24x7 Power for All:

Strategies for Karnataka

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Karnataka Electricity Regulatory Commission
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Deepthi Swamy

Nihit Goyal

Mohd. Saquib

SELCO Foundation

Felix Varghese

Juhi Chatterjee

Vivek Shastry

Karnataka Electricity Regulatory Commission
CSTEP and SELCO Foundation
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Center for Study of Science, Technology and Policy

18, 10th Cross, Mayura Street,

Papanna Layout, Nagashettyhalli, RMV II Stage,

Bangalore-560094 Karnataka, INDIA

Tel.: +91 (80) 6690-2500

Fax: +91 (80) 2351-4269

Email: cpe@cstep.in

Website: www.cstep.in

SELCO Foundation

#690, 15th Cross,

2nd Phase J P Nagar

Bengaluru – 560078

Email: vivek@selcofoundation.org

Website: www.selcofoundation.org

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List of Abbreviations

AC	Air Conditioner
Ag DSM	Agricultural Demand Side Management
APPC	Average Power Purchase Cost
APRHVDS	Andhra Pradesh Rural High Voltage Distribution System
AT&C	Aggregate Technical & Commercial
BEE	Bureau of Energy Efficiency
BESCOM	Bangalore Electricity Supply Company
BJ/KJ	Bhagya Jyothi/ Kutir Jyothi
BPL	Below Poverty Level
BTPS	Bellary Thermal Power Station
CAGR	Compounded Average Growth Rate
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CESC	Chamundeshwari Electricity Supply Company
CFL	Compact Fluorescent Lamp
CGS	Central Generating Stations
CKms	Circuit Kilometers
CRT	Cathode Ray Tube
DDG	Decentralised Distributed Generation
DDUGJY	Deendayal Upadhyaya Gram Jyoti Yojana
DISCOMs	Distribution Companies
DRE	Decentralised Renewable Energy
DSM	Demand Side Management
DTC	Distribution Transformer Center
EE	Energy Efficiency
EPS	Electric Power Survey
ESCOMs	Energy Service Companies
FiTs	Feed in Tariffs
FoR	Forum Of Regulators
FRI	Feeder Reliability Index
FY	Financial Year
FYP	Five Year Plan
GDP	Gross Domestic Product
GHG	Green House Gas
GoK	Government of Karnataka
GSDP	Gross State Domestic Product
GST	Goods and Services Tax
GW	Giga Watt
GWh	Giga Watt hour
HESCOM	Hubli Electricity Supply Company
HT	High Tension
HTLS	High Temperature Low Sag
HVAC	Heating Ventilating and Air Conditioning
HVDC	High Voltage Direct Current
HVDS	High Voltage Distribution System
INR	Indian National Rupee
IPPs	Independent Power Producers
IPs	Irrigation Pump Sets
ITIs	Industrial Training Institutes
JGY	Jyothi Grama Yojana

JNNSM	Jawaharlal Nehru National Solar Mission
KERC	Karnataka Electricity Regulatory Commission
KPTCL	Karnataka Power Corporation Transmission Limited
KREDL	Karnataka Renewable Energy Development Limited
kV	kilo Volt
kWh	kilo Watt hour
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LT	Low Tension
MESCOM	Mangalore Electricity Supply Company
MUs	Million Units
MVA	Mega Volt Amps
MW	Mega Watt
M&V	Measurement and Validation
NABARD	National Board of Agricultural And Rural Development
NEP	National Electricity Policy
NJY	Niranthara Jyothi Yojana
PCKL	Power Company of Karnataka Ltd.
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PV	Photo Voltaic
RE	Renewable Energy
RRBs	Regional Rural Banks
RTPS	Raichur Thermal Power Station
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SCEF	State Clean Energy Fund
SLDC	State Load Dispatch Center
SME	Small and Medium Enterprise
SPV	Special Purpose Vehicle
T&D	Transmission & Distribution
TIMES	The Integrated MARKAL EFOM System
UDAY	Ujwal DISCOM Assurance Yojana
UEC	Unit Electricity Consumption
VAT	Value Added Tax
Wp	Watt peak
YoY	Year on Year

Executive Summary

In June 2014 the Government of India launched the Power for All initiative with an aim to provide 24x7 power across the country by 2019. Subsequently, a sub-committee of the Forum of Regulators (FoR) prepared a national roadmap for the initiative. FoR defined the scope of the initiative to include reliable 24x7 power supply to domestic, industrial, and commercial consumers, power supply to irrigation pump sets for 8 to 10 hours, and access to all connected households by 2018 – 19. The roadmap made recommendations for fuel supply, generation, transmission and distribution sectors, and demand-side management. In view of the federal structure of India's power sector, a key recommendation of the FoR study was to formulate state level strategies to meet the objectives of 24x7 Power for All.

With reference to the context mentioned above, this study was commissioned by Karnataka Electricity Regulatory Commission (KERC) to identify key implementable strategies for the state of Karnataka for achieving the objectives of 24x7 Power for All. The study describes the power supply scenario in the State including estimates for future energy demand. The status of 24x7 power supply is analysed along the dimensions of access (electrification), adequacy (per capita consumption), affordability (cost of supply), availability (duration of supply), and reliability. Future plans for generation capacity are analysed to determine the range of foreseeable shortfalls till Financial Year (FY) 2020. Transmission capacity augmentation, renewable energy and energy efficiency options available to meet future demand are discussed in detail. The report concludes with the strategies that Karnataka should focus on in order to achieve the objectives of 24x7 Power for All.

Key Findings

Power Supply Scenario: The current installed capacity in the State is 15,568 Mega Watt (MW). Thermal and large-hydro sources contribute to nearly two thirds of this capacity. Short-term power purchases have accounted for a significant portion of supply in the previous years. The quantity purchased has grown at a Compounded Annual Growth Rate (CAGR) of 22% between FY2010 and FY2015. In FY2015, the sector had an energy and peak deficit of 4.3% and 4.5% respectively. Aggregate energy demand is expected to increase to about 1,12,675 MUs by FY2020, assuming that the shortages and losses are expected to continue. Peak demand is expected to continue to grow at a CAGR of 5.6% over the next five years, to reach 16,000 MW by FY2020.

Status of 24x7 power supply in Karnataka: This is assessed along the dimensions of access, adequacy, affordability, availability, and reliability. Village electrification rate in the state is currently at 99.5% in comparison to the national average of about 92-93%. However, nearly one million households still do not have access to electricity in the state. Districts with particularly low electrification rates are: Yadgir (78%), Bijapur (81%), Kodagu (82%) and Belgaum (84%). With a per capita electricity consumption of nearly 1,100 kilo Watt hour (kWh) in 2012, the consumption in Karnataka was above the country average of 884 kWh. However, its per capita consumption is lower than that of comparable states such as Gujarat (1,663 kWh), Tamil Nadu (1,277 kWh), and Andhra Pradesh (1,157 kWh).

Over the past four years, the peak demand was typically observed during the morning and the evening, and the rate of growth of peak demand was higher than the average demand throughout the year. For an illustrative analysis of an average daily load curve under Bangalore Electricity Supply Company (BESCOM), it was observed that the consumption by domestic category mainly gave rise to the shape of the morning and evening peaks. In terms of reliability of supply, in most towns and cities, reliability was close to 97%, with the average being at least 93%. However rural areas were lower on an average, at about 81%. A comparison with other states reveals that in terms of affordability of power, on an average, electricity in Karnataka is not too expensive or highly priced. At INR 4.76/kWh, it is cheaper than the national average of INR 4.79/kWh.

Generation Plan: The total energy generated from the current installed capacity is about 78,500 MUs, assuming typical operational capacity factors for the various sources. As per the current plans for capacity augmentation over the next five years, it is estimated that 25,918 MW of installed capacity will be available in FY2020 if there are no slippages in project commissioning timelines. Based on generation estimates from this capacity as per typical capacity factors, energy shortfalls are expected to increase from about 2,800 MUs in FY2016 to about 5,000 MUs in FY2019. Peak shortfalls are expected to range from about 460 MW in FY2016 to nearly 300 MW in FY2019. Hence, with the possibility of continued shortages even with current plans, in order to achieve 24x7 supply power supply, the state will need to implement the following additional options.

The performance of state-owned thermal plant can be improved by re-negotiation of fuel supply contracts based on the analysis of cost benefits of washed coal vs. unwashed coal. This should be accompanied by estimation of need for refurbishment and modernisation of plants, and arrangements for mining coal in captive mines.

Long-term power purchase from Independent Power Producers (IPPs), captive plants, and stranded capacity can be initiated. Exported volumes can be replaced by procurement through long-term Power Purchase Agreements (PPAs). Tendering route for long term procurement of power from IPPs can be explored, with contracting of peak power from stranded plants in the southern region by offering peak tariffs

Transmission and Distribution Plan: In order to meet the forecasted demand with generation capacity addition plans, adequate planning for augmenting both transmission (intra-state and inter-state) and distribution networks will be critical. As per the current capacity augmentation plans, 1,356 substations are expected to be available by the end of the 13th Five Year Plan (FYP). For managing reactive power in the network, it is recommended to initiate load characteristic studies, increase the minimum Power Factor (PF) for Low Tension (LT) consumers to 0.9 in line with other states, and place shunt capacitors in 11 kilo Volt (kV) distribution networks. Distribution Companies (DISCOMs) and Karnataka Power Transmission Corporation Limited (KPTCL), need to jointly develop maintenance practices and conduct detailed harmonics and equipment failure analyses to ensure reliability of reactive power sources.

The current Transmission & Distribution (T&D) losses in the state are at an average of 20.6%. If reduced to 12%, resultant savings in terms of energy would be around 4,200 MUs costing about INR 1,470 Crore per year at an Average Power Purchase Cost (APPC) of INR 3.5/ kWh. Main recommendations for the distribution sector include regular tariff revisions, uptake of financial restructuring measures recommended under the recently launched Ujwal DISCOM Assurance Yojana (UDAY) scheme, periodic Distribution Transformer Center (DTC) level metering to reduce losses in the network, phased implementation of feeder separation along with impact assessment, and initiation of High Voltage Distribution System (HVDS) pilots.

Role of Renewable Energy (RE): Karnataka has a high RE potential of about 30,000 MW. If implementation barriers are resolved, up to 10,000 MW/ 17,250 MUs of wind generation capacity can be added at a cost of INR 60,000 crore by FY2020. Similarly, up to 4000 MW/ 6300 MUs of solar capacity can be added by FY2020 at a cost of INR 32,000 Crore. Grid-connected RE capacity addition can be facilitated with effective implementation of single window clearance mechanism, facilitating project land allocation, and strengthening grid infrastructure. Support for low RE footprint technologies is recommended, along with the creation of a Renewable Energy

Management Center (REMC) to manage grid integration aspects from intermittent renewable sources.

To enable 24x7 power supply, Distributed Renewable Energy (DRE) solutions can play an important role in offsetting some of the issues associated with large-scale plants. They can offer long-term solutions for energy access through some critical enablers such as encouraging solar pump usage, and increased adoption of rooftop solar PV through suitable tariffs. It is also recommended to provide Value Added Tax (VAT) relief for RE devices and spare parts, recognise decentralised solar plants as industry, and evaluate the usage of DRE systems as an alternative to Bhagya Jyothi (BJ) installations.

A conducive ecosystem for promotion of DRE can be created by including specific targets for DRE under the state RE plans, and evaluating hybrid RE systems for micro and small-scale industries. Further facilitating factors include conducting an electricity access mapping exercise, and developing a skilled workforce to handle the maintenance of DRE technologies.

Role of Energy Efficiency (EE): EE measures that can be implemented by the state with the potential for significant savings include Agricultural Demand-Side Management (Ag DSM) through efficient Irrigation Pump Sets (IPs), and efficiency in end-use consumption from appliances and lighting.

The potential of energy savings from efficient pumping is gradually being recognised in different parts of Karnataka. Savings in the range of 30-70% have been achieved in pilot studies at Dodaballapur where 280 IPs were replaced, along with feeder separation, metering and HVDS lines for electricity supply. Further, efficient irrigation practices were employed and farmers' awareness regarding cropping patterns and cultivation practices was increased. Across the state, it is estimated that this option can be achieved at a cost of INR 200 Crore, with an energy saving of 1, 440 MUs and avoided capacity of 33 MW by 2020.

To estimate savings from energy efficient appliances, fans, refrigerators, television sets, air conditioners were modelled in this study. An EE scenario can be achieved in the long-term at a cost of INR 1,260 Crore, with an energy saving of 1,100 MUs and avoided capacity of 25 MW by FY2020.

Within lighting, technologies for both point and linear lighting are incorporated. In the case of uptake of improved efficiency measures in lighting, it is assumed that the State will successfully tap into opportunities for improving efficiencies, which would cost INR 1,030 Crore with a savings of about 4,700 MUs and 11 MW by 2020.

In the residential sector, the state could incentivise efficient appliances to reduce their higher upfront costs through appropriate financing mechanisms, such as loans and rebates. Establishment of a State Clean Energy Fund (SCEF) presents one approach to facilitate such financing. DSM pilots can be scaled up after measuring improvements from current consumption levels, and establishment of Measurement & Validation (M&V) protocols to measure savings. Initial investment risks need to be mitigated through appropriate financing mechanisms, which can be operationalised through an Ag DSM Revolving Fund.

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1. Introduction

The National Electricity Policy of 2005 (MoP, 2005) had strived to provide electricity access to all within five years and eliminate peak and average energy deficits by 2012. While the country has witnessed significant improvement in village and household electrification over the last decade, over 30% of the population still does not have reliable electricity access. Also, at about 900 kWh, per capita electricity consumption in the country is only one-third of the world average (The Economist, 2012) and over 300 million people are yet to receive access to electricity (Banerjee S. G., 2013). Even those with access to electricity receive unreliable and erratic supply, and the country has both peak and energy deficits of about 9% each (MoSPI, 2013).

In a bid to improve the situation, the government launched the Power for All initiative in 2014. This initiative aims to provide 24x7 power across the country by 2019 through various schemes to address specific challenges (MoP, 2014). Illustratively, the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) envisages feeder separation and strengthening of sub-transmission and distribution network, including complete metering.

As part of this initiative, a sub-committee of the Forum of Regulators (FoR) was tasked with preparing a national roadmap for 24x7 Power for All. FoR defined the scope of the initiative as reflected in the objectives below (FoR, 2014). The roadmap suggested several recommendations spanning fuel supply, generation, transmission and distribution sectors, and demand-side management.

