 17 that the PLF of the said plants dropped drastically in the months of July and October in the FY 2017-18.

Further analysis of the age of the plants revealed that the said plants are very old. Often older plants with old technology are found to have higher specific emissions. Units of Wanakbori TPS are 30-37 years old. In FY 2014-15, the plant's operating heat rate was found to be 13% higher than the design heat rate[15]. Gandhinagar TPS which has highest percentage of auxiliary consumption has two units that are 29 years old. Ukai TPS's three units were found to be around 40 years old, and the auxiliary consumption of the plant has increased despite retirement of its two older units. In FY 2014-15, the plant's operating heat rate was found to be 26% higher than the design heat rate.

[15] CEA

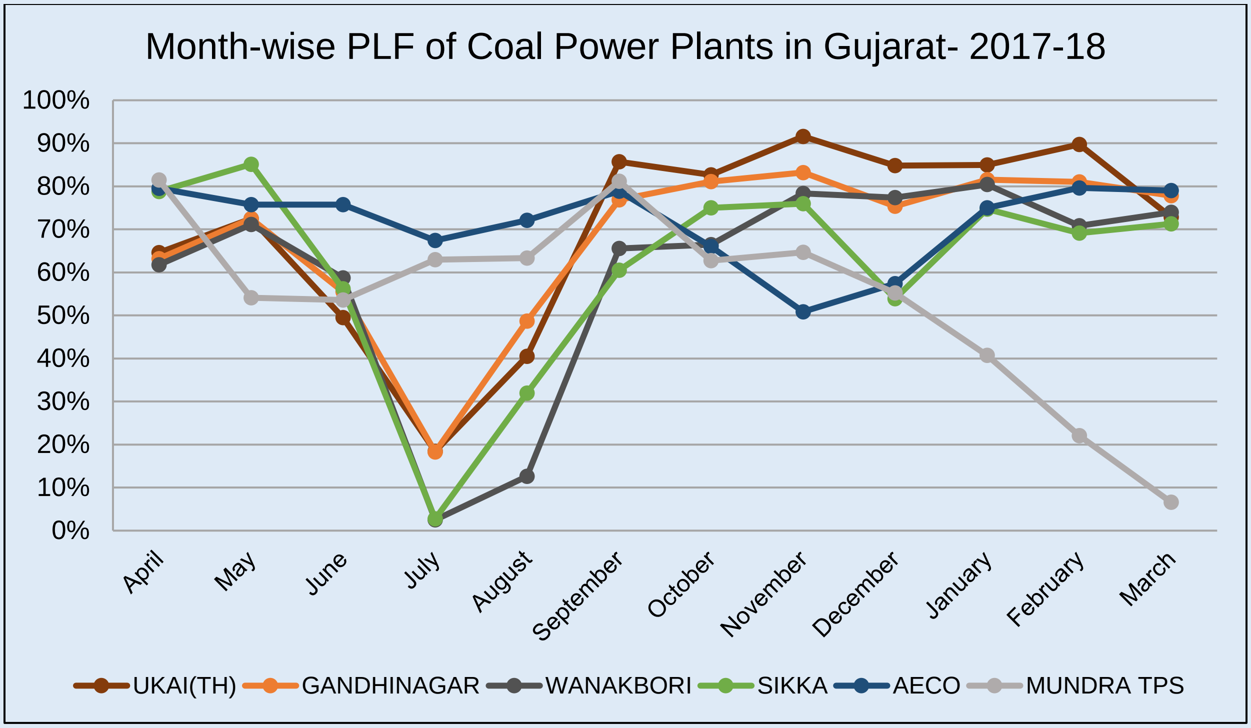


Figure 18: Month-wise PLF of Power Plants in Gujarat - Coal
Source: www.sldcguj.com and IRADe analysis

Further analysis of the age of the plants revealed that the said plants are very old. Often older plants with old technology are found to have higher specific emissions. Units of Wanakbori TPS are 30-37 years old. In FY 2014-15, the plant's operating heat rate was found to be 13% higher than the design heat rate[16]. Gandhinagar TPS which has highest percentage of auxiliary consumption has two units that are 29 years old. Ukai TPS's three units were found to be around 40 years old, and the auxiliary consumption of the plant has increased despite retirement of its two older units. In FY 2014-15, the plant's operating heat rate was found to be 26% higher than the design heat rate.

II. Lignite Power Plants

Lignite is an inferior quality coal, and has lower calorific values. Lignite power plants are thus inherently more polluting and have higher specific emissions. Thus, number of lignite power plants in the country is limited. There are only three lignite fired power plant in Gujarat. Figure 19 shows the specific emissions of lignite power stations in Gujarat.

[16] CEA

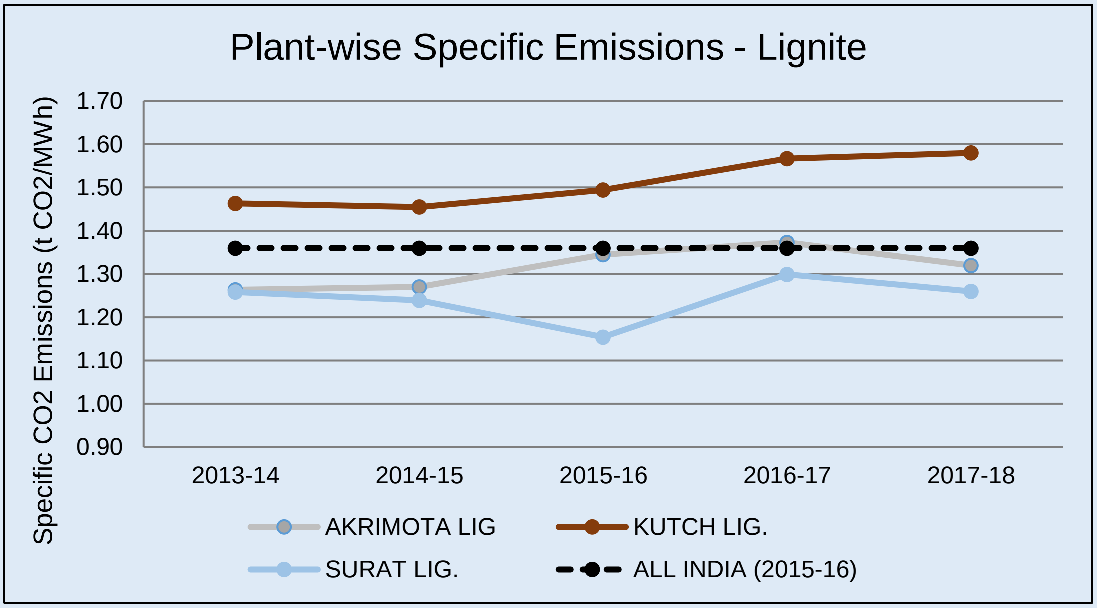
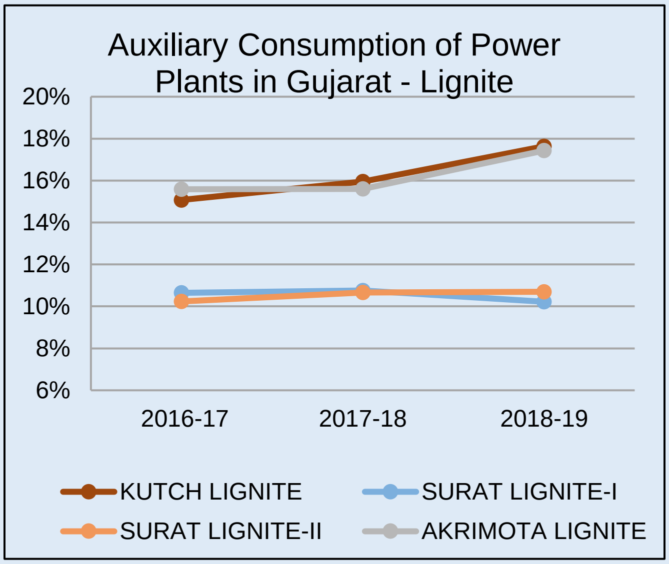


Figure 19: Plant-wise Specific Emissions - Lignite
Source: Central Electricity Authority and IRADe analysis

While emissions of Akrimota and Surat Lignite power stations are below the national average, specific emissions of Kutch Lignite Power Station are much higher.



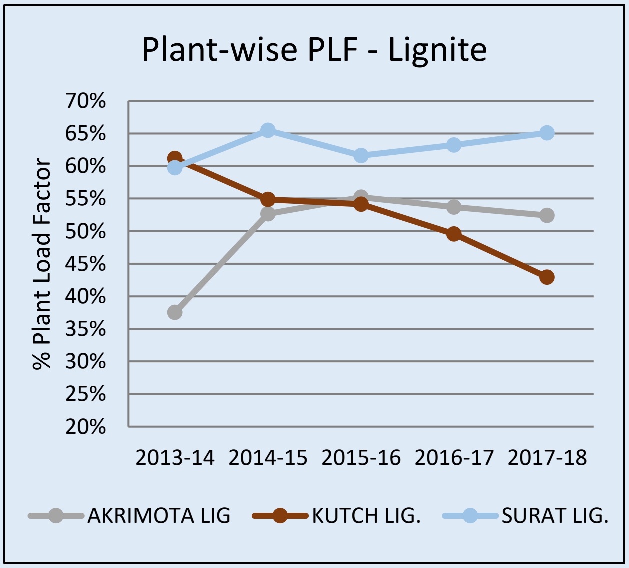


Figure 20: Auxiliary Consumption and Plant-wise PLF of power plants in Gujarat - Lignite
Source: www.sldcguj.com, Central Electricity Authority and IRADe analysis

From the Figure 20, it can be seen that PLF of the Kutch Lignite Thermal Power Station (KLTPS) has fallen progressively, which may be contributing to its higher emissions and auxiliary consumption. The specific emission of 1.58 tCO2(e)/MWh for KLTPS is perilously high as against a national average of 1.36 tCO_2(e)/MWh. The number is high even from the perspective of Lignite based station as a source of energy.

III. Gas Power Plants

Natural Gas is a cleaner fuel than coal and hence the emissions from gas power plants are comparatively lower. Figure 22 shows the plant wise specific emissions of gas power plants in Gujarat.