The objectives of the roadmap developed by the FoR were as follows:

- Reliable 24x7 power supply to domestic, industrial, and commercial consumers by 2018-19
- Power supply for irrigation pump for 8 to 10 hours a day depending upon the agro-climatic factors in different States; and
- Access to all connected households by 2018-19

In recognition of the federal structure of India's power sector, a key recommendation of the FoR study was the formulation of state-level strategies to meet the objectives of 24x7 Power for All. The state of Andhra Pradesh was the first to prepare such a plan and has already signed a Memorandum of Understanding with the Ministry of Power to roll out the initiative. Subsequently, Rajasthan and Delhi have also developed plans which are ready for implementation. To this end, the Karnataka Electricity Regulatory Commission (KERC), commissioned this study to identify state-specific strategies for achieving 24x7 power supply for all.

To give a brief overview of the power sector in Karnataka, the main institutions in the sector are the state-owned Karnataka Power Corporation Ltd. (KPCL) for generation, the state-owned Karnataka Power Transmission Corporation Ltd. (KPTCL) for transmission and five Electricity Supply Companies (ESCOMs) in Bangalore, Mangalore, Gulbarga, Hubli, and Mysore, for distribution of electricity to consumers. Additionally, Hukkeri Rural Electric Cooperative Society distributes power to consumers in Hukkeri Taluk and a few other villages in the area. The State Load Dispatch Center (SLDC) performs the role of system operator in the state's power system. In 2007, the state set up the Power Company of Karnataka Ltd. (PCKL), which is responsible for the procurement of power on behalf of the ESCOMs, both through long-term (Power Purchase Agreements (PPAs)) and short-term transactions.

Recognising the importance of the power sector in the economic progress in the State, Karnataka was one of the first Indian states to implement power sector reforms with the enactment of the

Karnataka Electricity Reforms Act in 1999. KERC was established as the regulatory authority of the state's power sector. Among other functions, it regulates the tariff for different categories of consumers. In the recent past, Karnataka state has been experiencing shortages consistently. The State has taken various initiatives to implement projects in the public and private sector for augmenting generation capacity.

This study analyses the status of 24x7 power supply in the state along the dimensions of access (electrification), adequacy (per capita consumption), affordability (cost of supply), availability (duration of supply), and reliability. The report concludes with the key strategies that Karnataka should focus on in order to achieve the goal of 24x7 Power for All.

The report is structured as follows: Section 2 describes the power supply scenario in the State which includes estimates for future energy demand; Section 3 deals with the status of power supply in Karnataka along the dimensions of access, adequacy, affordability, availability, and reliability. It also highlights the challenges faced by the state; Sections 4 and 5 lay out future plans for generation and transmission capacity respectively, till FY2020. Sections 6 and 7 discuss the Renewable Energy (RE) and Energy Efficiency (EE) options available to meet future demand; Section 8 concludes with the summary of key strategies that the State needs to implement in order to achieve 24x7 Power for All.

2. Power Supply Scenario

In this section, we assess the status of the power sector in the State, followed by a discussion of the expected energy and peak demand till FY2020.

2.1. Present Power Supply Position

This section provides a snapshot of the power sector in Karnataka, in terms of installed capacity of supply, trends in energy and peak deficits, and category-wise consumption.

2.1.1. Installed Capacity of Supply

The current capacity available on the supply side is listed in Table 1. In terms of ownership, state-owned thermal, large-hydro, wind, and solar plants account for about 42% of the total installed capacity. IPPs contracted under long-term PPAs contribute nearly as much at 43%. Of the remaining, most of the capacity is accounted by the state's share in Central Generating Stations (CGS) (Figure 1).

In terms of fuel source, nearly two-thirds of the installed capacity is in thermal and large-hydro sources, at 47% and 24% respectively. Most of the remaining capacity is accounted for by wind at 13% of the total share. Small hydro and nuclear power together account for 8% of the total capacity (Figure 2). A detailed list of plant-wise capacity for each source is provided in Annexure 1.

Table 1: Current Installed Capacity (MW) in FY2015

By Fuel Type	Installed Capacity (MW)	By Ownership	Installed Capacity (MW)
Large Hydro	3,674	State	6,499
Thermal (including diesel)	7,362	IPP	6,679
Nuclear	501	CGS	2,258
Solar	91	Others (inter-state hydro)	132
Wind	2,086		
Small Hydro	813		
Biomass	89		
Co-generation	953		
TOTAL	**15,568 MW**		

Source: PCKL

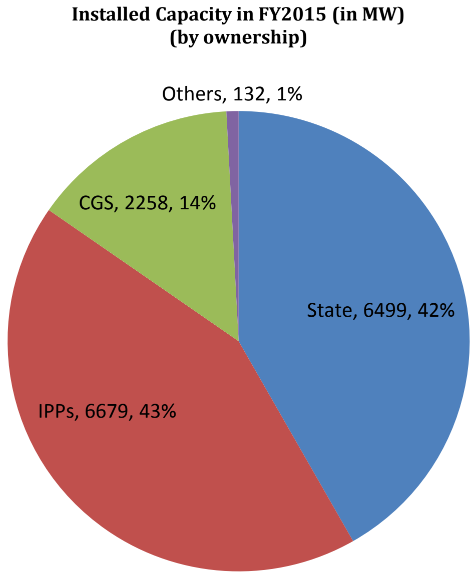

Figure 1: Installed Capacity in Karnataka in FY2015 (MW) - By Ownership

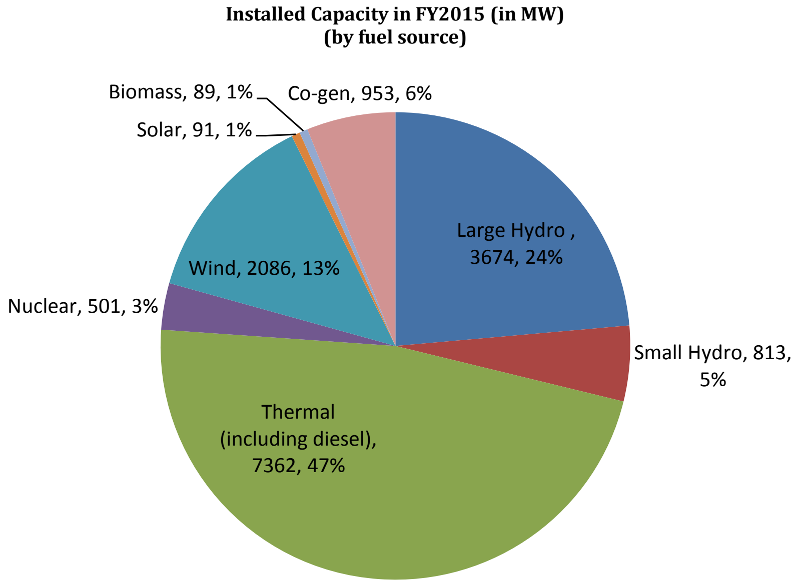

Figure 2: Installed Capacity in Karnataka in FY2015 (MW) - By Fuel Source

Short-term power purchases have accounted for a significant portion of the supply in the previous years. The state is increasingly relying on them, often in the peak months of the year when the rates are expensive, in order to meet the growing energy demand. The quantity purchased has grown at a CAGR of nearly 27% between FY2010 and FY2015. In FY2015, 5,867 MUs of short-term power was purchased through exchanges and bilateral transactions. The year-wise costs and quantity of short-term power purchases in the recent past are listed in Table 2 and Figure 3.

Table 2: Year-wise Costs and Quantity of Short-term Power Purchases in Karnataka

Year	Short-term Energy Purchased (MUs)	Cost per unit (INR/ kWh)
FY08	14	7
FY09	1, 964	6.8
FY10	1, 799	6.4
FY11	7, 815	5
FY12	6, 320	4.8
FY13	11, 046	4.3
FY14	6, 479	5
FY15	5, 867	5.3

Source: KERC

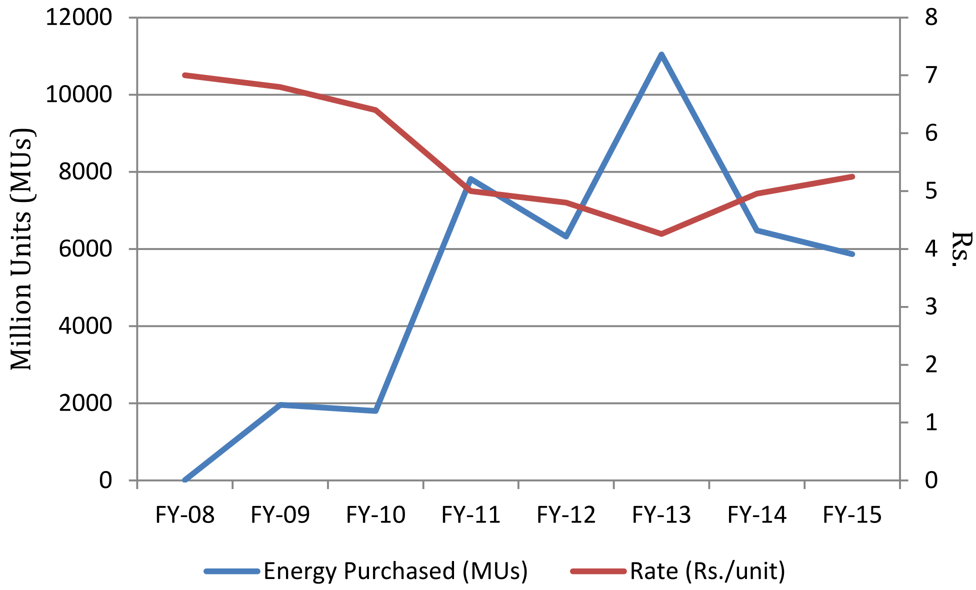

Figure 3: Short-term Energy Purchased and Costs (FY2008 – FY2015)

The month-wise short-term purchases made by the state in the year FY15 is listed in Annexure 2.

2.1.2. Unrestricted Energy and Peak Deficits

In terms of deficits, as against the unrestricted aggregate and peak demands estimated by the Electric Power Survey (EPS) of the Central Electricity Authority (CEA) (CEA, 2011), the State has steadily faced a shortage situation at an average growth rate of 7.8% between FY2008 and FY2015 (Figure 4). In FY2015, the state had an unrestricted energy demand of 62,643 MUs but could supply only 59,926 MUs, leading to an energy deficit of about 4.3%.

Figure 4: Unrestricted and Met Demand in the State (FY2008 - FY2015)

Andhra Pradesh and Himachal Pradesh, which are comparable to Karnataka in Gross State Domestic Product (GSDP) per capita, had energy deficits of 7% and 2%, respectively (NITIAayog, 2014). The reasons for such a high energy deficit in the state are numerous. First, the demand for electricity has grown rapidly due to rising per capita income, with increasing urbanisation and industrialisation. Second, the Plant Load Factors (PLFs) of state thermal plants have been as low as 60-68% in recent years, in comparison to PLFs of about 80% for central thermal plants. Third, though the state has allocated over 10,000 MW of RE capacity, only a small portion of this capacity has been commissioned.

The shortage situation observed at the aggregate level is further reflected in the inability of the state to meet peak demand. The peak demand in the state has grown from 6,583 MW in FY2008 to 10, 000 MW in FY2015 at a CAGR of 6.2% (Figure 5). The peak deficit has varied over the same period at an average rate of 10.6% and was 4.5% in FY2015. The highest peak deficit during the period was in FY2012, at about 19%.

Figure 5: Unrestricted Peak Demand vs. Peak Supplied from FY08 to FY15

The month-wise peak demand for the previous year is shown in Annexure 3. From the daily load curves for Karnataka published by KPTCL (KPTCL, 2014), it is observed that the state faces unscheduled shortages over and above the scheduled i.e. planned curtailments. The highest hourly unscheduled load observed between 2011 and 2014[1] was at 1,200 MW.

2.1.3. Category-wise Consumption

The share of the agricultural sector in the state's total electricity consumption is quite high at 37% (NITIAayog, 2014) (Figure 6). The state has nearly 2 million energised IPs, each consuming 10,000 kWh per annum on an average. In comparison, the specific consumption per IPs in Gujarat, Andhra Pradesh, and Tamil Nadu is approximately 16,000 kWh, 8,000 kWh, and 4,000 kWh, respectively. At about 800 kWh, specific electricity consumption in Karnataka is slightly higher than that in Gujarat (700 kWh), but significantly lower than that in Tamil Nadu (1,200 kWh) and Andhra Pradesh (1,700 kWh) (NITIAayog, 2014). The share of industry is lower than agriculture, despite the presence of several cement and steel industrial units in the state – possibly because of the heavy reliance on captive power due to its higher reliability (Deepika, 2015).

[1] Daily unscheduled loads are analysed for full years of 2011, 2012, 2013, 2014

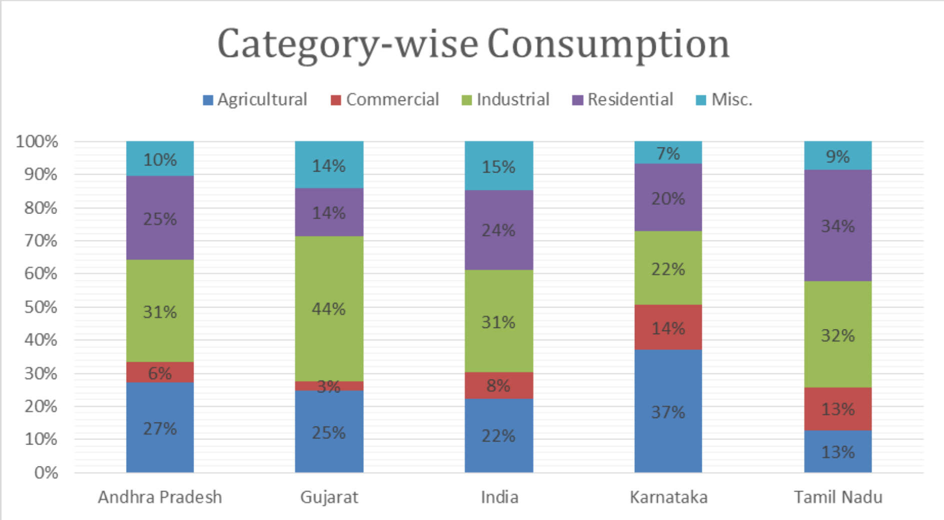

Figure 6: Category-wise electricity consumption in Karnataka and other states

2.2. Estimation of Future Demand for Providing 24x7 Power

While several projects are in the pipeline, is the situation of power shortages likely to change in the future? This section provides estimates of the future demand and supply of electricity to address this question.

2.2.1. Aggregate Energy Demand

The study uses the EPS estimates to project the future sector-wise energy demand in the state of Karnataka. The sectors considered are domestic, commercial, public lighting and water works, agriculture, industries, railway traction, and bulk supply. Demand is estimated till FY2020, as per the 18th EPS conducted by CEA (CEA, 2011). The 18th EPS estimates are based on a partial end-use methodology, which is a combination of time-series analyses and end-use methods. While using the time series method, a higher weightage is given to recent trends in order to account for energy conservation initiatives and improvements in technology. The demand is forecasted for various consumer categories namely domestic, commercial, public lighting and water works, irrigation, industrial, railway traction and bulk supply, at bus bars, for utilities only. The methodology used by CEA for estimating the demand is briefly described in Annexure 4. The demand from various consumer categories is expected to grow further by about 1.3 times of the current demand by FY2020. The sector-wise estimated demand is presented in Table 3.

Table 3: Sector-wise Projected Demand (Million Units) (MUs)

Category/ Year	**FY2016**	**FY2017**	**FY2018**	**FY2019**	**FY2020**
Domestic	13,895	14,884	15,791	16,752	17,773
Commercial & Misc.	8,268	9,202	10,192	11,237	12,389
Public Lighting	1,240	1,366	1,468	1,557	1,651
Public Water Works	2,880	3,070	3,266	3,468	3,683
Irrigation	18,237	19,420	20,764	22,026	23,386
Industries LT	2,951	3,253	3,587	3,954	4,360
Industries HT	10,507	11,545	12,243	12,983	13,768
Railway Traction	543	567	591	615	640
Bulk Supply	2,770	2,780	2,790	2,800	2,810
18th EPS Unrestricted Energy Consumption (Pre-T&D Loss Reduction)	**61,290**	**66,088**	**70,692**	**75,393**	**80,459**

Source: CEA

By FY2020, the estimated energy consumption is expected be about 80,450 MUs. The year-wise estimated demand till FY2020 is presented in Table 4. After accounting for Business As Usual (BAU) shortages and Transmission and Distribution (T&D) losses, the total unrestricted energy requirement is estimated to be 1,12,675 MUs in FY2020.

Table 4: Future Projected Energy Requirement (MUs)

Year	18th EPS Unrestricted Energy Consumption (Pre-T&D Loss Reduction) (MUs)	Estimated Consumption with BAU shortages (MUs)[2]	T&D Losses (BAU) (21%) (MUs)	Estimated Unrestricted Energy Requirement (MUs)
FY2016	61,290	67,617	17,974	85,592
FY2017	66,088	72,909	19,381	92,290
FY2018	70,692	78,048	20,747	98,795
FY2019	75,393	83,324	22,149	1,05,473
FY2020	80,459	89,013	23,662	1,12,675

2.2.2. Peak Demand

Peak demand, as seen in the previous section, has grown at a CAGR of 6.2% over the past 8 years. Table 5 below shows the projections for peak demand as per the estimates of the 18th EPS by CEA (CEA, 2011). The peak demand is estimated to continue to grow at a CAGR of nearly 10% over the next five years, to reach 16,000 MW by FY2020.

Table 5: Future Projected Peak Demand (MW) with 9% CAGR

Year	18th EPS Peak Demand Estimate (MW)
FY2016	12, 102
FY2017	13, 010
FY2018	13, 964
FY2019	14, 945
FY2020	16, 005

Source: CEA

[2] At an average BAU growth rate of 7.8%

3. 24x7 Power for All: The Challenge

What do we mean by 24x7 Power for All? FoR defined 24x7 power as reliable power for all urban and rural non-agricultural consumers and 8-10 hours of daily power supply for agricultural consumers. In this section, we explore this definition further and characterise it along the dimensions of access (electrification), adequacy (per capita consumption), affordability (cost of supply), availability (duration of supply), and reliability (quality of supply). We present the status of power supply in the state along these dimensions, in the context of the challenges faced.

3.1. Access

Electricity is an important input for economic and social development – it can directly and indirectly increase the standard of living of millions of people in our country through creation of livelihoods, facilitation of public services such as education and health, and access to energy services such as lighting and ventilation. In the international arena, attempts have been made to place electricity access within the framework of human rights (Bradbook & Gardam, 2009). Within the context of 24x7 power, ensuring access for all and last mile connectivity becomes an important factor in this regard.

On the whole, Karnataka has a good record in electrification. Village electrification in the state is 99.5% in comparison to the national average of about 92-93%. Though household electrification is also high (96% in urban areas; 88% in rural areas) and has increased significantly over the last decade, nearly 1 million households still do not have access to electricity in the state.

Figure 7 depicts the improvement in rural and urban household electrification rates for states comparable to Karnataka, from 2001 to 2011. The all India average for urban and rural household electrification has increased from 88% to 93% and from 44% to 55% respectively, from 2001 to 2011. In the same period, Karnataka's urban and rural household electrification rates have increased from 91% to 96% and from 72% to 87% respectively. While Karnataka's electrification rates are higher than the national average, it is still lower than that of Andhra Pradesh, which has an urban and rural household electrification of 97% and 90% respectively in 2011 (NITIAayog, 2014).

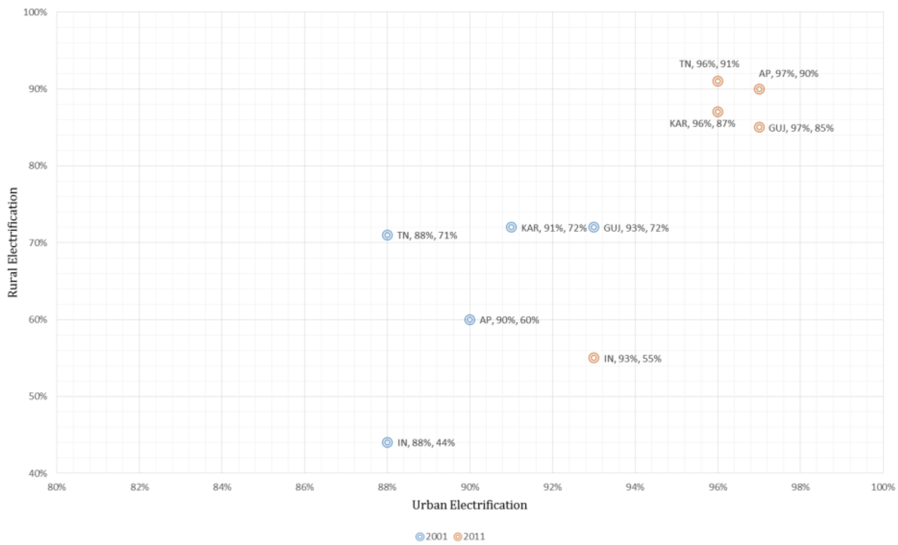

Figure 7: Electrification Rates for Karnataka and other Comparable States (2010 & 2011)

Electrification of remaining households has been challenging, in part, because of the hilly terrain and relatively low population density, which make grid extension expensive. Where grid extension is not feasible, electricity access can be provided under the Distributed Decentralised Generation (DDG) scheme of DDUGJY. Currently, there are 34 un-electrified villages in remote forests and coastal regions in Karnataka that can be considered for off-grid electrification through DDG (GoI, 2015). Grid extension to these areas would not only be economically unfeasible, but also environmentally harmful as transmission lines would have to cut through dense forests. Additionally, successful implementation of DDG projects would entail an in-depth assessment of the socio-technical factors in these villages.

Availability of reliable data can aid in formulating effective electrification policies. This includes data regarding electricity access in public buildings such as schools, public health centres, and Panchayat buildings that are crucial for providing services to citizens. Karnataka can aim to provide 100% electricity access with an emphasis on electrification of not only households but also public buildings, the agriculture sector, and industries. To facilitate this, databases of current status and power requirement for various institutional buildings and public utilities both in urban and rural areas should be maintained so as to plan demand-side management and reduce the power deficits that the ESCOMs face.

A decentralised mechanism for such data collection can be deployed by using existing ground level resources and public officials such as Panchayat and Taluk offices, Block Development Officers (BDOs), school administration, and entrepreneurs working in the energy sector.

3.1.1. District-wise Assesment of Access to Electricity

Assessment of district-wise access of the number and percentage of households to electricity indicates that Karnataka fares well in comparison to the districts of other states. The average percentage of households that have access to electricity over all the districts is approximately 89%. This has been verified by using data from the Census survey of 2011[3]. Bangalore is seen to have almost 100% electrification, while districts with particularly low electrification rates are: Yadgir (78%), Bijapur (81%), Kodagu (82%) and Belgaum (84%)(Figure 8).

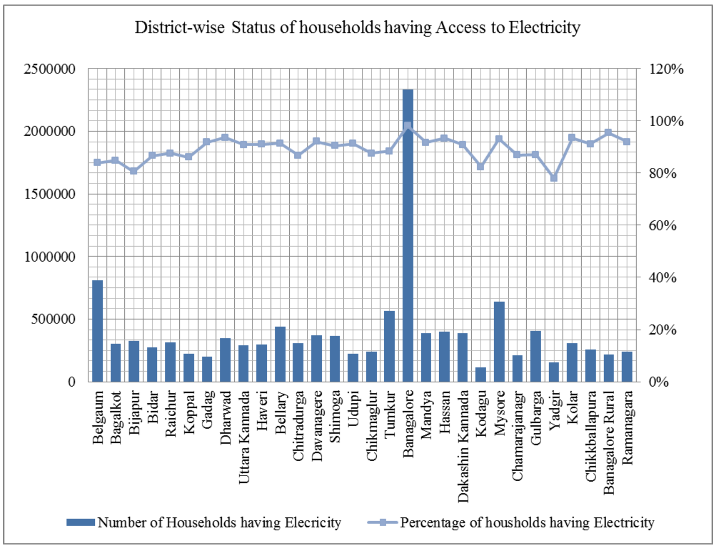

Figure 8: District-wise Status of households having Access to Electricity

[3] Note: criteria for deciding whether a household is electrified or whether supply is reliable hasn't been defined clearly

3.2. Adequacy

Adequacy of electricity signifies the relative per capita electricity consumption[4] and energy deficit in the state. With a per capita electricity consumption of nearly 1,100 kWh in 2012, the consumption in Karnataka was above the country average of 884 kWh. However, its per capita consumption is lower than that of comparable states such as Gujarat (1,663 kWh), Tamil Nadu (1,277 kWh), and Andhra Pradesh (1,157 kWh) (Figure 9).[5] Further, the per capita electricity consumption in Karnataka is one-fourth of the average per capita electricity consumption in China and one-fifteenth of the per capita electricity consumption of most developed countries (Bhaskar, 2015).

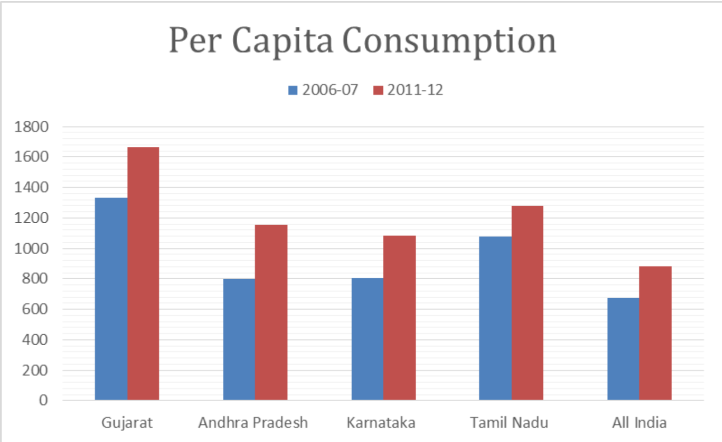

Figure 9: Per-capita electricity consumption in Karnataka and other states (2007 & 2012)

A minimum lifeline household consumption of 30 kWh/month (1 unit/household/day), was fixed as a norm in rural areas, by the National Electrification Policy (MoP, 2005) and tariff orders from KERC (KERC, 2014). If a lifeline consumption of 50[6] kWh per month is envisaged, Karnataka can reach a benchmark of about 1,500 kWh of production by FY2020 as the electricity infrastructure has reached most regions in the state. In the case of urban households, the goal can be set at 125 kWh/month (Pargal & Banerjee, 2014)[7] as per the growing trends, which presently for Karnataka stands at 86 kWh per month (Banerjee, Barnes, Singh, Kristy, & Samad, 2015). To achieve these goals, high energy deficits in the state must be addressed.

3.3. Availability

24x7 power for all includes availability of power to meet peak load at the diurnal and seasonal levels. Load curves for the state for two typical days are illustrated in Figure 10 (KPTCL, 2014).

[4] Here per capita consumption is measured on the basis of electricity fed into the grid and not the actual consumption, which would be much lower on account of Transmission and Distribution (T&D) losses.
[5] These states are considered to be comparable on the basis on proximate GSDP and population.
[6] 30 kWh/month has been fixed in line with current state level average consumption of 925 Kwh that could be increased to 50 kWh/ month while aiming for per capita consumption of 1500 kWh for the state.
[7] Derived from the assumption in this report that urban per capita consumption is double the rural per capita consumption

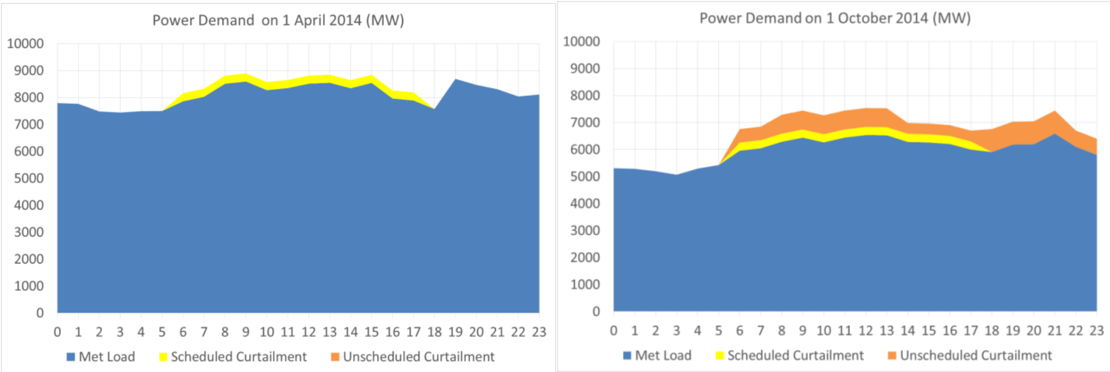

Figure 10: Observed peak demand on typical days in 2014 (MW)

Peak demand is typically observed during the morning and the evening. This is as per the frequency distribution of the peak load over a period of three years. Additionally, the rate of growth of peak demand is higher than the average demand throughout the year (summarised in Annexure 5).

Under BESCOM, the consumer category-wise consumption for an average of the 16 representative days of the year can be visualised as below (Figure 11).[8] On an average, the domestic category mainly gives rise to the shape of the morning and evening peaks.