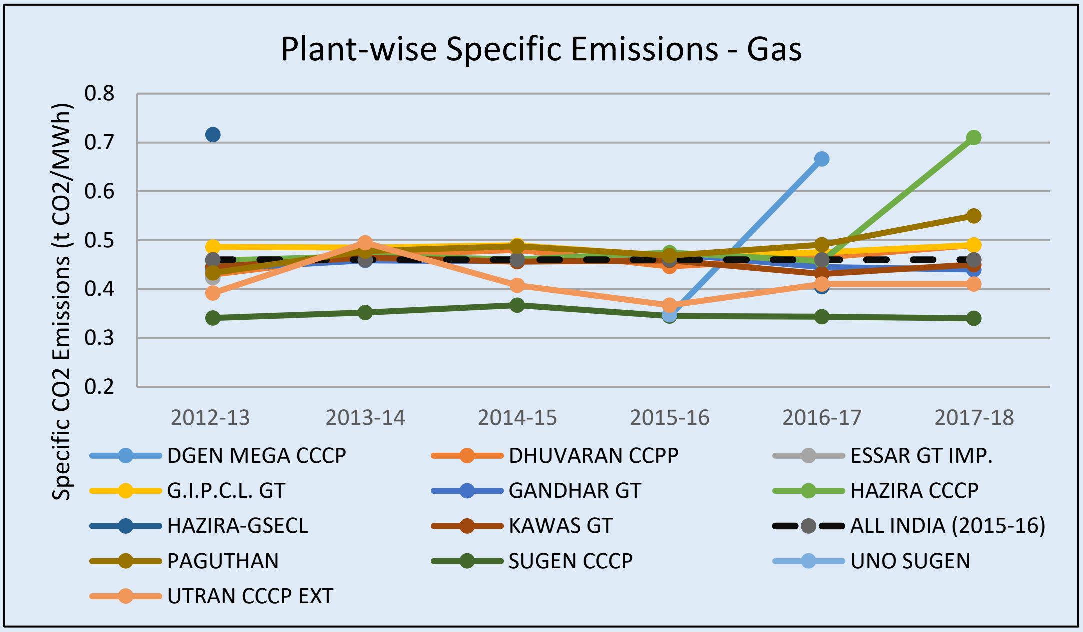


Figure 21: Plant-wise Specific Emissions of Power Plants in Gujarat - Gas
Source: CEA and IRADe Analysis

Emission patterns of the gas power plants are quite erratic due to highly variable nature of their PLF as shown in Figure 22.

Gas power plants in the country have had variable PLF's in past few years. Lesser than expected production of domestic gas in past years has been the major hurdle for gas power plants. Also, utilization of LNG in thermal power plants is expensive as compared to domestic coal. It may have thus become difficult for gas power plants to compete with other sources of electricity especially since the cost of renewables have come down. Lower PLFs are also found to negatively affect the operational efficiency of a thermal power station.

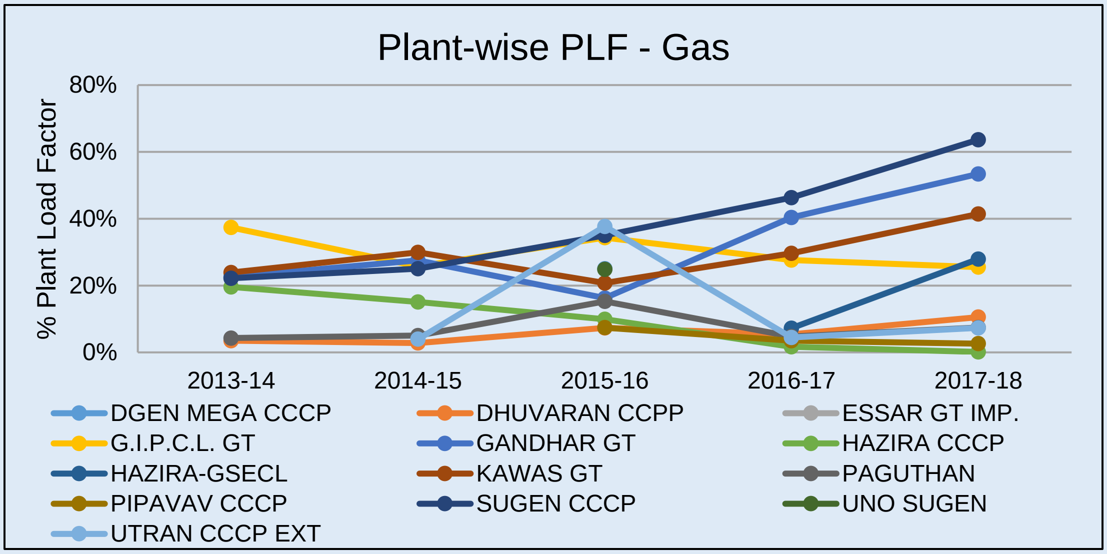


Figure 22: Plant-wise PLF of Power Plants in Gujarat - Gas

Source: Central Electricity Authority and IRADe analysis

Gujarat has lately procured gas through high sea bidding which is hopeful to bring down the per unit fuel or variable cost to INR 3.63/kWh from its Gas power stations. Although, it is believed that the procured gas will be used for generation of base as well as peak load plants and alleviate the financial situation of the gas thermal power stations especially the debt trap they are currently in, such innovative ways to improve the cost dynamics in favor of DISCOMs is highly appreciated and will also provide much needed options in balancing the grid better.

3.1.2 Future Opportunities

Renovation and Modernization (R&M) of the older thermal power plant units seem to be an obvious solution to increase the efficiency of thermal power stations (CEA, 2017c).17 However, there may be some instances where R&M of power stations might not decrease the emissions to a significant extent. Setting up of newer units and decommissioning of older units may present better results in some cases. New power plants may have higher fixed charges than older plants but variable charges of these plants are lower.

It is interesting to note although most of the thermal capacity of the state is 5-10 years old, a sizeable chunk (2,447 MW) is still more than 30 years old as shown in Figure 23Figure 23.

[17] R&M of units 1 and 2 of the Ukai TPS did not yield expected results as planned and the units had to be consequently retired. Moreover, the planned R & M of Gandhinagar TPS was also dropped.

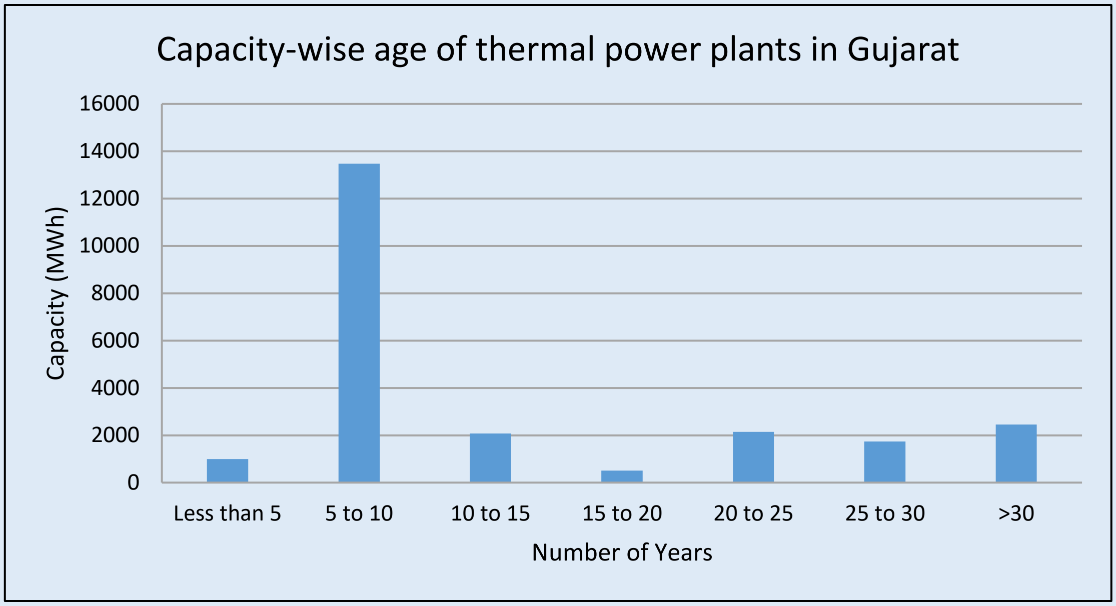
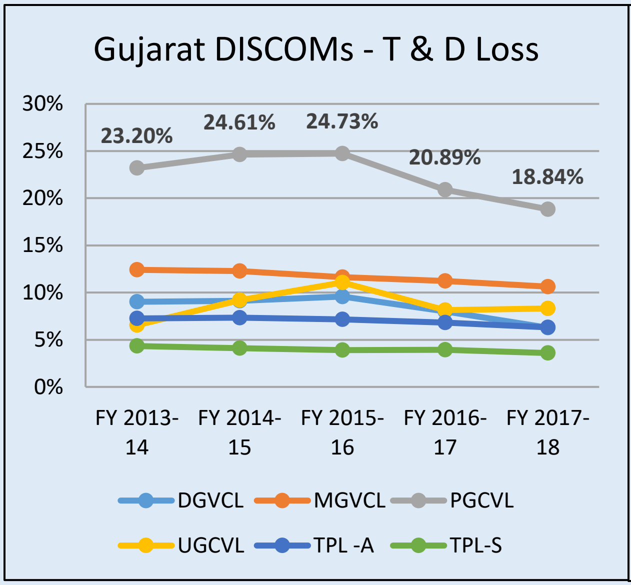


Figure 23: Capacity-wise age of thermal power plants in Gujarat
Source: Central Electricity Authority and IRADe analysis

3.2 Transmission & Distribution (T&D) Loss Perspective

Gujarat is the best performing state in terms of reducing the pilferage of energy in the distribution network. All the four DISCOMs are rated as the best state distribution utilities (assigned rating of A+) in the country by Power Finance Corporation (PFC). Gujarat is regular with its timely Tariff Orders, dissemination of the required data for public domain and many other regulatory requirements but the low T&D loss levels sets a benchmark for other state distribution utilities to follow. The low loss level is also the reason for strong financial health of DISCOMs in the country. Private DISCOMs viz. TPL- Ahmedabad, Surat and Dahej also have one of the lowest loss levels in the country. Given below is a figure of the losses of DISCOMs over last few years.



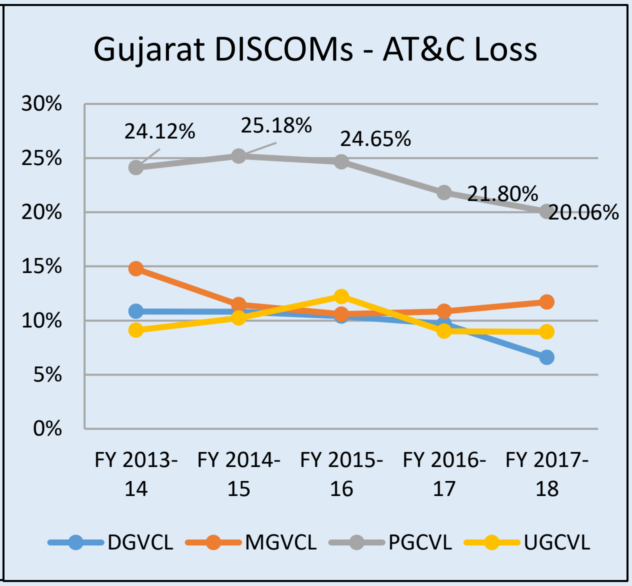


Figure 24: (a) Gujarat DISCOMs – T&D Loss (b): Gujarat DISCOMs – AT&C Loss
Source: GERC Tariff Orders; PFC – Performance of State Utilities

As can be seen and highlighted in Figure 24 (a) and Figure 24 (b), while the T&D loss levels of other DISCOMs are well below 13% in last five years and are progressively brought to sub 10% levels, Paschim Gujarat Vij Company Limited (PGVCL) still has high loss levels in its control area. As shown in Figure 24 (b), there has been substantial improvement in AT&C Loss levels, but a lot still needs to be done for PGVCL to reach the high standard level set by other DISCOMs.