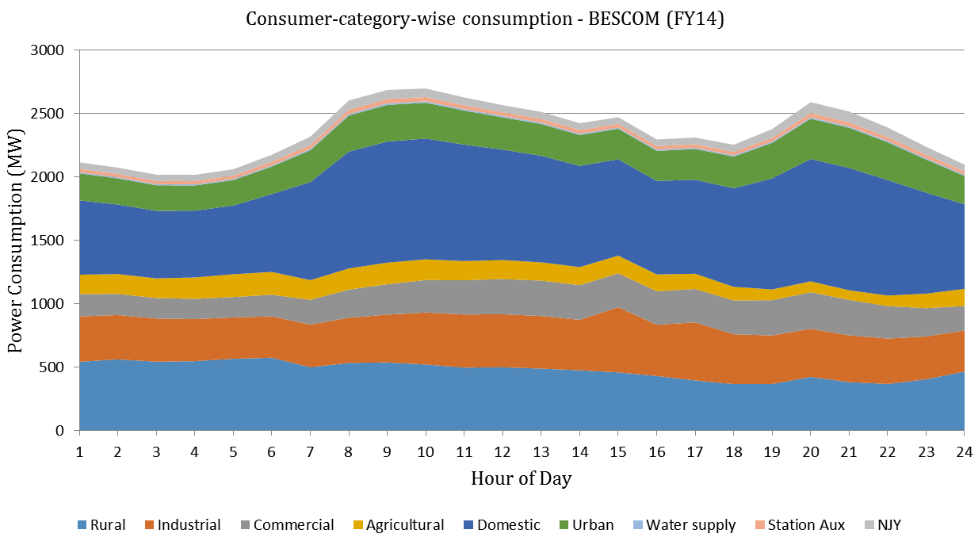

Figure 11: Consumer-category-wise consumption – BESCOM (FY2014)

Peak demand is typically met through quick ramping sources of generation such as hydro and gas, or short-term power purchases. An analysis of the power availability across the state can present a clearer picture of regional and seasonal disparities. As an illustration, supply availability has been analysed using SCADA data taken from KPTCL for representative days in 2014 (Annexure 5).

In Karnataka, power availability can be set at the below standards based on the existing trends in demand for both rural and urban areas. The ultimate aim should be to reach 24 hour supply for every household in the state:

- Rural areas should have 3 phase supply for a minimum of 12 hours during day time that can be used for running cottage industries, water pumps and other livelihoods activities
- Each household receives 20 hours of supply of single phase power and eventually moves towards 24 hours.

[8] Supervisory Control and Data Acquisition (SCADA) data for all the feeders along with the feeder classification as given by BESCOM were used for this analysis.

3.4. Reliability

Uninterrupted availability of power is considered as a strong indicator of reliability. Thus, feeder outages can be effectively used to compute a realibility index to gauge the efficacy of the quality of reliable power supply. A Feeder Reliability Index (FRI) can also be used as a suitable indicator to further study the disparities that exist between district headquarters and urban and rural areas. This exercise is also an important tool for devising appropriate strategies for the state government depending on how various areas within each ESCOM fare on providing reliable service of power.

A similar index has been developed by KERC to estimate the reliability of feeder outages for the five major ESCOMs in Karnataka, the results for which are shown in Table 6. The index at 11kilo Volt (kV) feeder level is calculated using the following formula (KERC):

Feeder Reliability Index= {[Total No of 11kv Feeder x 24 Hrs x No. of days] - [outage duration of all 11kv feeders during the month in Hrs]} x 100/ [Total No of 11kv Feeders x 24Hrs x No. of days]

Table 6: Reliability Index (in %) for 5 DISCOMs in Karnataka for FY2015

DISCOMs	District Headquarters	Towns and Cities	Rural Areas
BESCOM	97.31	96.90	94.53
MESCOM	97.90	94.99	90.75
CESC	96.39	92.13	71.03
HESCOM	97.25	95.97	65.86
GESCOM	93.29	84.86	84.36

Source: KERC

The indices mentioned above reinforce the observation that rural areas receive unreliable power supply in comparison to urban areas. In most towns and cities, reliability is close to 97%, with the average being at least 93%. While a 97% reliability is relatively high within the state of Karnataka, a higher standard of up to 99% may be achieved as has been by a few other states in the country (CEA, 2014). In most rural areas, the situation has improved but still proper care has to be taken to increase the reliability in some regions. The major observation are given below:

- The district headquarters under HESCOM has a reliability index of 97% whereas that of rural areas is about 65%

- Rural areas under BESCOM have the highest reliability index of 94%.

Other measures of reliability that are widely used by electric power utilities in the country are briefly described in Annexure 6.

3.5. Affordability

Affordability is an important criterion for 24x7 Power for All. While a detailed assessment of affordability is beyond the scope of this report, an initial analysis has been attempted by comparing the cost of power and electricity tariff in Karnataka to that in other states for information available for FY2014 (Table 7) (NITIAayog, 2014). This comparison reveals that, on average, electricity in Karnataka is not too expensive or highly priced – in fact, it is cheaper than the national average even though average incomes in Karnataka are slightly higher.

Table 7: Average Cost of Power and Tariffs for Karnataka and Comparable States (FY2014)

State	Cost of Power (INR/kWh)	Average Tariff (INR/kWh)
Andhra Pradesh	5.63	5.47
Gujarat	4.95	4.62
Karnataka	5.04	4.76
Tamil Nadu	6.45	4.93
All India Average	**5.93**	**4.79**

Source: NITI Aayog

The high share of cheap hydel power in the state is the primary contributor of affordable power. The costs and generation from various sources are shown in Figure 12. In FY2014, the state received 22% of its electricity from hydroelectric plants at an average tariff of INR 0.59. However, the percentage or share of hydel power in total electricity generation has been declining steadily and is likely to reduce in the future because of environmental concerns with exploiting the remaining hydel potential, particularly in the Western Ghats.

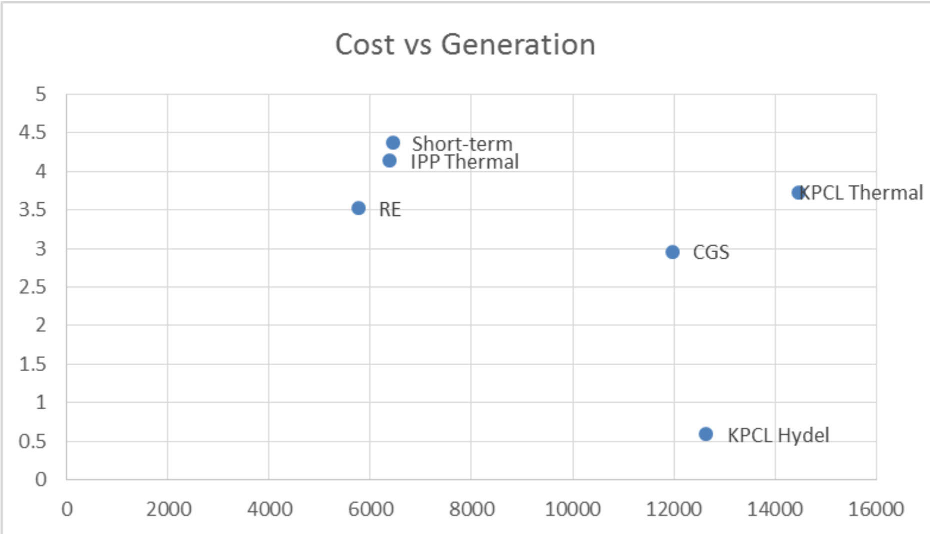

Figure 12: Cost vs. Generation from Different Sources in Karnataka (FY2014)

Source: KERC

Karnataka can aspire to further lower costs from the supply side, as current costs of electricity generation account for the low performance of state-owned thermal power plants (average PLF of about 65%). While the average cost of electricity from the CGS was INR 2.96 per unit, the average cost of coal-based electricity from KPCL was as high as INR 3.73. This poses a challenge to reduce the electricity tariffs in the state. The state also buys a high share of its thermal electricity from IPPs and short-term power purchases, both of which cost over INR 4 per unit on average.

4. Generation Plan

This section assesses the capacity addition plans of the state, to estimate the foreseeable deficits till FY2020, as against the unrestricted energy and peak demand estimated in Section 2. Feasible options for augmenting generation from existing and new capacity have been discussed.

4.1. Existing Generation

The energy generated (and purchased) for FY2015, is estimated to be about 78,493 MUs, based on the assumptions mentioned below for annual average capacity factors from different sources (Table 8).

Table 8: Energy Generated from Various Fuel Sources (FY2015)

Fuel Type	Annual Average Capacity Factors (%)	Energy generated and purchased (MUs)
State Coal	64%	15,249
IPP Thermal (Coal + Diesel)	70%	16,311
Large Hydro	40%	12,874
Diesel/Oil	30%	593
Wind	22%	4,020
Small Hydro	30%	2,137
Solar	18%	143
Biomass + Cogeneration	60%	5,477
CGS	80%	15,822
Total		72,626
Short-term and others		5, 867
Losses (~21%)		
Total Energy Supplied		**78,493**

4.2. Future Generation Plans

The current plan for year-wise capacity augmentation by the State for meeting the future demand is listed in Table 9. The estimated cumulative conventional and non-conventional capacity by FY2020 is 17,571 MW and 8,347MW respectively, resulting in a total installed capacity of 25,918 MW. The detailed project-wise list of new projects scheduled for 12th and 13th FYP for capacity augmentation is given in Annexure 7.

Table 9: Planned Capacity Addition (FY2015 to FY2020) (MW)

Source	FY 2015 Installed Capacity (MW)	FY2016	FY2017	FY2018	FY2019	FY2020	Total incremental capacity at the end of FY2020
Conventional Sources							
KPCL Hydro	3,542	10	0	0	16	276	3,844
Jurala Hydro	117	0	0	0	0	0	117
Tungabhadra Dam Share	14	0	0	0	0	0	14
Total Hydro	**3,674**	**10**	**0**	**0**	**16**	**276**	**3,976**
KPCL-PCKL Thermal	2,720	1,090	0	0	0	1,300	5,110
Yelahanka+IPP Diesel	225	0	0	0	840	0	1,066
IPP-UPCL+Jindal	2,660	0	0	0	0	0	2,660
Total Thermal	**5,606**	**1,090**	**0**	**0**	**840**	**1,300**	**8,836**
CGS	**2,258**	**321**	**800**	**435**	**35**	**590**	**4,439**
UMPP		**0**	**0**	**0**	**0**	**320**	**320**
Conventional-Total Installed Capacity	**11,537**						
YoY Addition of Conventional Capacity		**1,421**	**800**	**435**	**891**	**2,486**	**6,034**
Installed Capacity – Conventional Cumulative	**11,537**	**12,958**	**13,758**	**14,194**	**15,085**	**17,571**	**17,571**
Solar (Grid-connected + Rooftop)	**91**	**250**	**250**	**250**	**200**	**200**	**1,241**
Wind	**2,086**	**400**	**425**	**450**	**475**	**500**	**4,336**
Co-gen	**953**	**32.5**	**37.5**	**37.5**	**37.5**	**37.5**	**1,135.5**
Mini-Hydel	**813**	**100**	**100**	**100**	**125**	**125**	**1,363**
Bio-mass	**89**	**32.5**	**37.5**	**37.5**	**37.5**	**37.5**	**271.5**
Non-conventional Total Installed Capacity	**4,032**						
YoY Addition of Non-Conventional Capacity		**815**	**850**	**875**	**875**	**900**	**4,315**[9]
Installed Capacity Non – Conventional Cumulative	**4,032**	**4,847**	**5,697**	**6,572**	**7,447**	**8,347**	**8,347**
Total Installed Capacity	**15,568**						
YoY Total Capacity Addition		**2,236**	**1,650**	**1,310**	**1,776**	**3,386**	**10,349**
Total Cumulative Installed Capacity		**17,805**	**19,455**	**20,766**	**22,532**	**25,918**	**25,918**

Source: KERC and KREDL

4.3. Available Capacity to meet Future Energy Demand

Based on current plans, the state can supply the units mentioned below, against the expected unrestricted energy demand (as per EPS estimates). Energy shortfalls are expected to steadily increase from about 2,800 MUs in FY2016 to about 5,000 MUs in FY2019, even if the planned plants are commissioned on schedule, without any delays (Table 10).

[9] From KREDL's RE Policy 2014-20 and Solar Policy 2014-21

Table 10: Future Capacity Addition and Expected Energy Shortfalls (MUs)

Year	Available (Existing + Planned) Generation (MUs)	Estimated Energy Requirement (MUs)	Expected Energy Shortfall (MUs)
FY2016	82,791	85,592	2,801
FY2017	90,267	92,290	2,022
FY2018	95,236	98,795	3,559
FY2019	1,00,436	1,05,473	5,037
FY2020	1,16,790	1,12,675	-4,116

Hence, there is a possibility of continued shortages even with current plans. In order to achieve 24x7 supply power supply, the state will have to implement options other than planning for capacity addition, which are discussed in later sections of the report.

4.4. Available and Required Capacity to meet Future Peak Demand

The peak capacity available to meet the future peak demand, according to existing plans to augment generation capacity, is shown in Table 14. Peak shortfalls are expected to range from about 460 MW in FY2016 to 300 MW in FY2019, even if the planned plants are commissioned on schedule, without any delays (Table 11).

Table 11: Future Capacity Addition and Expected Peak Shortfalls (MW)

Year	Current Installed + Planned Capacity (MW)	Expected Peak Capacity Availability (MW)[10]	Expected Peak Shortfall (MW)[11]	Required Capacity (MW)[12]
FY2016	17,805	11,573	463	12,036
FY2017	19,455	12,646	364	13,010
FY2018	20,766	13,498	467	13,964
FY2019	22,532	14,646	299	14,945
FY2020	25,918	16,847	-841	16,005

Hence, it is clear that even with existing plans to augment capacity, peak shortfalls can be expected to occur if the trend of growth in peak demand in the recent past continues.

The State will have to plan to meet this demand through adequate capacity additions both in terms of base load and peak load availability. With increased RE capacity in the generation mix, any available hydro and gas-based capacity would most likely be required to manage the intermittency accompanying solar and wind-based generation. In this context, the State will have to explore other means of procuring long-term capacity to ensure it is adequately prepared to meet the growing peak demand.

4.5. Recommendations for Supply Side

In the context of the anticipated deficits estimated above, this section discusses some key strategies that can be employed in the generation sector in order to meet the future demand.

4.5.1. PLF Improvement in KPCL Thermal Plants

The PLFs of state-owned thermal power plants in Karnataka, namely Raichur Thermal Power Station (RTPS) and Bellary Thermal Power Station (BTPS), have remained low over the years as shown in Table 12.