Table 7: State-wise population/area (Person/km^2) and their T&D Losses 2016 – 17 (%)

State	Population/Area (Person/km^2)	T&D Losses 2016 – 17 (%)
Jammu & Kashmir	56	47
Himachal Pradesh	123	22
Punjab	551	18
Uttarakhand	189	25
Haryana	573	34
Rajasthan	200	30
Uttar Pradesh	829	24

Bihar	1106	30
Sikkim	86	24
Arunachal Pradesh	17	49
Nagaland	119	21
Manipur	128	37
Mizoram	52	35
Tripura	350	30
Meghalaya	132	36
Assam	398	25
West Bengal	1028	22
Jharkhand	414	16
Odisha	270	38
Chhattisgarh	189	26
Madhya Pradesh	236	27
Gujarat	308	18
Maharashtra	365	18
Andhra Pradesh	308	16
Karnataka	319	13
Goa	394	18
Kerala	860	18
Tamil Nadu	555	13

Studying the comparably high loss levels of PGVCL, it can be inferred that PGVCL has very large area to serve most of which is sparsely populated. It is a well known fact that if electricity is transmitted to far off places, there are more technical losses (i^2r losses) in the system as compared to a DISCOM which has same consumption quantum for a shorter control area. Thus, by design, it is obvious that PGVCL will always have more T&D loss as compared to other state DISCOMs which have less area to serve. But, it is important to establish the allowable loss percentage for PGVCL when compared with other state DISCOMs.

To arrive at the allowable loss levels for PGVCL, the relation between Population Density and AT&C Loss level needs to be established. For this purpose, the below mentioned Figure 26 is plotted which shows the loss levels in 28 Indian states in comparison to their total area.

As shown in Figure 24 given above, the distribution of loss levels is concentrated near a specific area and hence the data set is optimum for regression analysis. Outputs of regression analysis is given in Appendix 2.

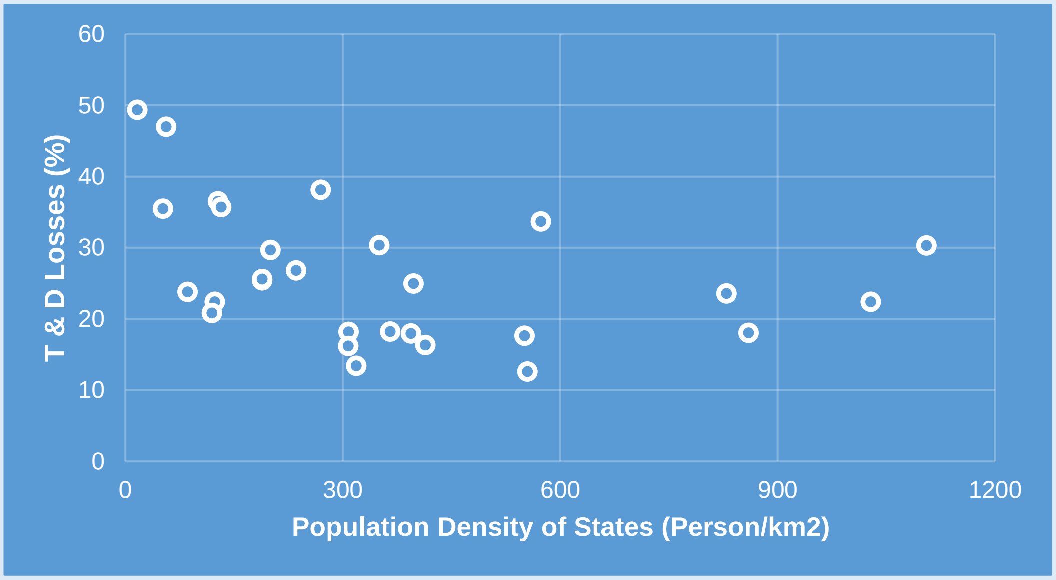


Figure 25: T&D Loss Vs Population Density
Source: CEA General Review 2018, CENSUS 2011

Thereafter, the findings of the above output were replicated for the state of Gujarat discoms to find out their optimum levels of AT&C loss levels. Figure 25 shows the Area and rural population served, Density of population in the control area and AT&C loss levels of DISCOMs in Gujarat state.

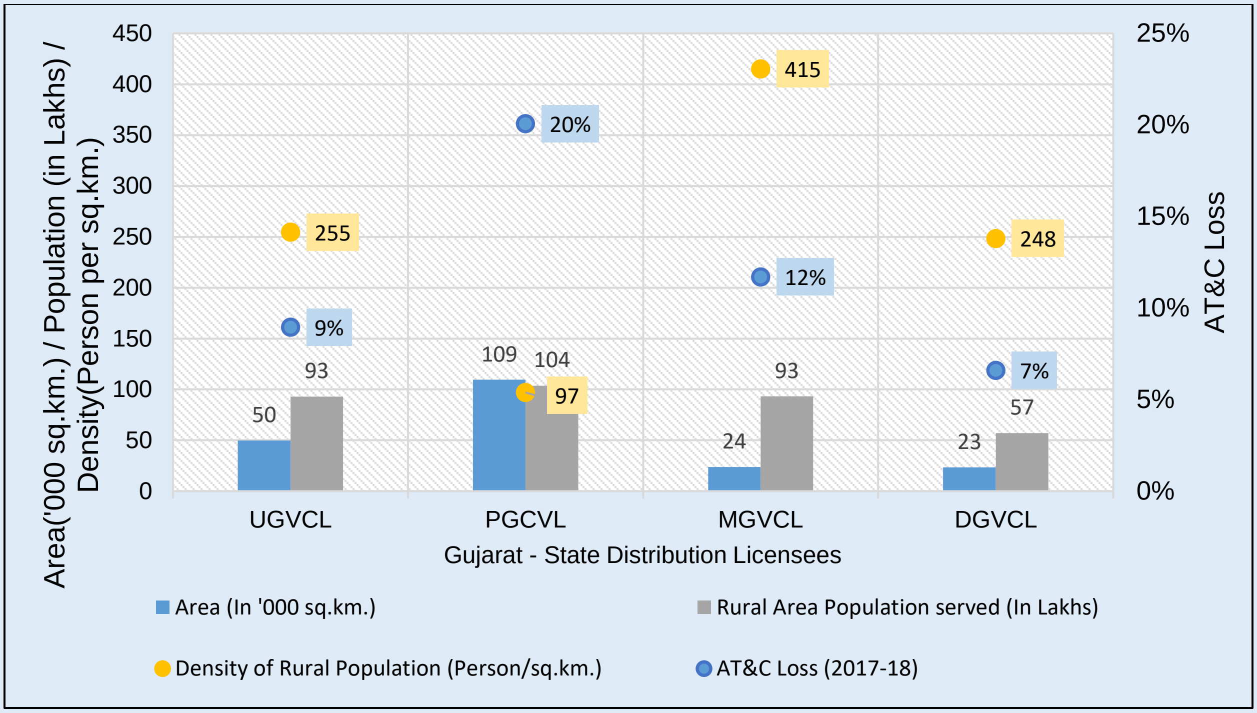


Figure 26: Gujarat Discoms - Command Area dynamics (FY 2017-18)

Source: MoP, 2019; Census 2011 and IRADe analysis

As is clear from the

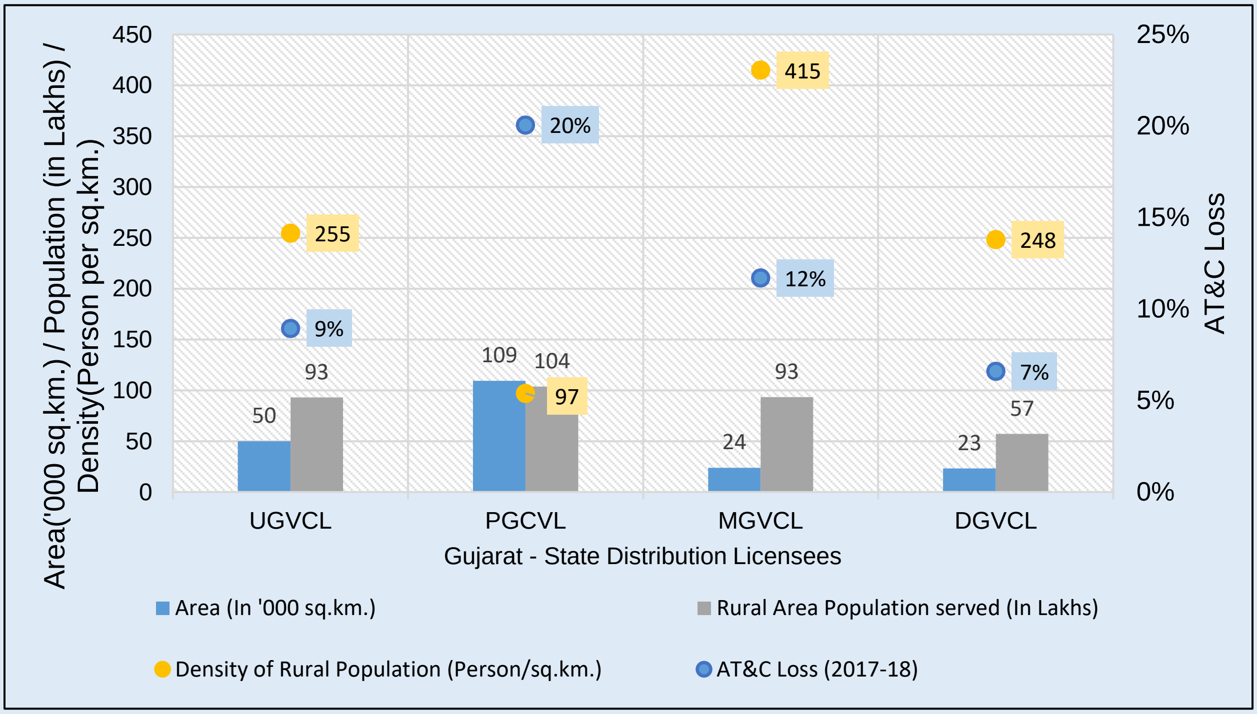


Figure 26, the AT&C loss levels of PGVCL is highest at 20.06% (Ministry of Power, 2019) among the four DISCOMs owing to larger rural area being served by the DISCOM.

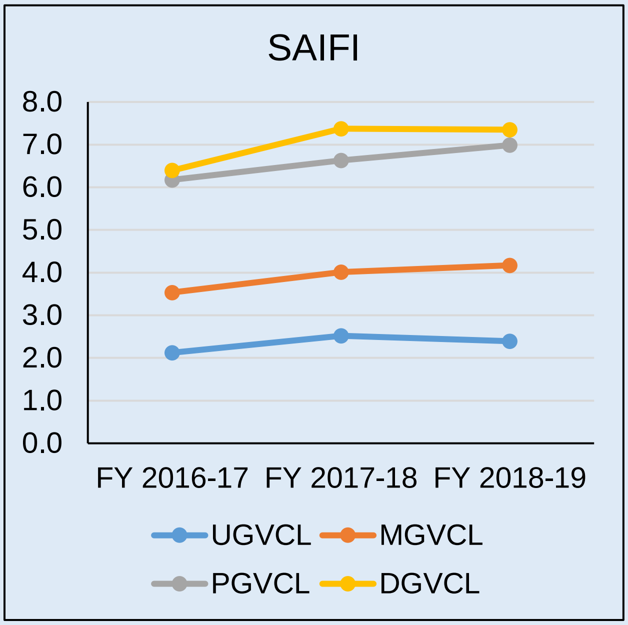
Thus, to account for the effect of rural area population served by PGVCL, an allowable value as compared to other DISCOMs is calculated based on the output given by the regression done above. The equivalent AT&C loss value of PGVCL as compared to the other DISCOMs is 4% i.e. if the other Gujarat DISCOMs has a AT&C loss level of 10% (say), the on par loss levels for other DISCOMs would be 14%.

Thus, there is a substantial scope of reduction of losses in PGVCL area, despite its low population density.

3.3 System Reliability

Gujarat is considered as a developed state as well as a state wherein the average per capita income is better than most other states in India. The Per capita income of the state (FY 2014-15) is INR 124678 (Press Information Bureau, 2017) as compared to per capita net national income of INR 86454 (FY 2014-15). The Net State Domestic Product (NSDP) of the state for FY 2014-15 was INR 789949 Crores (Press Information Bureau, 2017) which is next only to Maharashtra, Tamil Nadu, Uttar Pradesh and Karnataka. Hence, the energy appetite of the state is strong and is growing. Gujarat is home to many large industries as well as thousands of small scale industries viz. the thriving textile industry, engineering, chemicals, petrochemicals, drugs & pharmaceuticals, dairy, cement & ceramics, and gems & jewelry, which consumes substantial energy. Uninterrupted supply of electricity is thus important for these industries to run seamlessly.

Diesel Generators (DGs) are kept as backup of power so as to avoid loss of manufacturing and waste of unfinished goods, in the event of loss of power due to load shedding. DGs are also used extensively for temporary connections viz. marriage functions, political events or similar mass gatherings. The usage of DGs burn diesel, which is a heavily polluting fuel and adds to the unwanted carbon content in the environment. The only way to avoid usage of DG for electricity generation for various purposes, is to provide uninterrupted supply of power for which reliability of supply is an important parameter for the DISCOM. The below figure shows the System Average Interruption Frequency Index (SAIFI)18 and System Average Interruption Duration Index (SAIDI)19 of the state DISCOMs in past three years.



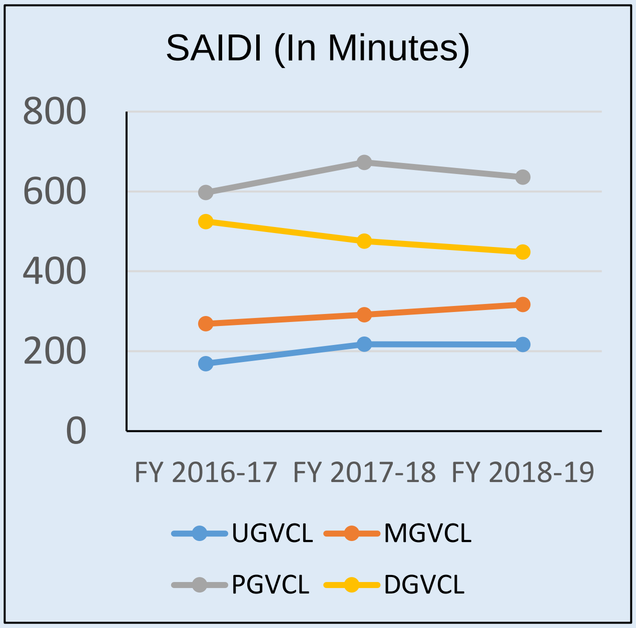


Figure 27: Year-wise SAIFI and SAIDI (in minutes)

As can be interpreted from Figure 29 given above, the average interruption frequency in the system is higher for PGVCL and DGVCL as compared with UGVCL and DGVCL. Figure 27 shows that the average outage duration for each consumer served in PGVCL is quite high as compared to other DISCOMs.

3.4 PGVCL – A brief insight on distribution performance

PGVCL is the largest DISCOM in terms of area in the state. It is also the DISCOM with highest losses in the state. While other DISCOMs have one of the minimum loss levels in the country,

[18] SAIFI - (Average interruptions per customer per year. Calculated as: Total Numbers of Consumer Interruptions) / (Total Numbers of Consumer Served)
[19] SAIDI - SAIDI is the average outage duration for each customer served.

PGVCL has a substantial scope of improvement in terms of the loss levels as well other performance viz. Average System Interruption, Transformer Loss Levels, etc. Hence, PGVCL has been selected as a focused DISCOM in the following section:

PGVCL – Brief Profile

- Area Served – 99,791 km^2 (approx.)
- Population Served – 17.5 Million (approx.)
- Total Consumers – 59,00,961
- Circles/Divisions/Sub-Divisions – 12/45/246
- Total HT Lines – 1,92,304 KM
- Total LT Lines – 1,21,782 KM
- DISCOM with Substantial Rural Areas

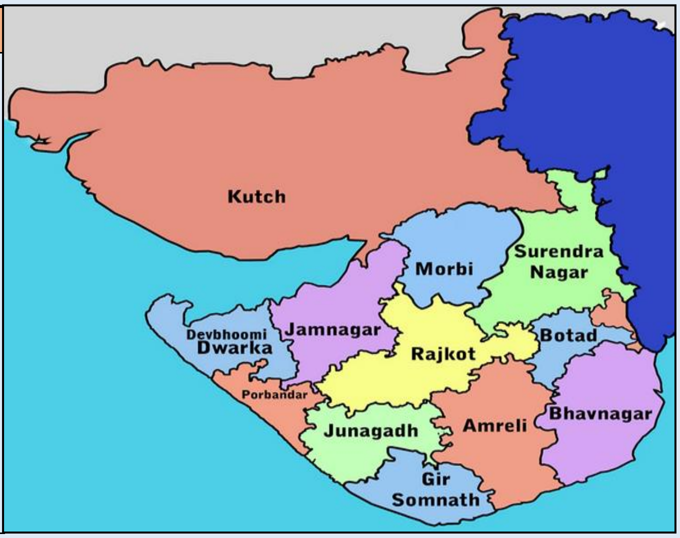


Figure 28: PGVCL – Brief Profile

Paschim Gujarat Vij Company Limited (PGVCL) caters to the western part of the state and has an obligation to serve very remote locations in its control area *viz.* Kutch, largest district in the country having a total area of 45,674 sq.km. and has a population density of only 46 people per sq.km. PGVCL has an HT: LT ratio of 1.57 with the total high tension and low tension lines in the DISCOMs area being 1,92,304 km and 1,21,782 km respectively. The DISCOM has 12 circles. Jamnagar Circle has 24 feeders where almost a quarter of power supplied is lost (approx. 50% of total feeders in PGVCL wherein loss levels are more than 25%). The Distribution transformer failure rate in PGVCL was 8.5%[20] in FY 2018-19, which although is less than its previous two years, is higher than other Gujarat DISCOMs.

Figure 28 shows the loss levels of towns across Gujarat and the average duration of power cuts in a month.

Figure 29: AT&C Loss level of Gujarat Town Vs Average duration of power cuts in a month
Source: urjaindia.in

[20] GERC

As shown in Figure 29 given above, the loss levels of PGVCL towns are highest in Gujarat. Also, as shown by the graph in the above figure, longest duration of power cuts is also in the PGVCL towns.

4. Market Based Mechanism to Control Emissions

4.1 Overview of Electricity Market Structures

Before discussing specific details related to Gujarat, it is worthwhile summarizing market-based mechanisms as they relate to electricity markets, and their intersection with emission. This interaction, as will be evident later on, is relevant, since market design, or at least its details, ought to depend upon the technologies under consideration, and those are affected by emission-related policies. Market design principles for electricity markets with significant penetration of variable renewable energy (VRE) has been articulated recently for many settings (see Joskow (2019), for a recent example), and I draw freely upon the insights from this literature relevant to the case of Gujarat.

There are primarily two goals of electricity market design: efficient operational management of the market; and efficient provision of long-run incentives to appropriately invest in (divest) capacity. A further goal can be to ensure that risks are appropriately shared between different actors (e.g. consumers versus producers). Most electricity market designs attempt to approach both goals with a single market design, supplemented by a host of "out-of-market" or subsidy and other policies and payments. One can also distinguish two types of "products" in the electricity market: electricity itself, and some form of "reliability". Pricing the former is straight forward in principle, but pricing the latter appropriately need not be, and has led to many different approaches, as will be discussed subsequently. In any case, two broad approaches exist to electricity market design: voluntary dispatch or self-dispatch21 (in the style of the Nordics and Germany, Spain) or centralized dispatch (most U.S.-based markets). 22 There is a further classification of electricity markets as "energy-only" or as "energy-plus-capacity", with the latter involving some form of payments for having reserve capacity to meet either reliability or unexpected surges in demand. Either form of market design is compatible with energy-only or energy-plus-capacity markets.

[21] These are markets in which participation in a centralized power exchange is voluntary, and bilateral contracts are allowed to be utilized. Many countries in the EU (and the UK) have a set of markets similar to this design.

Much of the principles of electricity market design emerged from management of dispatchable generation, whereas globally electricity markets are rapidly being redesigned based upon significant penetration of non-dispatchable generation. This raises new questions and suggests possible redesign of existing market mechanisms. A brief word regarding the two types of market designs can set the stage for a Gujarat-specific discussion.

4.1.1 Approaches to Electricity Market Design

4.1.1.1 Voluntary Dispatch/ Self Dispatch Model

The voluntary dispatch model, working successfully for close to two decades in the Nordic and German cases, involves completely market-based dispatch at all-time intervals, up to 15 minutes prior to dispatch, based on an exchange independent of the system operator. Any party leading to system imbalance is responsible for settling it (physically or financially), and intermittent generation (solar and wind), which is not "must run", bears the responsibility for any imbalances (although the German case was slightly different until recently). These often are, but need not be, energy-only markets, meaning that both operations and long-run investments decisions rely on the market price (prices, since there are many markets here, from the day-ahead to the balancing market). There are "out of market" policies and payments, such as a Green Certificate market that significantly affect the electricity market, usually by depressing the price (occasionally to below zero).[23] Grid-related constraints here are "priced in" (ensuring that the grid monopoly is appropriately incentivized) and the system operator is responsible for balancing the grid, while individual market participants are financially responsible for the related costs (with a small "reserve market" for balancing).[24]

4.1.1.2 Centralized Dispatch Model

The centralized dispatch model that is common in the U.S. differs only slightly from this purely voluntary mechanism: a similar voluntary bid mechanism is used, but the bids are evaluated and

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[22] These are also called "power pool" markets where voluntary bidding clears the market, with "one-sided" (only suppliers bid) or "two-sided" (supply and demand both bid) pools possible. Bilateral contracts usually are not encouraged.
[23] Many countries have moved from a feed-in-tariff to a Green Certificate type of system (Germany and Spain), meaning that prior to this move, those had also a "within market" payment mechanism.
[24] There is often a price cap on the day-ahead price (implying a cap on all prices), and there is sometimes a Nuclear-specific policy (Swedish tariff), that effectively makes capacity addition infeasible and affects retirement policies.