[10] At 65% of total installed capacity
[11] Calculated as per the difference between available capacity and the 18th EPS peak demand requirement
[12] Equivalent to 18th EPS peak demand requirement

Table 12: Year-wise Plant Load Factors (PLFs) of State-owned Thermal Plants

Year	RTPS	BTPS
FY2008	89.2%	-
FY2009	84.5%	-
FY2010	67.9%	61.7%
FY2011	78.6%	57.0%
FY2012	63.0%	66.0%

Source: KPCL

This may be partly due to the shift from washed coal to unwashed coal, and partly due to other reasons such as frequent equipment failure and coal availability challenges. Among the projects scheduled for implementation, there are some for which clearances are delayed due to pending coal allocations, as well as partial availability of coal linkages. Such factors have contributed to the energy shortfalls in the state. Therefore appropriate actions are required to be taken to address these issues to improve PLFs.

An increase in PLF from current levels of 65% to 85% will lead to additional generation of nearly 5,000 MUs annually from the existing installed capacity, which is equivalent to the generation from a 650 MW thermal power station operating at 85% PLF.

Key strategies for improving the PLF of state thermal plants are as follows:

- Analyse cost benefits of washed coal vs. unwashed coal and re-negotiate supply contracts, if necessary[13]
- Estimate the need for refurbishment and modernisation of state-owned thermal plants by conducting benchmarking studies with plants of similar vintage in the country
- Identify potential and make arrangements for mining coal in captive mines.

4.5.2. Long-term Power Purchase from IPP, Captive Plants, and Stranded Capacity

In the state of Karnataka and in the southern region in general, there is an opportunity to contract capacity from thermal and gas-based plants that are currently not under long-term PPAs. As of November 2014, Karnataka was among the top five states that sold 65% and 46% of electricity volumes transacted through bilateral transactions and power exchanges, respectively. In November alone, the state sold close to 530 MUs (CERC, 2014).

Some of the actions that the utilities to procure power over the long term are:

- Contract exported volumes under long-term PPAs
- Re-initiate the tendering route for long-term power procurement of power from IPPs (which was initiated in 2009 and aborted in 2011).

In addition to the volumes mentioned above, the state can explore the option to utilise stranded capacity within the southern region. As per CEA, there are about 12,350 MW of coal-based, and 7,950 MW of gas-based capacity stranded in the country as of May, 2014 (Table 16). In Karnataka, there is no stranded capacity at present.[14] However, there are about 306 MW and 572 MW of coal-based stranded capacity in the neighbouring states of Tamilnadu and Maharashtra respectively. Additionally, there is about 3,030 MW of gas-based capacity stranded in the neighbouring states of Andhra Pradesh, Kerala, Puducherry, Tamilnadu, and Maharashtra. Possible reasons for the capacity being idle or stranded include lack of fuel linkages, mismatch with demand-forecasting,

[13] With washed coal, per unit of energy generation is relatively higher but due to increased generation (from high PLF), the gross/net revenue increases significantly which can potentially make use of washed coal economically viable

[14] The Udupi Thermal Power Plant which was stranded was recently purchased and made operational (ET, 2014).

and poor financial health of utilities (CERC, 2014). In addition to capacity being stranded, there is congestion in the regional grids. Close to 6,000 MUs of electricity volumes were lost owing to transmission congestion in the country.

Table 13: Region-wise Stranded Capacity (MW) (FY2013)

Region	Coal/lignite based stranded capacity (MW)	Gas-based stranded capacity (MW)	Total stranded capacity (MW)
Western	3,445	4,229	7,674
Eastern	5,345	68	5,413
Northern	3,262	1,447	4,709
Southern	306	2,151	2,457
North-eastern	0	57	57
Total	12,358	7,952	20,310

Source: CERC

With plans to increase RE-based generation in the State, quick ramping gas-based capacity would be suited for managing the intermittency associated with wind and solar-based generation. The State can explore options to procure this capacity from neighbouring states as a priority.

Out of the total stranded capacity in the country, about 300 MW of coal-based capacity, and 2,151 MW of gas-based capacity is stranded in the southern region (Table 13). Some actions that the state can take to utilise this capacity are as follows:

- Obtain clearances required for making new coal blocks operational through a Special Purpose Vehicle (SPV) which should pursue the required clearances before auctioning them to the developers
- Bring captive plants that are lying idle in the southern region during peak hours under long-term PPAs with suitable peak-tariffs
- Mandate load flow analysis in demand forecasting in order to estimate the demand spatially; this will also help transmission planning for significant capacity addition from intermittent RE sources such as wind and solar
- Identify the high-congestion corridors and augment transmission capacity to avoid generated power from being unutilised
- Measure the performance of utilities using parameters involving interventions that facilitate use of stranded capacity.

5. Transmission and Distribution (T&D) Plan

This section gives an overview of the status and future plans of the T&D sector. Sector-specific strategies for achieving the objective of 24x7 power for all in the State are briefly discussed.

5.1. Transmission System Plan

As can be seen in the previous section, both unrestricted energy and peak demand are expected to considerably increase from present levels i.e. from 62,640 MUs to 1,12,675 MUs and from 10,000 MW to 16,000 MW respectively by FY2020. In order to meet the forecasted demand with generation capacity addition plans, adequate planning for augmenting both transmission (intra-state and inter-state) and distribution networks will be critical. Details of the current transmission network in the State are listed in Table 14.

Table 14: Details of KPTCL Network (FY2015)

Number of Consumers	INR 2.09 Crores
Length of Transmission Lines	42,198 Circuit Kilometers (CKms)
No. of Substations	1,412
No. of Distribution Transformer Centers (DTCs)	5,87,170
High Tension (HT) Lines	2,80,901 CKms
Low Tension (LT) Lines	5,12,916 CKms

Source: KPTCL

Here, the results from a perspective planning study conducted by the Power Research Development Consultants (PRDC) (PRDC, 2013), is presented as the T&D requirements for the current generation plans. The broad methodology followed is as follows:

- Present KPTCL network of 400 kV, 220 kV, 110 kV, and 66 kV voltage levels is used to study the operational flow (base case load flow studies) for the peak load condition of 2011-12 along with the model of the southern regional grid. The results of the load flow studies are compared with the SLDC values for voltage and line loadings. It is ensured that the difference between the simulation results and recorded values is limited to 5%, and the network for the base case is established

- Base case network is developed each for 2016-17 and 2021-22 network conditions considering the proposed 765 kV networks and approved generation plans for the regional and inter-regional network

- Year-wise transmission system addition and capital budgeting is carried out for 12th FYP period

Based on the methodology mentioned above, the following major spatial lines and transformers have been identified for strengthening:

- Kolar High Voltage Direct Current (HVDC) to Kolar 220 kV line is loaded up to 207 Mega Volt Amps (MVA). It is recommended to replace this conductor with High Temperature Low Sag (HTLS)
- Commissioning of Baikampady 220/110 kV Substation (S/S) should be expedited as it can reduce the load on Kavoor S/S. Also, since this loading can be reduced only by 95%, transformer replacement may be required with 2 units of 150 MVA
- Commissioning of 220 kV S/S at Benkikere should be expedited as the voltage profile in the region is low

- Expedited augmentation of transformer capacity at Karwar is required to meet contingency

The overall network strengthening of transmission capacity in the state is given below for the major transmission lines, for the 12th and 13th FYPs (Table 15 and Table 16).

Table 15: Proposed Addition of Substations (S/S) by the end of 2016-17

Voltage Class (kV)	No. of existing S/S	No. of proposed S/S in 2013 – '14	No. of proposed S/S in 2014 – '15	No. of proposed S/S in 2015 – '16	No. of proposed S/S in 2016 – '17	Total No. of S/S by the end of the 12th FYP
765/400	-	1	-	-	2	3
400/220	15	1	1	3	1	21
220/110	42	-	-	4	4	50
220/110/66	-	-	-	-	-	-
220/66	48	2	4	3	10	67
110/33 and 110/11	389	16	22	18	11	456
66/33	7	-	-	-	-	7
66/11	591	14	13	21	18	657

Source: PRDC

Table 16: Proposed Addition of Substations (S/S) by the end of 2021-22

Voltage Class (kV)	No. of existing S/S	No. of proposed S/S in 12th FYP	No. of proposed S/S in 13th FYP	Total No. of S/S by the end of 13th FYP
765/400	-	3	-	3
400/220	15	6	5	27
220/110	42	8	7	56
220/110/66	-	-	1	1
220/66	48	19	5	71
110/33 and 110/11	389	67	23	479
66/33	7	-	0	7
66/11	591	66	55	712

Source: PRDC

The trend in substation augmentation and corresponding investments in the transmission network in the past decade are shown below in Figure 13. The general capital budget for FY2016 is INR 7,746 Lakh (KPTCL, 2015):

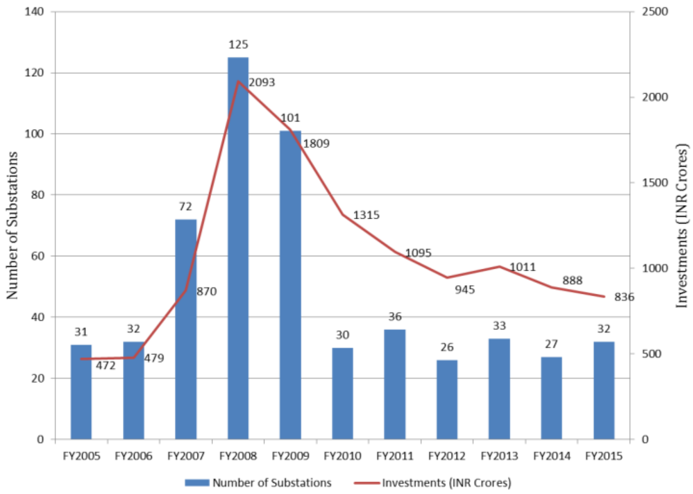

Figure 13: Investments in Transmission Network (FY2005 - FY2015)

An operational case study was also carried out wherein the database for the entire southern grid was simulated for network conditions during a typical peak period with peak demand of 8,459 MW (PRDC, 2013). Based on the observations from the case study, the following strategies can be employed by KPTCL for managing reactive power in the network:

- Initiate load characteristic studies
- Increase minimum Power Factor (PF) for large LT consumers from 0.85 to 0.9 along with heavier penalties for low PF (or incentives for high PF), in line with other states
- Place shunt capacitors in 11 kV distribution networks. This can be initiated by DISCOMs based on studies to reduce losses and improve voltage profiles
- Develop (by KPTCL) suitable reactive power pricing for exchanges at interface points to prevent drawal of reactive power by DISCOMs and to maintain a minimum PF of 0.95 at these points
- Develop (jointly by DISCOMs and KPTCL) maintenance practices with detailed harmonics and equipment failure analyses to ensure reliability of reactive power sources

5.2. Distribution System

The distribution system is often considered to be the weakest link in the Indian power sector for various reasons including the poor financial status of DISCOMs, high Aggregate Technical & Commercial (AT&C) losses, aging infrastructure, etc. Financially, unrecovered dues result in significant financial burdens to ESCOMs. Additionally, it has often been cited that the work culture in the utilities do not have adequate commercial orientation to treat every unit of electricity supplied as sale of electricity for which appropriate price needs to be recovered (Pargal & Banerjee, 2014). The metering is often faulty and the supply is not metered for all categories of consumers. This results in unauthorised use of power and thefts. The utilities are thus caught in a vicious cycle of poor quality of supply, leading to inadequate recovery of cost of service, affecting their ability to incur capital and maintenance expenditure to improve quality of supply.

5.2.1. Potential for Reducing T&D Losses

In Karnataka, there are five DISCOMs which have different levels of losses as shown in Table 17 (KERC, 2014) (KPTCL, 2015).

Table 17: ESCOM-wise T&D Losses (FY2014)

ESCOM	Distribution Losses	T&D Losses[15]
BESCOM	14.5%	18.3%
MESCOM	12.1%	15.9%
CESC	16.2%	20%
HESCOM	19.9%	23.7%
GESCOM	21.7%	25.5%
STATE	**16.8%**	**20.6%**

Source: KERC & KPTCL

If these losses are brought down to 12% by appropriate actions, the resultant savings in terms of energy would be around 4,200 MUs costing about INR 1,470 Crore per year at an Average Power Purchase Cost (APPC) of INR 3.5/ kWh. Also, the annual energy saved is equivalent to generation from a 560 MW thermal power station operating at 85% PLF.

Hence, there is considerable scope for reduction in the T&D losses, and the savings can significantly contribute towards meeting the shortfalls.

[15] By adding 3.8% of Transmission Loss as reported by KPTCL for FY2014

5.2.2. High Voltage Distribution System

In order to reduce AT&C losses in the distribution system, various DISCOMs across the country have adopted HVDS. HVDS has been introduced specially in the rural areas where, often, Low Tension (LT) lines are long due to geographically dispersed loads (including IPs), leading to higher technical losses in the LT line conductors. HVDS has the potential to reduce these technical losses due to reduced current in the lines. Also, illegal tapping of connections in the 11kV HVDS networks is more difficult in the 11kV HVDS networks as compared to LT networks, hence reducing commercial/theft losses. Further, better voltage profiles are obtained at the load centres, especially at the tail-end of the feeders (Dembra & Sharma, 2014).

With the KERC directive of maintaining low LT/HT ratio and AT&C loss reduction, BESCOM has taken up the HVDS projects on a pilot basis. The work in all the pilot feeders is expected to be completed by 2016 (BESCOM, 2015). However, the Measurement and Validation (M&V) of the pilot projects are required, and the outcomes need to be analysed before implementing HVDS at the state level.

Existing methods for load management in rural areas are discussed in Annexure 8.

5.3. Recommendations for Distribution System

Based on the discussions of the issues mentioned above, the main strategies for the distribution sector are identified as follows:

- *Regularly revise tariff (by Regulator) to enable DISCOMs to recover costs:* As seen previously, the share of industrial category in electricity consumption in the state is low, despite the presence of several cement and steel industrial units in the state. This is possibly because of the heavy reliance on captive power due to its higher reliability. Tariffs would need to be rationalized in order to prevent this category of consumers from switching entirely to captive power, thus reducing the revenues recovered by DISCOMs

- *Utilise measures under central financial restructuring schemes:* The financial restructuring measures recommended under the central UDAY scheme needs to be suitably implemented to clear accumulated losses and arrears of unrecoverable dues from consumers from DISCOMs' balance sheets.

- Replace electro mechanical energy meters with high precision meters with data storage and retrieval facilities

- *Conduct periodic DTC level energy auditing to reduce losses:* It is recommended to introduce accountability systems for recovery of charges for power supplied on each feeder/DTC based on energy audit of feeder/DTC level metering.

- *Mandate daily monitoring of feeder-wise power quality parameters:* Penalties for non-compliance of prescribed quality parameters can be imposed in calculating consumer tariff. Improved service reliability along with access will in turn increase adoption of electricity by households.