“dispatched” centrally, with the dispatcher being responsible for balancing and grid-related tasks (locational prices may be used, but need not be). A variety of ways exist to procure “ancillary services” and to balance the grid, from purely scarcity pricing in an energy-only market (e.g. Electric Reliability Council of Texas (ERCOT)) to a variety of capacity payments mechanisms supplemented by scarcity pricing (PJM[25], California Independent System Operators (CAISO)), often supplemented by forward markets.[26] The Security Constrained Economic Dispatch (SCED)-type models are often used by the central dispatcher here for operational purposes. Long-run incentive mechanisms are often designed by a variety of mechanisms, ranging from public utility commissions setting standards for aspects to mandates related to “green electricity” at the state level and federal subsidies for different technologies. In summary, the centralized dispatch models can be energy-only or energy-plus-capacity, and both are often used in different jurisdictions in a federal set up. Markets of this form can be significantly market based or not, and long-run incentives may be easier or harder to discern, depending upon many aspects, and reliability may be higher or lower than a purely voluntary market.

In both market designs, as already alluded to, significant policy mechanisms exist that arise from carbon-emission mitigation programs: subsidies or mandates for intermittent renewable electricity (usually termed Variable Renewable Electricity, VRE), primarily wind and solar. Significant penetration of these (from more than 30% in Denmark to about 20% in CAISO and ERCOT) have led to market redesigns in many contexts, to better reflect the underlying nature of these, and emerging, technologies. Three types of concerns have arisen everywhere in relation to carbon-mitigation via policy-driven increases in VRE: long-run incentives for adequate investment in generation capacity; short-run changes in operation induced by intermittency in availability; related to the previous concern, exploring mechanisms and technologies to assist in addressing intermittency.

[25] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.
[26] In essence, the former trusts that by allowing prices to rise, additional capacity may be available while the latter provisions additional capacity by paying for idle capacity to rapidly come online.

Table 8: Summary of Voluntary and Centralized Dispatch Model

Parameter	Voluntary/ Self Dispatch Model	Centralized Dispatch Model
Modus Operandi	Completely market-based dispatch based on an exchange independent of the system operator	Bids are evaluated and “dispatched” centrally, with the dispatcher being responsible for balancing and grid-related tasks
Classification	Often (but need not be) Energy-only market i.e. both operations and long-run investments decisions rely on the market price	Can be energy-only or energy-plus-capacity market. Long-run incentive mechanisms are often designed.
Preference for technology	Party leading to system imbalance responsible for settling it (physically or financially)- No preference for intermittent power	Preference for intermittent power
Applicability	Independent of set up. Completely driven by market forces	Often used in different jurisdictions in a federal set up
Out of Market Policies	Green Certificate market that significantly affect the electricity market, usually by depressing the price	a. standards for aspects to mandates related to “green electricity” b. Subsidies for different technologies
Balancing Provision	Availability of Reserve Market for balancing	a. purely scarcity pricing in an energy-only market b. capacity payments mechanisms supplemented by scarcity pricing often supplemented by forward markets
Geographical Example	Nordic and German Market	ERCOT, CAISO, PJM

4.1.2 Electricity markets and Significant shares of Variable Renewable Energy (VRE)

In brief, concerns two and three in the last section pertain to understanding how significant shares of intermittent electricity may be integrated into existing grids and technologies in a least-cost manner, and how appropriate incentives may be provided to newer ways of dealing with intermittency. The central concern is this: with a fixed generation technology mix in the short-run, significant increases in variability in generation induced by large shares of VRE may lead to increased costs of balancing the system. Increase in variability is challenging for any form of market design to efficiently deal with for at least two reasons: first, flexible technologies (or demand flexibility) will be needed to help balance the grid when forecast errors have large load implications; and second, these resources will need to be found in a market increasingly fragmented by out-of-market policies, such as operations-related renewable mandates (“must run" or preferential treatment). The second point in particular means that the price of electricity may not be reflective of its true value, leading to difficulties in providing appropriate incentives to market participants.

Different countries and settings have made, or are discussing, differing ways of dealing with this question: voluntary exchange-based markets (largely in the EU) are moving to finer-time-scale markets (15-minute or even 5-minute intra-day markets), to better align with finer-time-scale forecasts, and removing operational restrictions (such as preferable access) to renewables. Others, such as the centralized dispatch markets in the U.S., are moving to either scarcity pricing or to energy-plus-capacity markets (CAISO, UK). Yet another response is to allow spatial smoothing of forecast errors, with market integration across jurisdictions (in the EU). Everywhere, there is an increasing interest in newer technologies such as grid-scale electricity storage and demand response-driven by technological advances as aids to minimizing the costs of variability.

As to the long-run implications of fragmented markets with increasing variability in generation, there is an increasing focus on a so-called "missing money" problem, where the reduction in average price due to significant increases in zero-marginal cost generation disincentivizes non-zero-marginal cost generation technologies (base load or peaking plants). In addition, while flexibility is of significant greater importance with large shares of VRE, the low price of balancing power/ancillary services may disincentivize even flexible-but-rarely-used generation (a problem that capacity reserve markets are designed to address, at great expense). This is of particular concern for countries with little hydro-generation and many older thermal power plants that have significant ramping constraints, such as India.

4.2 Electricity Market and Implications for Gujarat

As explained earlier in the chapter, the power sector in the state of Gujarat is in a highly developed stage and in addition to meeting its full demand without any restrictions, it is also able to export a substantial component of its generation outside the state. The per capita electricity consumption in the state being much higher than the all India average, also demonstrates high growth of electricity in the State and the leading position the state is having in the area of electricity production. However, electricity production owing to the use of the fossil fuel resources such as coal and gas is also a source of emissions and hence poses equal challenges to the state to control the emissions. A number of schemes launched by the central and state government which directly address the issue of emissions are in vogue and are being efficiently used by the state.

However, looking into the steep growth in the electricity generation and the ambitious targets towards the control of emissions, the avenues to be deployed towards the control of emissions need to be further strengthened. In the following sections, a brief description of the mechanism already in operations as well as some of the newly proposed mechanism is given:

4.2.1 Market Mechanisms already in operation

In order to fight climate change and reduce emissions, three market-based mechanisms directly related to the Green House Gas (GHG) emission came into prominence in India and these are i) Renewable energy certificates (RECs) scheme; ii) Perform Achieve Trade (PAT) scheme; and iii) Emissions trading scheme (targeting air pollution).

4.2.1.1 REC Scheme

Under REC scheme, utilities can make up their renewable energy targets by buying renewable energy certificates. Each REC, which is generated by a renewable energy producer is the equivalent of 1 megawatt hour (1 MWh) and tradable via two power exchanges: Indian Energy Exchange (IEX) and the Power Exchange of India Ltd (PXIL). As on April 2020, 42 projects accounting for a total of 561 MW in Gujarat are registered under the REC mechanism. In terms of purchasing REC as compliance to Renewable Purchase Obligations (RPO), in FY 2017-18, a total of 9,45,398 RECs[27] were purchased by various entities in Gujarat of which around 207153 RECs were purchased by the DISCOMs. The purchase share by DISCOMs has decreased from around 60% in FY 2015-16 to 22% in FY 2017-18. While other obligated entities are still purchasing RECs to comply with their RPO, the share of purchase by DISCOMs is further expected to go down because of cheaper RE power available to them than opting for REC route.

Is REC Mechanism in its existing state sustainable?

Competitive bidding has brought down the cost of RE power to below INR 3/kWhr. This is definitely a good news for the consumer but it also highlights a difficult situation regarding registration of new REC projects. If the RE based power cost less than the conventional power itself, it makes less sense on part of DISCOMs to buy the conventional component of RE based power at Average Pooled Purchase Cost (APPC). If DISCOM does not buy power at APPC, there will be substantial decrease in projects being registered in REC mode leading to plateaued supply of RECs in the market. In Gujarat, most of the RECs are now being bought by obligated entities other than the DISCOMs. Does this mean the market for upcoming REC projects or old projects with remaining life but out of PPAs now lies on purchase of power by Captive and Open Access consumers? It is a situation that policymakers would have to look into.

[27] Source: POSOCO report on REC Mechanism- Key learnings, Data analysis and Way forward, Aug 2018

4.2.1.2 Perform, Achieve and Trade (PAT) scheme

The second scheme known as Perform Achieve and Trade (PAT) scheme is a flagship program of the Bureau of Energy Efficiency (BEE), Ministry of Power, and Government of India. The program involves trading in energy saving certificates between energy intensive industrial productions units identified as designated consumers (DCs). Although the scheme does not involve any direct trading based on absolute or relative CO2 emissions but the potential unit of energy saved (expressed in tonnes of oil equivalent) could easily be converted into CO2 emission equivalent. For Gujarat power sector, PAT mechanism has further highlighted the efficient operation of the DISCOMs. Three out of the four DISCOMs have over-achieved their targets identified under PAT Cycle 2. Below table shows the targets and achieved numbers by DISCOMs under PAT 2.

Table 9: PAT 2 Targets for DISCOMs and Achievement

DISCOM	Baseline T&D Loss (%) FY 2014-15	Target T&D Loss (%) FY 2018-19	Achieved Loss Levels % (FY 2018-19) (Source- Tariff Orders)
UGVCL	9.20%	9.20%	11.20%
DGVCL	9.10%	9.10%	5.90%
MGVCL	12.27%	11.89%	9.98%
PGVCL	24.61%	23.08%	20.50%

Source: BEE and GERC

4.2.1.3 Emission Trading Scheme (ETS)

The third scheme known as Emission Trading Scheme (ETS), is an innovative emission trading scheme on an air pollutant namely respiratory solid particulate matter (RSPM) with serious potential health implication. The scheme has been piloted in industrial clusters of three polluting states in India (Gujarat, Maharashtra and Tamil Nadu). The scheme shifts away from the traditional command and control regulation where the industrial point sources have to comply with the norms set by the Central Pollution Control Board (CPCB) or else pay a high penalty. It instead sets a pollution target for an area based on ambient air quality standard and allocates permits to industrial point sources that would then be traded based on gains or shortfalls from compliance after verification.

4.2.2 Proposed Mechanism related to Power Market

4.2.2.1 Wholesale Markets - Contemporary Approach

A national electricity market strategy appears to be emerging for India, at least per the CERC: energy-only exchange-based voluntary markets that are national, with a proposed national Reserves Regulation Ancillary Services (RRAS) for a "balancing market" (capacity reserves for ancillary services, CERC (2019), Safiullah et al (2016)). At the state level, it is possible that Gujarat, and other states, may opt for a centrally dispatched model, a la the U.S. (via the SCED, as discussed below), or a purely voluntary dispatch model, a la the Nordics? Both have their benefits but the Nordic model's success may have as much to do with its systemic features as with pure market design.[28] In the centrally dispatched system, obviously a central/regional/state agency (the NLDC/RLDC/SLDC, as envisaged by the CERC) will be the responsible entity. A Contemporary approach is discussed below, and Gujarat may follow such an approach.

4.2.2.1.1 Development of Ancillary Services in the State to provide Reserves

In order to develop ancillary market for Gujarat, it is important to revisit the energy mix in the state.

(i) Installed capacity:

The total installed capacity of the state as on 30.06.2019 is 32.6 GW. The share of different entities in the total generation capacity is well distributed amongst the state sector, central sector and private sector, the share of private sector being maximum. As shown at the start of the chapter, fuel wise break-up, the share of solar and wind capacity, which is considered as infirm generation and provides variability is substantial in nature, of the order of around 30% and makes it necessary to have adequate avenues in the grid towards addressing flexibility. However, at the same time, if we look at the components of thermal and gas capacity, they are 50% and 20% respectively, and can be used for providing the flexibility, in case adequate provisions and incentives are available to such generators for flexing their generation.

[28] A part of the success of the Nordic model may be due to the surplus capacity in the system (meaning that prices will not bid up significantly), the hydro- and nuclear-dominance, and the very well developed and managed transmission and distribution systems.

(ii) Principles of forecasting and scheduling in the state:

In order to maintain load generation balance in the state, the SLDC of the state is following the principle of forecasting and scheduling in line with the provisions as defined under Grid Code issue by Gujrat Electricity Regulatory Commission (GERC) and under this a rigorous exercise towards demand forecasting is carried out based on the season, past pattern of the load during current period and expected load etc. Based on the load forecasting and available share from the central sector generation as well as based on the availability of State's own generation and the generation as offered by the private sector plants, an optimum day ahead schedule is formulated on the basis of generation availability ranked on the basis of merit order as well as technical constraints if any towards evacuation of any particular generation or part there-of. While preparing the schedule, due care is imparted to renewable sources of generation, particularly wind and solar with respect to their must run status and all efforts are made to dispatch the full capacity without any spillage. During the course of day also under real time situations, in case of any change in the generation availability or sudden change in demand due to weather conditions or otherwise, the change in the schedule is effected in the real time conditions.

(iii) Imbalance handling by SLDC

In order to handle the imbalance arising due to instant to instant change in demand as well as due to variability of the renewable generation, the state has been varying the hydro, thermal and gas generation to the extent possible. However, the flexibility achieved towards such variation is limited due to the reasons of limited operational capacity on bar in case of gas due to the reasons of higher operating cost, must run status in case of some of the hydro generation and difficulties expressed by the thermal generation to back down below a certain level due to technical and commercial reasons.

(iv) Challenges faced by the state due to Imbalances and effects on emission

As a result of imbalances, and absence of adequate measures available to address the same, the state is faced with the following challenges:

- The state periphery is deemed as one control area and it has to maintain the flow on its cross border connections with the other control areas (states) within the agreed schedules. Any changes in such flows vis a vis agreed schedules result into deviations and the state has to settle the deviations at a relatively higher price as per the principles agreed under Deviation Settlement Mechanism (DSM), which ultimately results in the enhancement of the average cost of supply;

- Many a times in order to control the area control error, and at the same time keeping into consideration the technical minimum level of some of the operating units as well as respecting the must run status of some other units, certain generation has to be operated which may not be in line with the true merit order and efficiency. This ultimately results into, higher cost of average supply as well as enhanced emission due to operation of relatively uneconomical generation;
- Since renewable sources of energy viz. wind and solar are infirm in nature, they introduce certain variability in the grid and the challenges to the system in the form of deviations. Since the avenues towards addressing these deviations are limited, the state has to ensure that these deviations do not go beyond a certain level. To achieve this, one of the prevalent practice adopted by the state of Gujrat, as well as any other state is to keep the capacity of renewable sources viz. wind and solar to a limited level. Hence in order to restrict the quantum of deviations as well as absence of readily available reserves available in the grid to address such deviations, the capacity of wind and solar is restricted, which is also a lost opportunity towards control of emissions.

(v) Basic principles towards creation of reserves in the state under ancillary services:

In order to address the issue of imbalances and control the deviations within limits, the state can take measures towards applicability of reserves in the state grid under ancillary services and following measures can be taken in this respect:

- Since the state is surplus in respect of its generation capacity and has surplus availability in almost all variants of fuel, a merit order list can be prepared based on the variable cost of energy in respect of all the unrequisitioned surplus capacity on bar, which is willing to participate in contribution towards reserves;
- In respect of all such generation a data base can be prepared and kept handy in respect of technical minimum restrictions and ramp up/ramp down rates (MW/Minute);
- Based on the schedules and actual drawls in real time conditions, the control area error of the state can be computed in real time and based on that the requirement of additional generation required to offset such control area error can be found out.

(vi) Action plan towards implementation of reserves under ancillary services:

Based on all such details viz., available spare capacity of each willing generator on bar, the technical minimum and ramping up/ramping down rates of different generators, and the variable cost of each of the generator a suitable modeling exercise can be carried out and the model can be put into operation as a part of real time scheduling. The model shall render the following outputs under its results on continuous basis:

- The generator and the quantum of power it has to supply as reserves under ancillary services and the likely time blocks during which it shall remain operational;
- Based on the ramping rates (MW/Minute), the time within which such generation capacity should come into actual operation;
- The charges which shall be paid to the individual generators based on their variable charges plus certain mark up charges;
- The average cost of the reserves based on all such ramped up generation during a particular block;

(vii) Further refinements in the philosophy in long run:

The philosophy as described above shall enable the state to harness certain capacity as reserves capacity under ancillary services and help towards addressing the challenges faced by the state due to Imbalances and towards controlling the emissions. In the long run the process can be further refined and made more market oriented by preparing the merit order list, based on the bids received by each of the willing generator. In such a situation, the number of candidates and the capacity which may be participating in such a process may also be increased further and a better completion and reserve price may be determined.

4.2.2.1.2 Development of Economy Dispatch Model in the State, on the lines of Security SCED

Given the federal structure of India, a coordinated multilateral scheduling model is followed in Indian power sector, where each state is considered as a control area and decides about the load generation balance in the area under its domain and the generation which shall be scheduled to meet its demand. In order further refine such a mechanism, a need has been felt for an overlay at centralize level and overall optimization at the inter-state level, duly factoring technical constraints such as technical minimum, maximum generation, ramping constraints, transmission constraints, etc. Such a mechanism, precisely known as Security Constrained Economy Dispatch (SCED) has been brought-in at the central level about an year back and has found out to be very productive in terms of overall economy as well as addressing the issue of emission to certain extent. It is a market based principal and can be replicated at the state level also with certain modifications. The philosophy towards designing and implementation of such a mechanism in Gujrat is elaborated in the following sections:

(i) Basics about Security Constrained Economy Dispatch (SCED):

Security Constrained Economy Dispatch (SCED) is the optimization of Scheduling and Dispatch process to further optimize scheduling and dispatch of thermal ISGS pan-India, causing economy in the overall system. This is an overlay exercise in the Indian Power System by the load despatcher at the national level to improve the dispatch process, subject to honoring the system wide operation related and resource level constraints, as well as maintaining the freedom & choice of states to requisition power as per their demand requirements and keeping existing contracts and PPAs intact.

Under this, by expanding the ambit of generation resources optimization process at the end, reduction in the overall system operating costs have been achieved. This works on an algorithm-based dispatch software, under which incremental dispatch instructions are sent by the operator at the national level, close to real time (after all the states have tried to balance their demand-generation portfolio) and cause economy by increasing lower cost generator schedules and decreasing the costlier generation. Before implementing and putting this process into actual operation, a prototype software was prepared for this purpose and after the permission of the regulator at central level as on 16th July 2018, the trial process were started in open loop for more than 6 months to generate results for the purpose of the analysis. After the trial exercise gave promising results and insights, the actual SCED process was put into operation w.e.f. 1st April 2019 and is continuing.

(ii) Basics about Security Constrained Economy Dispatch (SCED):

Based on the operation of above scheme, Power System Operation Corporation (POSOCO), which is also the grid operator at Regional and National level has come out with a report highlighting the performance of the scheme during the period of 1st April 2019 to 31st December 2019 and benefits derived out of it. In the report it has been highlighted that during the period of 9 months of operation, 52 nos. of generating stations, with a total installed capacity of 58,060 MW have participated in this scheme. The daily average perturbation in the generation was of the order of 1320 MW and during the period of 9 months, the overall reduction in the production cost was of the order of Rs. 845 Crores. Details of some of the major benefits as have been observed are detailed in the subsequent paras.

(iii) Economic Gains out of Security Constrained Economy Dispatch (SCED):

The Figures below show the pattern of the pre and post SCED cost in Paisa/KWH, during the period April –Dec. 2019. As can be seen in the figures there is a saving of the order of around 3 Paisa/unit in the average cost of the electricity generation, which when converted into overall saving, turns down to be a saving of the order of Rs. 3 Crores/day. As stated earlier, the saving was due to replacement of some of the costlier generation by the generation with lesser cost. In addition to the saving in the overall cost, SCED also led to accumulation of the collected reserves, particularly in the generating units with higher cost. In addition to saving in the cost and accumulation of the reserves, SCED also helped in reducing the number of instructions required to be issued for change in the schedule, which ultimately reflected towards the saving on operational matters.