- Introduce HVDS in areas with high AT&C losses to reduce them to below 10%, based on outcomes from initial pilots.

- Introduce feeder separation across all districts, in a phased manner, to accurately account for agricultural consumption. Impact of feeder separation should also be measured
- Permit limited short time open access during periods of load shedding
- Implement reactive power compensation measures at the distribution end so that the transmission network is not overloaded

6. Renewable Energy

In this section, we discuss the main barriers to achieving capacity addition of grid-connected RE in the state, as well as uptake of DRE options in regions with inadequate energy access. Key strategies for harnessing the abundant RE potential in the State are identified.

6.1. Grid-connected Renewable Energy

Karnataka is blessed with a high RE potential of about 30,000 MW. A large part of it is from wind and solar. The status of the capacity that has been allotted, commissioned and cancelled by KREDL is shown in Table 18 (KREDL, 2015).

Table 18: Status of Grid-Connected RE Capacity in Karnataka (FY2015)

Status of Capacity	Wind Capacity (MW)[16]	Grid-connected Solar Capacity (MW)[17]
Allotted	13,244	1,100
Commissioned	2,686	101
Cancelled	2,623	70
Balance Allotted Capacity to be Commissioned	7,935	929

Source: KREDL

The potential of biomass is estimated to be about 2,500 MW. The state has over 100 MW of biomass capacity installed. However, a majority of it is non-operational due to the inability to secure the supply chain of biomass sources like rice husk which have alternate uses in other industries, and uneconomical tariffs (Sudhakar, Ramamurthi, & Sharma, 2014)

For RE projects in general, there are issues in implementation of the single window clearance mechanism, and availability of revenue land. Difficulties are also faced in obtaining right-of-way clearances for connecting RE project sites to the nearest grid infrastructure.

In addition to capacity, there needs to be adequate planning for ensuring transmission capacity to evacuate and absorb the intermittent and variable power generated from wind and solar. If there is inadequate transmission capacity, generated power can go unutilized. Also, crucial to increasing the share of RE in the energy portfolio are back-up mechanisms for integrating intermittent RE power into the grid. Options like gas-based and pumped hydro storage plants, if incentivised suitably can be ramped up quickly when required.

If the issues mentioned above are addressed, up to 10,000 MW/ 17,250 MUs of wind generation capacity, can be added at a cost of INR 60,000 Crore by FY2020. Similarly, up to 4,000 MW/ 6,300 MUs of solar capacity can be added by FY2020 at a cost of INR 32,000 Crore[18].

6.1.1. Recommendations for Rapid Grid-Connected RE Capacity Addition

- *Implement single window clearance:* The RE Policy 2009-14 mentions the role of KREDL as a single window clearance agency. However, there is no grievance redress mechanism for the stakeholders. KREDL should strengthen inter-departmental coordination for effective implementation of the mechanism

- *Revive Biomass industry:* The sector can be rejuvenated by formulating a small-scale biomass policy. This can include a district-wise biomass resource survey to identify

[16] As of July 2015
[17] As of May 2015
[18] Assumed capital costs of Rs. 6 Crores/MW and Rs. 8 Crores/MW for wind and solar respectively

opportunities for small scale plants, and mechanisms for leasing small holdings of revenue wasteland for the growth of captive feedstock plantations.

- *Design suitable capital subsidy for repowering of wind farms:* Some of the high potential sites in the state are currently under-utilised due to installation of low-capacity turbines at lower hub heights. The state can develop a roadmap for repowering these sites by identifying the incremental capital or tariff support required for making it economically feasible to replace older turbines

- *Streamline project land allocation process:* Several wind projects in the State face a land squatting problem. Projects that are cancelled should be reallocated on a priority basis. Generation of government-owned resource data can enable competitive mechanisms for allocating the resource efficiently

- *Strengthen grid infrastructure:* For enabling better power evacuation KPTCL should also make a long-term transmission plan for the state, in alignment with the National Green Energy Corridor Plan (PGCIL, 2012). This will strengthen the grid between RE rich zones and urban load centres and avoid congestion in the future

- Establish a *Renewable Energy Management Center* to manage increasing share from renewables in the energy mix

- *Encourage optimal utilisation of pumped hydro storage:* The potential for pumped hydro storage should be estimated in existing and new hydro-electric projects. Potential projects should be suitably incentivised to meet the peaking requirements of the grid and balancing of intermittency from renewables

- Study complementarity of generation from sources like wind and solar in greater detail (by SLDC's) to schedule the sources optimally and evaluate feasibility of wind-solar hybrid projects

- Invest in state of the art forecasting techniques to ensure that wind patterns can be predicted to a manageable extent.

6.2. Decentralised Renewable Energy (DRE)

To enable a 24x7 power supply, there will be an enormous pressure on the central generation capacity to increase substantially and which will require high level of investments, longer gestation periods, and may adversely impact the environment. In extremely remote areas and hilly terrains, the cost of extending the central grid is substantially high (Nouni, Mullick, & Kandpal, 2008). Additionally, in small towns, unreliable supply has led to the decline of small and medium enterprises and has added up their costs owing to the use of alternatives for backup power including diesel generators (Pargal & Banerjee, 2014). At this juncture DRE solutions can play an important role in offsetting some of these generation requirements. Some additional benefits of DRE solutions include reduction in T&D losses and reduction in load from industrial category (through captive generation). They can also reduce peak demand from domestic category due to localised generation and consumption, and promote micro-industries and livelihood activities.

6.2.1. DRE Recommendations

The current off-grid schemes under DDG[19] and the Jawaharlal Nehru National Solar Mission (JNNSM) have not been operationalised successfully due to multiple reasons like inflexible scheme design (promoting only one type of technology design), unattractive payment terms, complex ownership models (Build Operate Maintain Transfer with no local stakeholder ownership in DDG) and lags in subsidy disbursal (Sudhakar, Ramamurthi, & Sharma, 2014). Most off-grid deployment has been carried out by the private sector and voluntary organisations. Details of projects sanctioned under the off-grid solar applications of JNNSM during 2014-15 are given in Table 19.

Table 19: Off-grid Projects Sanctioned under JNNSM (FY2015)[20]

Technology	Sanctioned MNRE CFA (Lakhs)	Released MNRE CFA (Crores)	Capacity (kWp)
Solar Pumps	7,268	0	20,784
Solar Power Plants	250	0	150
Power Plants	400	0	500
Solar Charging Station	1,358	0	244

Source: MNRE

As is evident from the figures above, there is a general time lag in the disbursement of the subsidies from the National Bank for Agricultural and Rural Development (NABARD) to the regional rural banks (RRBs) across the country, thus gradually dis-incentivising financing for solar and other DRE technologies. In this context, the following are major recommendations to enable DRE options as long-term solutions for electricity access. They can be divided into two categories of regulatory and ecosystem enablers:

Regulatory Measures

- *Encourage solar pumps to reduce rural morning peak:* Existing schemes should be retrofitted to ensure the uptake of solar pumps by a majority of farmers by designing a proper incentive system. As illustrated in Annexure 5: , rural feeders are active mainly at night. As maximum power outages occur between 12 am - 6 am, IPs are operated during the night, which may result in inefficient use of power supplied. Installing solar IPs can lead to increased availability of constant power supply throughout the day with corresponding increase in productivity.

  The initial cost of installation of solar IPs might be high, and hence there is a need for designing proper schemes and policies to incentivise their uptake. A brief economic analysis of installing solar IPs is presented in Annexure 9.

- *Provide VAT relief for RE devices and spare parts (and GST relief in the future):* VAT has been levied on solar products and spare parts along with subsidies for solar products. A relief mechanism of 5.5% VAT (Goods and Services Tax (GST) relief once it is in place) on RE devices and 14.5% on spare parts can make the systems affordable for the end users. Otherwise the effective subsidy is reduced to less than 25% which becomes a barrier for

[19] DDG Projects have not been operationalized in Karnataka even after KREDL has invited tenders for the same due to the reasons mentioned above.
[20] As on 31.08.2014

poor households to purchase the system.[21] In this case the State can create an extra incentive for poor customers to support them in buying the systems.

The Government of Karnataka (GoK) recently announced VAT relief on Solar PV panels and Solar inverters which is a welcome step towards making solar technology more affordable for rural households (GoK, 2015)[22]. This can be supplemented with VAT exemption as well as exemption from GST (if introduced in the future), as mentioned above.

- *Encourage roof-top solar and grid feed-in from urban areas:* In urban areas, rooftop solar with grid integration can encourage self-consumption and reduce peak demand on the grid. By providing assured premium Feed in Tariffs (FiTs) on a long term to residential consumers, their deployment can be materialised.

- *Incentivise adoption of DRE by moving towards FiTs and short-term PPAs for small developers:* For commercial establishments (with mainly lighting loads and high tariff rates), solar can be an optimal solution in terms of cost. Most of the evening peak can be shaved through adoption of DRE technologies (Pecan Street Inc., 2013).

- *Provide clarity regarding building by-laws to suit large scale deployment of rooftop PV:* A large-scale deployment of solar rooftop plants requires necessary amendments in the building by-laws in consultation with Housing and Urban Planning department.

- *Recognise decentralised solar plants as an industry:* All solar plants can be treated as industry under the schemes of State Industrial Department within the Draft Model Solar Policy for states (GoI, 2015). This will incentivise developers, and provide legal recognition to micro-grid installations in case of grid extension.

- *Use DRE (micro grids and solar home energy systems) as an alternative to Bhagya Jyothi (BJ):* The existing BJ scheme can be effectively implemented with a one-time investment in solar home systems/micro grids rather than having to spend on subsidised power. Even though the scheme provision is for a single light bulb, there is no mechanism to ensure limiting of the load and monitoring of consumption. The State is spending recurring costs on this scheme while ownership of other appliances like fans, television sets, etc. has increased[23], which may result in reduced revenues for the State. Annexure 9 shows a comparative cost-benefit analysis of the BJ scheme for 2012-13 with solar home systems. Replacement with solar-based micro grids and home systems can be executed on a pilot basis, in districts with low electrification rates i.e. Yadgir (78%), Bijapur (81%), Kodagu (82%) and Belgaum (84%).

[21] Internal SELCO analysis
[22] Order No. FD 71 CSL 2015, dated 3rd August, 2015.
[23] Interview with the staff of a solar company.

Measures for Creation of an Enabling Ecosystem for Promoting DRE

- *Develop a comprehensive RE plan for the state with specific targets for DRE:* A dedicated RE plan can be formulated with a targeted approach for DRE systems, with adequate flexibility in terms of technologies and business models. A dedicated RE fund can be created for implementation.

- *Evaluate hybrid systems for micro and small-scale industries*[24]*:* These systems can be used for providing reliable power supply for micro and small-scale industries to substitute some of their load requirements while simultaneously reducing costs for back-up power. DRE solutions coupled with measures for promoting EE can be designed for micro and cottage industries in rural areas and can act as an anchor load for promoting electrification.

- *Conduct electricity access mapping:* For effective planning of DRE systems at taluk and village levels, data on existing household access and public amenities should be made available. This can be implemented by Gram Panchayats, with the expertise of Panchayat Development Officers.

- *Create a support group at the state level:* For effective policy formulation and implementation, a stakeholder body can be formed at the state level. It can include members from relevant government departments, policy research organizations, academia and practitioners.

- *Develop a skilled workforce to handle maintenance of DRE technologies:* Courses can be conducted by the ESCOMs through the Industrial Training Institutes (ITIs) to train electricians and technicians for maintaining DRE technologies; they can in turn also operate as "Renewable Energy Technicians" and service and maintain the off-grid systems in their communities. Presence of trained personnel would also lead to growth of RE enterprises.

[24] A hybrid system can use a combination of technologies as per the site-specific availability. It can create an opportunity to optimize the power generated, by utilizing the inherent complementarity between generation patterns from sources such as small wind and solar PV. An additional example is the use of solar PV in combination with biomass in order to offset the intermittency and reduce the average cost from solar based generation.

7. Energy Efficiency

In this section we discuss measures for EE that can be implemented by the State, i.e. efficiency in end-use consumption across appliances, lighting, and IPs. Some of them are evaluated using an integrated energy modelling suite – The Integrated MARKAL EFOM System (TIMES). [25]

7.1. Agricultural Demand-side Management (Ag DSM)

The potential of energy savings from efficient pumping is gradually being recognised in different parts of Karnataka. For instance, in the HESCOM region, 590 pump sets were replaced under Ag DSM leading to 37% electricity savings. In Mysuru, a program to replace over 1,000 IPs is being carried out (EESL, 2015). In Dodaballapur, 280 IPs were replaced, along with feeder separation, metering and HVDS lines for electricity supply. Further, efficient irrigation practices, including drip irrigation, construction of field bunds and check dams were employed. Also, farmers' awareness regarding cropping patterns and cultivation practices was increased. These measures achieved savings in the range of 30 – 70% (Chaturvedi, Goyal, & Meshram, 2011). Because of massive savings in electricity and subsidies for irrigation pumping, the State should actively initiate mitigating challenges identified in implementation of Ag DSM projects.

Solar IPs (SIPs) also provide an opportunity for farmers to obtain reliable access to electricity by reducing their dependence on grid. If all inefficient pump sets are replaced with efficient electric IPs and SIPs[26], then about 5,000 MUs of electricity generation can be avoided in 2030. This would also lead to reduced demand for coal, lower the subsidy bill on electricity, and avoid 4 million tonnes of Green House Gas (GHG) emissions from the power sector.

Karnataka's new solar pump promotion scheme, Surya Raitha, offers guaranteed buy back of surplus solar power from farmers owning the pump sets at attractive FiTs. Effective implementation of the scheme can accomplish multiple objectives, namely: improved rural livelihoods, conservation of groundwater through a built-in incentive for economised water usage, enhanced quality of irrigation due to reliable supply, reduced carbon footprint, improved financial health of utilities through reduced farmer subsidies, and reduction in T&D losses through local generation (Shah, Verma, & Durga, 2014).

Surya Raitha gives priority to farmers without grid connection for allocating subsidised SIPs. However, it can broaden the uptake to include farmers who are willing to replace their grid connections with SIPs as it is in the long-term interest of improving DISCOM finances by reducing farmer subsidy shares. Also, implementation would have to ensure tamper-proof net metering and periodic auditing of sales (Shah, Verma, & Durga, 2014).

The pumps modeled in this study are 3-star, 5-star and SIPs. The life and Unit Electricity Consumption (UEC) of each appliance is based on data published by the Bureau of Energy Efficiency (BEE). The approximate costs have been determined based on online and telephonic surveys.