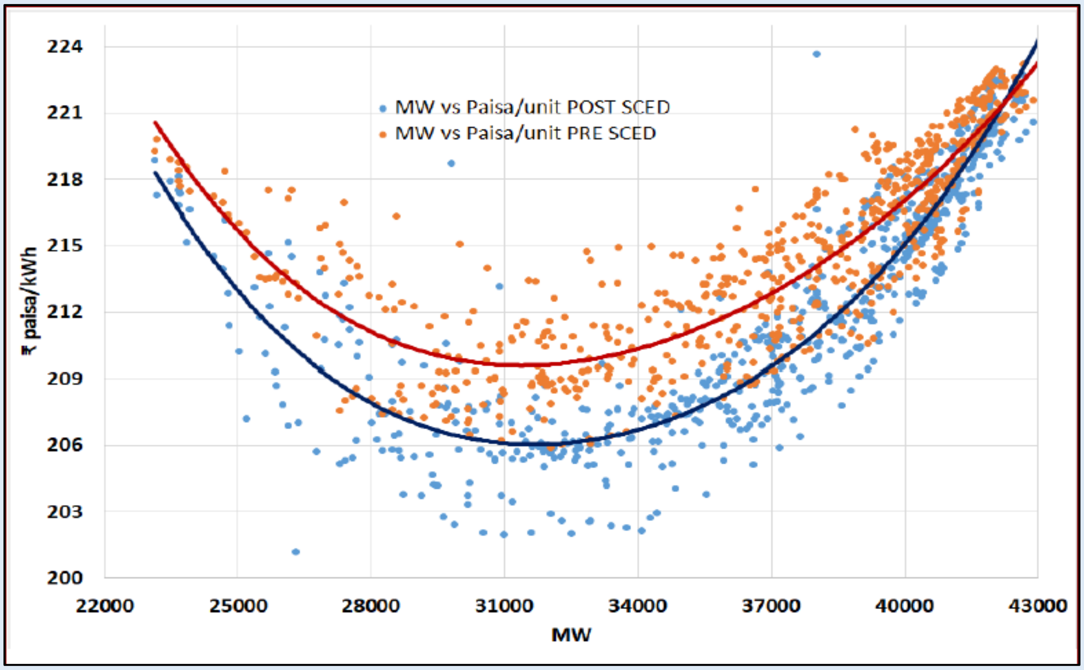

Figure 30: MW Vs Average Price (paisa/kWhr) - Typical Week
Source: Detailed Feedback Report on SCED Pilot

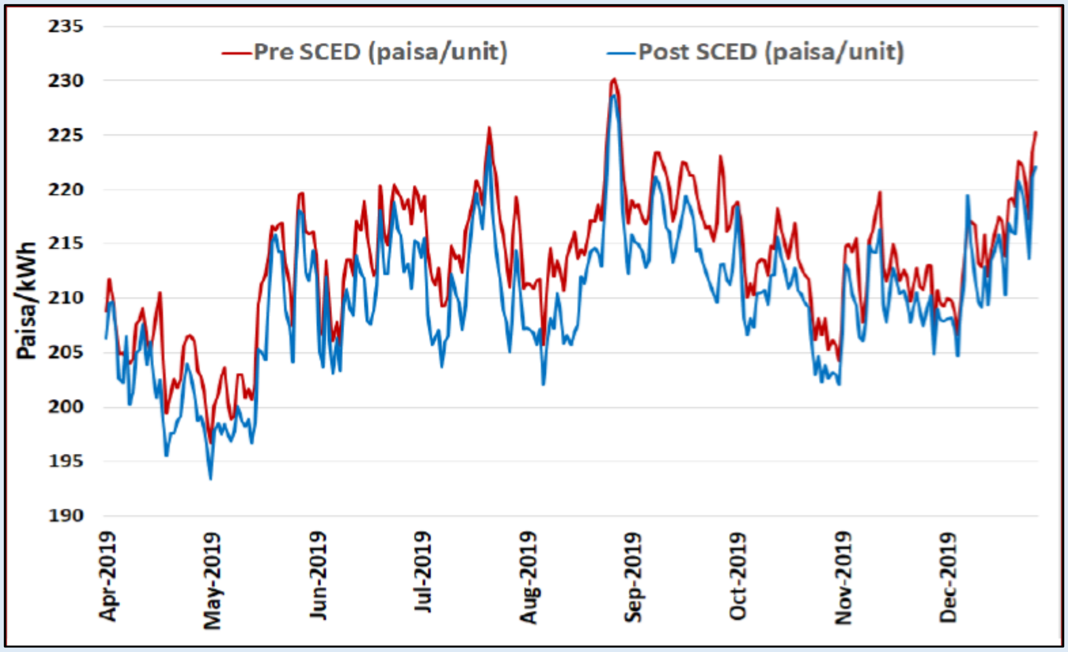

Figure 31: Pre- SCED and post- SCED (paisa/kWhr)
Source: Detailed Feedback Report on SCED Pilot

(iv) Saving in the estimated emissions with implementation of SCED:

The impact on emissions by SCED was also analyzed using the CO^2 baseline database. Figure below show the estimated block wise change in CO^2 emission in a typical month may 2019. It can be observed that there was a 0.19% reduction in CO^2 emissions. This saving in emissions is primarily due to use of more economical and efficient generation, by virtue of replacement of costlier variable cost generation by the generation with lesser cost.

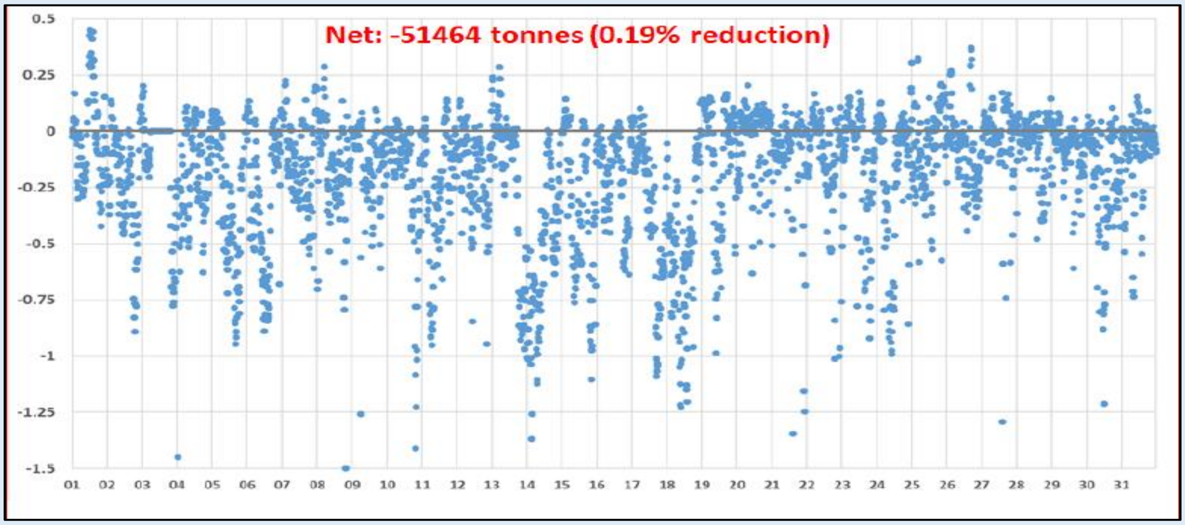

Figure 32 : Estimated Block wise Change in CO2 emissions (May 2019) (%)
Source: Detailed Feedback Report on SCED Pilot

(v) Implementation of market based scheme in Gujrat on the principles of SCED:

If we compare and co-relate the operation philosophy in a state control area with that of a regional/national control area, there are similarities on a number of counts, except that in a state control area the participating generating entities and load entities are the customers directly linked to the state system and follow the principles as laid down under the frameworks developed for the particular state. Since in Gujrat also there are generator and load entities and scheduling are dispatch process is followed in a manner almost similar to RLDCs/NLDC, the market mechanism on the lines of Security Constrained Economic Dispatch can be implemented in state of Gujrat also and as a result of this certain savings in the operating costs as well as overall operational economy and efficiency can be achieved. As explained in case of the central sector, this shall also result in the saving in emissions.

4.2.2.1.3 Controlling Carbon Emission through Demand Side Management

The earlier two sub-sections elaborate that how the economy and efficiency and control of emissions in the power system can be achieved by means of generation control. Similar to that, there can be very effective ways and means available in the market, to bring in economy and efficiency and reduction in emissions, by way of demand side management. The brief details in this respect and way forward towards implementation of demand side management measures in the state of Gujrat are as detailed below:

(i) Demand Side Management (DSM) Basic Philosophy:

DSM principally refers to the actions to be taken on the customer's side of the meter in order to change the amount or timing of energy consumption. Electricity DSM strategies have the goal of maximizing the end-use efficiency by using the presently operating generation capacity in most optimum manner and/or by avoiding/postponing the construction of new generation capacity. The main drivers towards DSM can be:

- Cost reduction towards meeting the given energy demand;
- Environmental and social improvement by reducing the emissions;
- Improving the reliability and use of the network;

(ii) Action Plan towards implementation of DSM Philosophy in the state of Gujrat:

In the state of Gujrat, Demand Side Management (DSM) can be pursued as an activity and under this the state utility needs to develop a model, which shall drive the DSM in the State. While working out this model, the following issues can be of critical importance:

- Types of DSM Measures:

  The following different types of DSM measures can be considered:

  - Energy reduction program—Reducing demand through more efficient processes, buildings or equipment
  - Load management program—Changing the load pattern and encouraging less demand at peak times and peak rates
  - Load growth and conservation program - Diverting different energy sources (fuel) to better (more efficient) electrical sources

- Tariff incentives and penalties:

  The following philosophy can be pursued in respect of Tariff incentives and penalties:

  - Time of use rates — under this, utilities keep different charges for power use during different periods. Higher peak time charges would encourage a user to run high load activities in an off-peak period when rates are lower;
  - Power factor charges — Under this, the utilities put certain penalties on the users for having power factors below a certain value, say 0.90;
  - Maximum demand Charges – The users are incentivized towards capping their peak demand, which generally occurs during peak hours, hence helping in controlling overall peak;

- Action required to implement DSM Measures:

  - Devising a market mechanism to incentivize DSM — Suitable mechanism needs to be defined, clearly outlying the incentives available by going-in for such measures;
  - Introducing suitable tariff mechanism — The tariff mechanism should clearly outline the advantages available to the consumer by suitably modifying its demand pattern;
  - Introducing the requisite metering system – The metering system on the lines of Time of the Day (TOD) needs to be introduced in order to quantify the benefits;

- Information Dissemination:

  - Marketing — The commercial benefits arising out of this need to be propagated amongst the customers;
  - Awareness Campaign — Awareness about the program needs to be made public;
  - Accrued Benefits — The case studies showing the accrued benefits need to be shared through different medias;
  -

(iii) DSM : Specific gains towards environmental and social improvement

The specific gains towards environment and social improvement on account of reduction in the energy use and enhancing the share of renewable energy are distinctly clear. This can be summarized as follows:

- By reducing energy use – Incentivizing the energy efficiency, shall reduce energy consumption and hence leading to reduced greenhouse gas emissions;
- By reducing network loadings/losses – Saving in terms of electricity losses, shall ultimately result in carbon emission reduction;
- By enhancing renewable share – Shifting peak/levelling the load curve, shall allow higher penetration of renewables and hence reduced greenhouse gas emissions

4.2.2.2 Wholesale Markets - Alternate Approach

An alternative approach is outlined here, one that makes significantly greater use of market-based approaches. The key principle is that market participants will themselves provide their bids and offers for power e.g. at a day-ahead level. The dispatching entity merely ensures that these are appropriately matched, taking into account systemic criteria (transmission availability, nature of power e.g. "must run") and appropriately pricing transmission congestion. The benefit of this approach is that the generators deals with questions related to its own constraints (ramping etc) and the retail entity is responsible for forecasting demand, while the system operator's focus can turn to questions of greater significance, such as dealing with mismatch closer to delivery time. Such a mechanism is in use in many regions of the U.S. An added benefit is that secondary markets (forward contracts and hedging) can be more significantly used by market participants to manage some of their risks. This will be discussed in greater detail below, but as currently structured, the system operator for Gujarat bears the risk, which is then potentially transferred to consumers.