In the BAU scenario, it is assumed that about 50% of electrical IPs in use over a long term (by 2030) are rated as 5-star, and 5% of pump sets are run on solar power. A more aggressive target can be exercised as an option, where 100% of all electric IPs are rated 5-star, and 10% of pump sets are run on solar power. Based on the data and assumptions mentioned above, it is estimated that this option can be achieved at a cost of INR 200 Crore, with an energy saving of 1, 440 MUs and avoided capacity of 33 MW by 2020.

[25] The model is used to provide a consistent framework to analyse decisions, with their systemic effects across sectors. The savings in electricity generation, capacity addition, and electricity demand are measured by comparing an Energy-Efficient scenario with a Business As Usual (BAU) scenario, which captures inherent improvements in efficiency.

[26] Solar pump sets are assumed to constitute 10 per cent of the total pump sets in 2030

7.2. Energy Efficiency in Appliances

Karnataka's RE Policy 2009-14 envisages various programmes in DSM for improving EE in the residential and commercial sector.[27] The appliances modelled for this study include lighting, fans, refrigerators, Television (TV) sets, and Air Conditioners (ACs) (Annexure 10). Data includes appliance cost, UEC, and life of the appliance. The life and UEC of each appliance is based on data published by BEE. Approximate costs are based on online and telephonic surveys.

Efficiency-wise shares of various appliances in 2010 are not available. Based on sales of appliances over the last few years assumptions are made on penetration of high efficiency appliances. They vary between 0 and 20% for the base year.

In the BAU scenario, it is assumed that close to 40 to 50% of appliances is 5-star, with a negligible penetration of super-efficient appliances.

In the case of uptake of improved efficiency measures, it is assumed that the State will successfully tap opportunities for improving efficiencies. Initiatives for DSM and EE in buildings result in a high penetration of 5-star and super-efficient appliances. It is assumed that about 40-50% of the demand for lighting in residential and commercial sector is met by using Light Emitting Diode (LED) bulbs and tube lights, while Compact Fluorescent Lamps (CFLs) meet the remaining demand. The contribution of 5-star and super-efficient fans to ventilation demand increases to about 40% each. Cathods Ray Tube (CRT) and Liquid Crystal Display (LCD) TVs are completely replaced by LED TVs by 2030, reducing electricity demand for entertainment. Efficient refrigerators are assumed to constitute about 80% of the total stock by 2030, and the penetration of 5-star ACs increases to about 60% in the residential sector and 80% in the commercial sector.

Based on the data and assumptions mentioned above, the EE scenario can be achieved in the long-term at a cost of INR 1,260 Crore, with an energy saving of 1,100 MUs and avoided capacity of 25 MW by 2020.

7.3. Energy Efficiency in Lighting

Within lighting, technologies for both point and linear lighting are incorporated.

In the BAU scenario, it is assumed that close to 80% of lighting devices are comprised of CFL and 5-star tube lights, with negligible penetration of LED lighting.

In the case of uptake of improved efficiency measures, it is assumed that the State will successfully tap into opportunities for improving efficiencies. In this scenario, the penetration of CFLs and 5-star tube lights increases to about 50%. Based on the above assumption, it would cost INR 1,030 Crore to achieve this option, with savings of about 4,700 MUs and 11 MW by 2020.

Street lighting in India is believed to be generally inefficient because of usage of inefficient luminaries, poor design, and poor power quality (Johnson, Phadke, & Can, 2014). As street lights are used for nearly 4,000 hours in a year, efficient technologies present significant scope for energy savings. Various technologies for street lighting are presented in Annexure 10.

[27] These include high efficiency lighting programmes using LEDs in the residential sector, commercial high efficiency lighting through LEDs and solar lamps, solar water heating, EE implementation in public buildings through ESCOMs, EE improvement in SMEs, EE in municipal street lighting, and implementation of the green buildings programme.

7.4. Recommendations for Improving Energy Efficiency

- *Incentivise adoption of EE appliances:* Increased uptake of efficient appliances benefits the consumer benefit through reduction in electricity bills. In the residential sector, the state could incentivise efficient appliances to reduce their higher upfront costs through appropriate financing mechanisms, such as loans and rebates.

- *Establish and operationalise a State Clean Energy Fund (SCEF):* This can be used as one approach to facilitate some of the financing mechanisms mentioned above. KERC has recently released a draft DSM Regulation (KERC, 2015), which proposes the setting up of a State Energy Conservation Fund.[28] It is proposed that this fund may be matched by an equivalent capital subsidy from GoK through a budgetary provision. This fund can also be used by the ESCOMs for load management and energy conservation.

- *Scale up DSM pilots:* Improvements in EE initiatives should be measured by comparing with current consumption levels along with establishment of M&V protocols. Initial investment and associated risk should be mitigated through appropriate mechanisms. This can be facilitated through setting up of an Ag DSM Revolving Fund.

- *Time of Use (ToU) pricing:* Time-based pricing for domestic consumers should be implemented in ESCOMs with high morning and evening peak loads. This could help to smoothen the load curve by redistributing peak demand across the day. The impact of ToU pricing on consumption patterns should be measured in parallel

[28] The fund will be collected through an additional 'energy efficiency charge', which will be levied on consumers except agricultural and residential.

8. Strategies for Achieving 24x7 Power Supply

As per the current plans for capacity addition, it is expected that there would be an incremental conventional capacity of 6,034 MW that will be added by FY2020, from large hydro and thermal sources. This would result in a conventional installed capacity of 17,571 MW by FY2020. There are plans to also add 4,315 MW of renewable capacity, resulting in a total renewable installed capacity of 8,347 MW by FY2020.

There is an unrestricted energy demand of 1,12,675 MUs expected in FY2020, with a continued shortage situation anticipated till FY2019 (with current plans for capacity addition). However, there would be a net reduction in the demand, if measures for increased demand-side efficiency are taken up as discussed in the previous section. Demand-side savings of up to 7,240 MUs is achievable from successful implementation of EE programmes in lighting, appliances, and pumping (Ag DSM). Generation from existing capacity and short-term power purchases currently amount to about 78,500 MUs. If the assumed capacity factors that are considered for estimating the current generation are applied to the incremental capacity addition that is planned till FY2020, then the incremental generation from various sources would be as follows. Based on the current unit cost of generation for the various sources, it would imply an incremental investment of approximately INR 15,000 Crore by FY2020 (Table 20).

Table 20: Costs of Incremental Capacity Addition by FY2020[29]

Fuel Type	Annual Average Capacity Factor (%)	Incremental Capacity added by 2020 as per current plans (MW)	Generation (MUs)	Per unit cost of generation (INR/kWh) (FY2015)	Incremental Cost by 2020 (INR Crore)
Large Hydro	40%	302	1,058	0.59	62
State Coal	64%	2,390	13,400	3.73	4,998
IPP Thermal	70%	320[30]	1,962	4.14	812
CGS	80%	2,182	15,291	2.96	4,526
Gas	40%	840	2,943	3.73	1,098
RE	26%	4,315	9,827	3.52	3,459
Total		**7,534**	**35,975**		**14,956**

Additionally, there is a cost of about INR 2,490 Crore from implementing the demand-side efficiency measures, resulting in a total cost of INR 17,446 Crore by 2020. Using the ratio of investment costs of 2:1:1 (Generation: Transmission: Distribution), the corresponding costs for the Transmission and Distribution sectors are INR 7,478 Crore each, resulting in a total cost of INR 32,402 Crore for the power sector.

[29] For FY2015 at current costs
[30] From UMPPs

8.1. Key Strategies

Below is a summary of the specific strategies that need to be implemented by the State in the Generation, Demand and T&D sectors in order to achieve 24x7 power supply for all by FY2020:

8.1.1. Generation

8.1.1.1. Performance of state-owned thermal plants

- Analyse cost benefit of washed vs. unwashed coal; re-negotiate supply contracts accordingly
- Estimate the need for refurbishment and modernisation of thermal plants
- Identify potential and make arrangements for mining coal in captive mines

8.1.1.2. Rapid RE capacity addition

- Implement single window clearance
- Revive biomass industry
- Design capital subsidy for repowering of wind farms
- Streamline project land allocation
- Strengthen grid infrastructure
- Establish a Renewable Energy Management Center
- Incentivise utilisation of pumped hydro storage in existing and new hydro-electric projects

8.1.1.3. Decentralised RE

- Develop a comprehensive RE plan for the state with specific targets for DRE
- Evaluate hybrid systems for micro and small-scale industries
- Conduct electricity access mapping
- Create a support group at the state level with involvement of relevant stakeholders
- Develop skilled workforce to handle maintenance of DRE technologies
- Strongly encourage solar pumps to reduce morning rural peak
- Provide VAT relief for RE devices and spare parts (and GST relief in the future)
- Encourage rooftop solar and grid feed-in from urban areas
- Incentivise adoption of RE by moving towards FiTs, short-term PPAs for small developers
- Provide clarity regarding building by-laws for large scale deployment of rooftop PV systems
- Recognise decentralised solar plants as an industry[31]
- Use micro grids and solar home energy systems as an alternative to the BJ scheme

8.1.1.4. Long-term power purchase and stranded capacity utilisation

- Bring captive plants that are lying idle during peak time under long-term PPAs
- Contract exported volumes under long-term PPAs
- Re-initiate the tendering route for long-term power procurement of power from IPPs
- Obtain clearances required for making new coal blocks operational through SPVs
- Mandate load flow analysis for demand forecasting
- Identify high-congestion corridors and augment transmission capacity to avoid generated power from being unutilised
- Measure utilities' performance on parameters involving interventions that facilitate use of stranded capacity

[31] Draft solar policy, MNRE

8.1.2. Demand-Side

- Incentivise EE appliances with appropriate financing mechanisms, operationalised through establishment of a State Clean Energy Fund
- Scale-up DSM pilots with establishment of M&V protocols to measure savings, and an Ag DSM Revolving Fund to mitigate investment risks
- Implement ToU pricing in ESCOMs with high morning and evening peaks

8.1.3. Transmission & Distribution

- Utilise measures under central financial restructuring schemes such as UDAY
- Replace electro mechanical energy meters with high precision meters with data storage and retrieval facilities
- Conduct periodic DTC level energy auditing to reduce losses
- Mandate daily monitoring of feeder-wise power quality parameters
- Introduce HVDS in areas with high AT&C losses to reduce them to below 10%
- Introduce feeder separation across all districts in a phased manner, with measurement of its impact in parallel
- Permit limited short time open access during periods of load shedding
- Implement reactive power compensation measures at the distribution end so that the transmission network is not overloaded

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Annexure 1: Detailed List of Generating Stations (FY2015)

Table 21 presents the detailed source-wise list of generating stations in Karnataka for FY2015:

Table 21: Detailed List of Generating Stations in Karnataka (FY2015)

S. No.	Power Stations	Units x MW	Installed capacity (in MW)
	I. KPCL Power Generation Projects		
A. HYDRO PROJECTS			
	Cauvery River Basin		
1	Sir Sheshadri Iyer Hydro Electric Station (Shivanasamudram)	4x6	42
		6x3	
2	Shimsha Hydro Electric Station	2x8.6	17.2
		Total	**59**
	Sharavathy valley Project		
3	Linganamakki Dam Power House	2 x 27.5	55
4	Mahathma Gandhi Hydro Electric Station	4x21.6	139.2
		4x13.2	
5	Sharavathi Generating Station	10 x 103.5	1,035
		Total	**1,229**
	Gerusoppa Hydro Electric Project		
6	Gerusoppa Dam Powerhouse	4 x 60	240
	Kali Hydro Electric Project		
7	Supa Dam Powerhouse	2x50	100
8	Nagjari Powerhouse	5x150+1x135	885
9	Kadra Dam Powerhouse : 3 x 50 =150	3 x 50	150
10	Kodasalli Dam Powerhouse : 3 x 40=120	3 x 40	120
		Total	**1,255**
	Varahi Hydro Electric Project		
11	Mani Dam Powerhouse	2x4.5	9
12	Varahi UGPH :4 x 115 =460	4 x 115	460
		Total	**469**
	Krishna Basin Project		
13	Almatti Dam Power House	1X15	290
		5x55	
	Mini Hydro Electric Project		
	Bhadra Project		
14	Bhadra Right Bank Canal Powerhouse	1x7.2	13.2
		1x6	
15	Bhadra Left Bank Canal Powerhouse	2 x12	26
		1x2	
16	Munirabad Power House(Thunga Bhadra Basin)	2x9	28
		1x10	
17	Ghataprabha Dam Powerhouse	2 x 16	32
18	Mallapur Mini Hydel Scheme	2x4.5	9
19	Sirwar Mini Hydel Scheme	1x1	1
20	Kalmala Mini Hydel Scheme	1 x 0.40	0.4

21	Ganekal Mini Hydel Scheme	1 x 0.35	0.35
		Total	**110**
	Total Hydro		**3,652**
B. COAL BASED THERMAL POWER STATIONS			
22	Raichur Thermal Power Station 1 to 7 Unit	7 x 210	1,470
23	Raichur Thermal Power Station Unit-8	1x250	250
24	Bellary Thermal Power Station Unit-I	1x500	500
25	Bellary Thermal Power Station- Unit-II	1x500	500
	Total Thermal		**2,720**
C. DIESEL GENERATION STATION			
26	Yelahanka Diesel Generating Station	6x18	108
D. WIND POWER STATION			
27	Kappadagudda Wind Farm	0.225 +11x0.230	4.56
E. SOLAR ENERGY			
28	Yelesandra Solar PV Plant, Kolar Dist		3
29	Itnal Solar PV Plant, Belgaum District		3
30	Yapaldinni Solar PV Plant, Raichur District		3
31	Simsha Solar PV Plant, Shimshapur, Mandya District		5
	Sub Total Solar		**14**
	KPCL Project TOTAL		**6,499**
II. IPP Projects			
A. HYDRO PROJECTS			
1	Mini Hydel Projects		702.6
B. COAL BASED THERMAL POWER STATIONS			
1	UPCL	2 x 600	1,200
2	Jindal (Coal and COREX)	2 x 130 + 4 x 300	1,460
	Sub Total		**2,660**
C. DIESEL GENERATION STATION			
1	Tata Electric	5x16.26	81.3
2	Rayalseema Alkalies	3x12	27.2
3	ITPL	9	9
	Sub Total		**117**
D. WIND/SOLAR/OTHERS			
1	Wind mill & Solar		2,157.9
2	Co-Generation		952.66
3	Bio-Mass		88.5
	Sub Total		**3,199**
	IPP Project Total		**6,679**
III. Karnataka's Share from Interstate Hydro Generating Station			
1	TB Dam Share (20%)	8x9	15
2	Priyadarshini Jurala Hydro Project (50%)	6x39.1	117
	Sub Total		**132**

IV. Karnataka's Share from Central Generating Station			
Sl.No	**Power Stations**	**Units x MW**	**Karnataka's share of Installed capacity (MW)**
A. Coal based Thermal Power Stations of M/s. NTPC			
1	Ramagundam TPS	3x200+4x500	513.8
2	Talcher Stg-II	4x500	382.8
3	Simhadri Stg-II	2x500	210.7
4	Vallur TPS	3x500	129.7
	Sub Total		**1,237**
B. Lignite based Thermal Power Stations of M/s. NLC			
5	Neyveli-II-NLC	7x210	301.2
6	Neyveli TPS-I	2x210	108.1
7	Neyveli TPS-II	2x250	109.9
	Sub Total		**519**
C. Nuclear Power Generating Stations of M/s. NPCIL			
8	MAPS	2x220	31.9
9	Kaiga	4x220	248.4
10	Kudankulam	1x1000	221
	Sub Total		**501.4**
		Sub Total of CGS	**2,257.6**
	GRAND TOTAL		**15,568**

Source: PCKL

Annexure 2: Month-wise Short Term Purchases in FY2015

Table 22 presents the month-wise short term power purchases made by the State in FY2015, through exchanges and bilateral transactions:

Table 22: Month-wise Short-term Power Purchases in Karnataka (FY2015)

Month	Energy purchased (MUs)	Average Rate (INR/kWh)	Approximate Amount (INR Crore) (including open access)
Apr-14	942	5.40	508
May-14	447	5.30	237
Jun-14	396	5.31	211
Jul-14	262	5.10	134
Aug-14	264	5.08	134
Sep-14	271	5.11	138
Oct-14	384	5.13	197
Nov-14	417	5.16	215
Dec-14	633	5.28	334
Jan-15	652	5.27	343
Feb-15	578	5.25	304
Mar-15	622	5.22	325
TOTAL	**5,868**	**5.25**	**3,080**

Source: KERC

The maximum short-term power purchased was in April 2014. In terms of peak demand observed, this is also among the months when the peak demand requirement was also high.