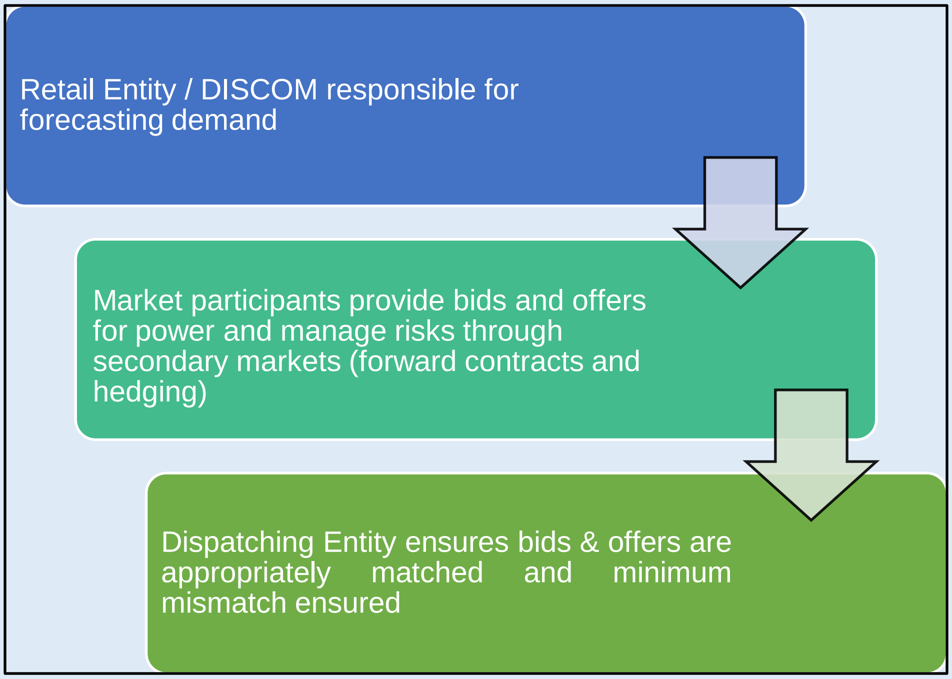

Figure 33: Alternate Approach to Wholesale Market Design

Clearly, for this approach to work in practice, many pre-requisites must be met: a market set-up can either be set up by Gujarat or existing markets (IEX and PXIL) may be made use of; retail entities must be capable of generating their own demand forecasts and to be able to bid with confidence based upon it; appropriate products (especially hedges) available in national electricity markets for electricity market participants (generators and retailers) to use; an ability to develop models and frameworks helping these participants manage the risk of imbalances, a market for settling which is detailed next; a system operator whose role is to manage the system in an efficient way, distributing risk largely upon the party generating it, minimizing overall system cost and maximizing system reliability.[29]

This approach has many benefits over a competing multi-markets framework such as in the EU/UK[30], in particular its simplicity and the fact that it can work with existing national markets and frameworks.

[29] An unanswered question in this context pertains to existing long-term PPAs that, under current conditions, are far too onerous for the system operator and consumers.

[30] This market structure is common in more mature electricity markets in the EU/UK, and consists of: a day ahead market, multiple-time-horizon intra-day markets, and a balancing market. It is unlikely that such a complex and fully-market-oriented structure can work in the context of Gujarat, since the requisite conditions may not be met and there are significant risks involved in such markets initially, particularly when demand and generating are rising rapidly, as in India.

4.2.2.3 Balancing Markets

As already discussed, significant and rapid increases in VRE generation call for significant attention to managing the electric grid much more rapidly than before (with central dispatch of base- and peak-load mix of generation). Market mechanisms can ensure that market participants are willing to provide the needed flexibility, by appropriately altering either generation or demand. At the national scale, the CERC has proposed a Frequency Support Ancillary Services (FSAS) mechanism, via the reserve regulation ancillary service (RRAS), as the preferred mode of dealing with all imbalances. Gujarat will presumably harmonize its approach to system balancing and ancillary services with this national proposal. Assuming India uses the CERC model, NLDC will eventually be the dispatcher (in a US –style central dispatch model) and scarcity pricing will need to be generated by the NLDC, with inputs from Gujarat's SLDC, and accounting for transmission and other constraints.

In view of the state-level nature of the responsibility for system stability, Gujarat state will presumably have some flexibility in designing mechanisms in tune with its circumstances, in this national market umbrella. Given Gujarat's significant share of Wind (21%) and possibly older-generation and less-flexible thermal (50%), and existing long-run PPAs for thermal and Gas (15%), current challenges in maintaining system stability at least cost is likely to be enhanced, particularly in view of the ambitious targets for wind and solar in the near future.

The principles underlying any market design for Gujarat's case are articulated next. In an ideal setting, a North-American-style centralized dispatch model will need to first generate a scarcity price (a la PJM and ERCOT's ORDC method or other variants, see Hogan and Pope (2017)), possibly supplemented with a capacity reserve market. This can also be supplemented by forward markets for electricity. This market design can provide many advantages to Gujarat, with its large share of inflexible thermal and highly variable wind. First, the possibility of capacity reserves may make it feasible to design mechanisms to persuade certain thermal/gas plants to switch over to market-based mechanisms from PPAs. Second, this style of a market can make it possible to ensure that any imbalance-causing party bears the cost of their imbalances, including exporters, as is common practice. Third, a clear market-based structure for these services is likely to elicit better response from newer technologies that are significantly more flexible (rapid ramping thermal) or even battery-based or other form of storage and demand response (including via virtual power plants[31]).

While the implications of specific aspects of market design specific to Gujarat's context will need to be developed, the underlying principles are articulated above. It is also important to note that the costs of balancing an increasingly variable system can be significantly lowered by spatial integration with the rest of the national grid, and this integration must inform the market design for Gujarat.

Benefits of generating Scarcity Price for Balancing Market through Centralized Dispatch Model supplemented by Capacity Reserve or forward market of electricity

- Possibility of capacity reserves may make it feasible to design mechanisms to persuade certain thermal/gas plants to switch over to market-based mechanisms from PPAs
- Market makes it possible that any imbalance-causing party bears the cost of their imbalances, including exporters.
- Clear market structure will promote adoption of more flexible technologies or even battery-based or other form of storage and demand response (including via virtual power plants)

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While the implications of specific aspects of market design specific to Gujarat's context will need to be developed, the underlying principles are articulated above. It is also important to note that the costs of balancing an increasingly variable system can be significantly lowered by spatial integration with the rest of the national grid, and this integration must inform the market design for Gujarat.

4.2.2.4 Long run Incentives for Capacity addition

Capacity addition for both the wholesale and the balancing markets are of key importance nationally and for Gujarat. Both aspects depend not only upon market design, as will be articulated next, but also upon policy framework, including minimizing changes in "out of market" policies favoring VRE. To take these policies first, the structure of eliciting VRE capacity must be: as

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[31] To illustrate, Statkraft, the Norwegian TSO also operating in the UK, recently was allowed to bid its "virtual power plant" in the UK balancing market. See https://www.statkraft.com/newsroom/news-and-stories/archive/2020/vpp-balancing-services/

simple as possible; structured as transparently as possible; and must have a time line that is clear at the beginning. This is particularly relevant for states such as Gujarat that have large shares of VRE, and are also targeting significant increases. In Gujarat's case, the lowering trend in average price of electricity with large shares of VRE may not incentivize new non-VRE capacity, which has implications for both the wholesale and balancing markets. Similarly, eliciting significant capacity additions in VRE, with an existing large share of VRE, will also need increasing out-of-market payments and subsidies, in view of the lowering average prices with increases VRE shares (known as "cannibalizing", see e.g. Prol et. al (2020)).

For Gujarat, long-run capacity investments may be better stimulated by having long-term (at least ten year) goals and mechanisms in place that are fixed beforehand. To illustrate, the RECs associated with RPOs must have a strengthened market, in line with international best practices that include banking and development of secondary markets; and if needed, a "stop" mechanism may be implemented in the interim, to ensure sanctity of existing RECs, as also envisage in many settings with green certificates (e.g. the Nordics, see THEMA (2018)). A stop mechanism will reduce the uncertainty regarding who will end up being financed in the end.

While newer technologies, ranging from flexible thermal to VPPs and storage, may play a role in both wholesale and balancing markets (as is increasingly common in many countries), market design here is vital to ensuring that appropriate amount of capacity is available. In particular, a stable market with clearly articulated principles is important: whether through capacity reserves (which can be quite expensive) or scarcity pricing (with a very large price cap) that can draw in expensive power over short durations, flexible resources can be incentivized.

5. Conclusions

Gujarat power sector is a mature market and is in a much healthier state than most of the other DISCOMs in the country. A lot of credit for this goes to the professional management of utilities, support of the government and significance of GERC to turnaround the state in the last decade. Gujarat is one of the leading states in RE terms, with Solar and Wind potential in the state substantially good and efforts being made to tap in the resource in the most efficient way. The DISCOMs in the state are a benchmark for others in the country to follow.

Despite all its positives, Gujarat still can do a lot in terms of reducing the carbon intensive growth in the state. Some of the points that arise out of this research are as follows:

1. Renewable Energy integration in the system needs to be done in a more organic way. In the past, Gujarat has signed Power Purchase Agreements (PPAs) at a comparatively higher cost because technology at that time was expensive and was in an evolving phase. Lately, Gujarat, in order to reach out the bottom-most cost in Solar Energy, has gone for cancellation of transparent bidding for RE capacity in the state. This might do more harm than good by making investors wary of the uncertainty of policies of the state. As electricity demand in Gujarat increases, Gujarat should encourage establishment of new low cost renewable power plants.

2. Renewable Purchase Compliance is an important intervention and strict adherence to the same and enforcement by GERC is very vital in promoting RE power in the state. This should of course be done while maintaining grid stability and policy for betterment of forecasting and scheduling needs to be done in a better way. However, for this RPO should be fixed keeping in mind the space DISCOMs have for buying renewable power. As demand increases and if RPOs are announced some years ahead and if low cost renewable power is encouraged, the share of renewables could increase in economically attractive way.

3. Very old thermal power stations in the state still enjoy high PLF despite their higher fuel cost. This is due to the fact that the opportunity cost of absorbing more renewable power is more than the marginal cost of power from such plants. Modernization of such plants need to be

made economically attractive. Low interest loans from Green Climate Fund may be sought for it.

4. PGVCL is a rare blip in otherwise almost perfect power distribution sector with comparatively high losses in the system, higher transformer failures, increased power cuts and duration of disturbance for end consumers, etc. Commercial Losses are also high in the PGVCL control area which needs to be reduced significantly. While higher AT&C losses in PGVCL compared to other DISCOMs of the state are justifiable to some extent due to its low customer density and large geographical area it serves, there is still significant scope to reduce AT&C losses. Smart-meters and distribution SCADA with energy audit system may aid in addressing the problem theft, which possibly incentivizes the State Distribution company to impose more frequent power cuts. This will lead to less usage of polluting Diesel Generators and hence aid in decreasing environment carbon content.

5. Energy banking has also been suggested as a means to ensure reliable supply, while also replacing expensive power with cheaper power available from outside the state. Dedicated transmission corridors has been advocated to be given preference when yearly planning of Central Transmission Utility is done.

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