Annexure 3: Month-wise Power Supply Position in FY2015

Table 23 presents the month-wise power supply position in the state in FY2015 in terms of peak demand.

Table 23: Month-wise Power Supply Position during FY2015 (in terms of peak demand) (MW)

Month	Requirement (MW)	Availability (MW)	Surplus(+) /Deficit(-) (MW)	Surplus(+) /Deficit(-) (%)
Apr-14	**10,001**	9,503	-498	-5%
May-14	9,285	8,499	-786	-8.5%
Jun-14	9,388	8,261	-1,127	**-12%**
Jul-14	8,953	8,137	-816	-9.1%
Aug-14	8,433	7,878	-555	-6.6%
Sep-14	8,300	7,973	-327	-3.9%
Oct-14	8,352	7,574	-778	-9.3%
Nov-14	8,818	7,955	-863	-9.8%
Dec-14	9,410	8,967	-443	-4.7%
Jan-15	9,825	9,175	-650	-6.6%
Feb-15	9,810	9,349	-461	-4.7%
Mar-15	9,889	**9,549**	-340	-3.4%
Annual Peak Shortfall	**4.5%**			

Source: KERC

The highest peak demand occurred in April, 2014, at a requirement of 10,000 MW, while the maximum shortfall was observed in June 2014, at 12%. The maximum peak supplied, i.e. 9,549 MW supplied in March, 2015 was not in the month of the occurrence of the highest peak demand. The overall peak shortfall in the year, estimated as a difference between the maximum peak demand observed and maximum peak supplied, was 4.5%.

Annexure 4: Methodology for Demand Estimation

The methodology used by CEA for estimating the demand for the various consumer categories is briefly summarised below:

- Domestic: Consumption has been estimated on the basis of number of electricity consumers and their specific electrical energy consumption

- Commercial: Consumption has been estimated on the basis of number of electricity consumers and their specific electrical energy consumption

- Public lighting and water works: Consumption is based on connected electric load and average electricity consumption per kW of connected electric load

- Irrigation: Consumption is estimated based on the number of irrigation pump-sets, average capacity of pump-sets, and average electricity consumption per year per kW of connected electric load, during particular hours of operation

- Industry: Consumption is estimated based on a combination of past trends and plans for development in the next two plan periods (12^{th} and 13^{th}). Higher weightage has been given to LT industries to cope with overall infrastructural development

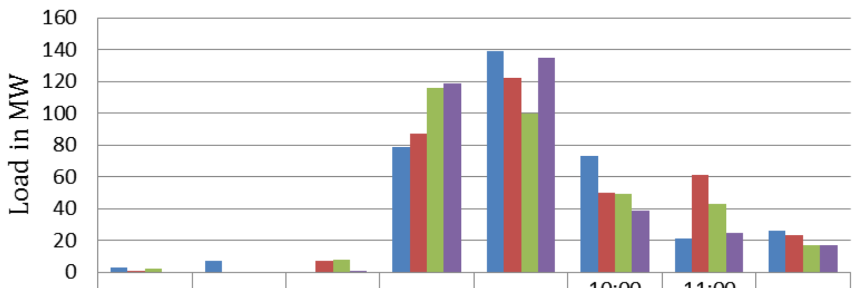
- Railway traction: Estimates are based on the requirement of existing railway tracks and plans for track electrification by the Railway Board

- Bulk non-industrial HT supply: Estimates include end-use in research establishments, institutions, hospitals, ports, military establishments, power projects etc.

Annexure 5: Analysis of SCADA Data

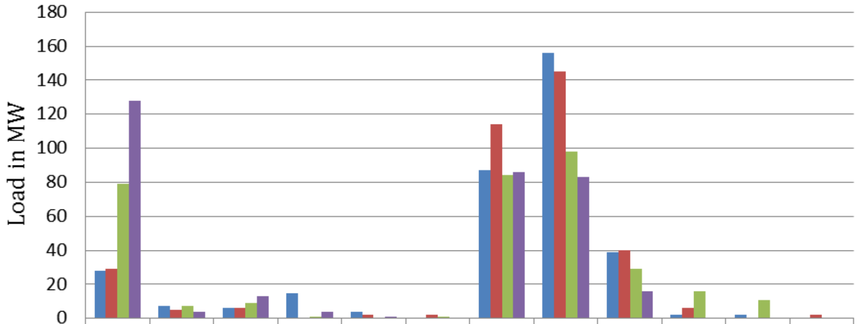
The frequency distribution of morning and evening peak load frequencies during 2011, 2012, 2013, and 2014 are illustrated in Figure 14 [32].

Morning Peak Frequencies



	1:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12 noon
2011	3	7	0	79	139	73	21	26
2012	1	0	7	87	122	50	61	23
2013	2	0	8	116	100	49	43	17
2014	0	0	1	119	135	39	25	17

Evening Peak Frequencies



	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	12 midnight
2011	28	7	6	15	4	0	87	156	39	2	2	0
2012	29	5	6	0	2	2	114	145	40	6	0	2
2013	79	7	9	1	0	1	84	98	29	16	11	0
2014	128	4	13	4	1	0	86	83	16	0	0	0

Figure 14: Frequencies of observed morning and evening peaks (2014)

Most of the peak load lies between 6 am to 10 am, and between 6 pm to 10 pm. There is thus scope for implementing demand-side measures through options such as time-of-use pricing in order to reduce the peak loads in these periods.

The load duration curves provide a representation of the ordered load curves for the years 2011–14, as shown in Figure 15.

[32] Peak load data was analysed for daily load curves published by KPTCL for the years 2011, 2012, 2013 and 2014 (until 23rd Nov, 2014)

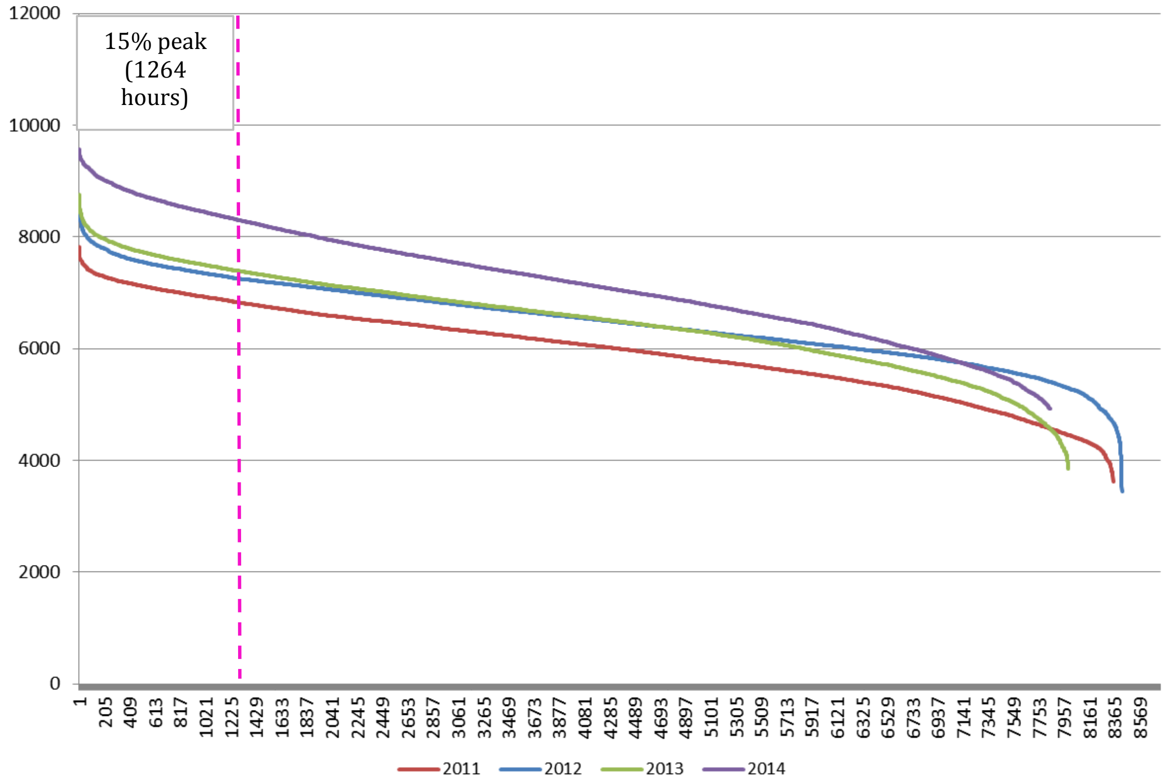


Figure 15: Load Duration Curves (2011-2014)

As can be observed, the rate of growth of peak demand is higher than the average demand throughout the year.

Seasonal Variation

Across various seasons of monsoon, spring, winter and summer, there is a large variation in the power consumed. The peak demand plotted on a monthly basis illustrates the seasonal variations in demand (Figure 16). A peak in the summer months, between February and May is consistently observed during the three years. Any ambitious targets from intermittent RE sources such as wind and solar will have to take into account the seasonal variations in their capacity utilisation factors in order to plan for meeting the seasonal peaks.

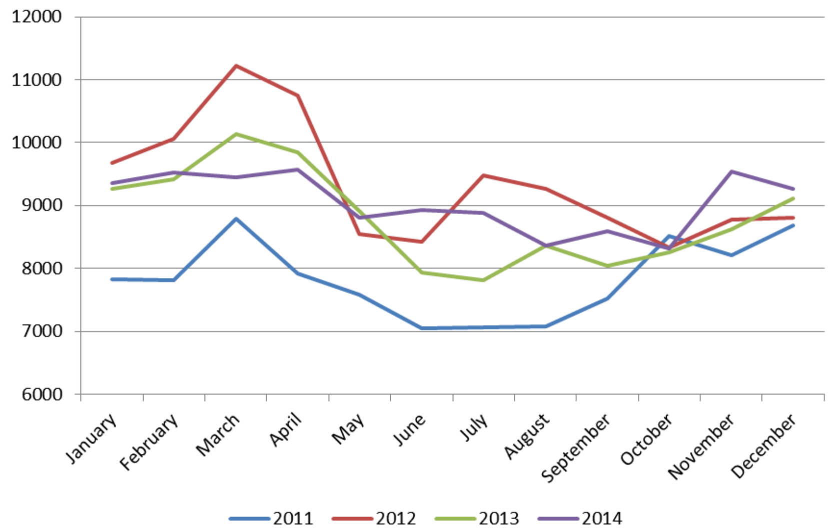


Figure 16: Monthly Peak Load (2011-2014)

An assessment of seasonal variation in rural feeders was conducted using feeder-level data (SCADA data from ESCOMs). Considering that the major contributors to the rural loads are IPs, it is not surprising to see that the maximum amount of power being consumed is during the summer months, when the farmers are heavily dependent on pump sets for irrigation. Further, during the months of June and July, the power consumption reduces by more than 50% when the monsoons are the source of water. But even with large variation in seasonal power consumption, the daily trend is relatively flat, with occasional peaks recorded between 12 am to 6 am (Figure 17 and Figure 18).

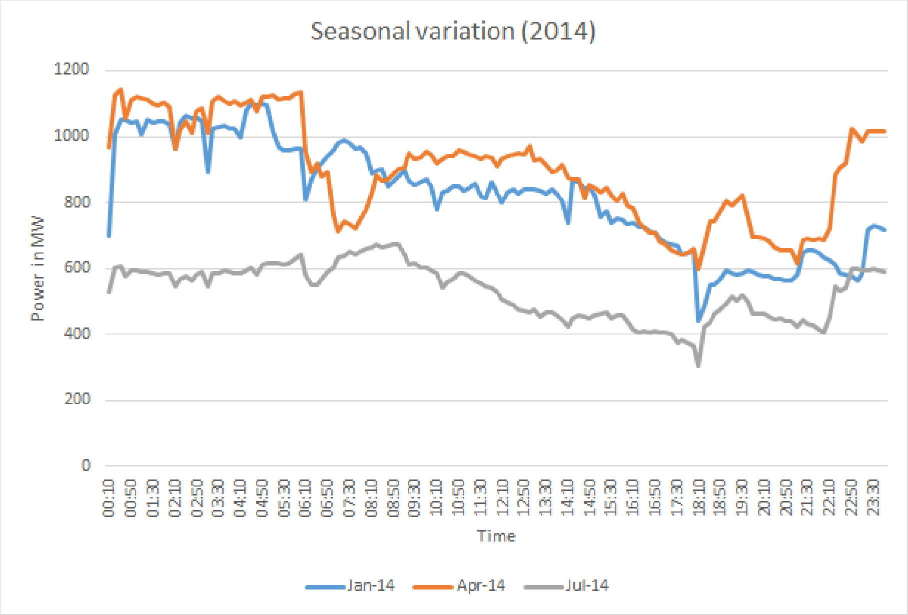


Figure 17: Seasonal Variation in Power in Rural Feeders under BESCOM (2014)

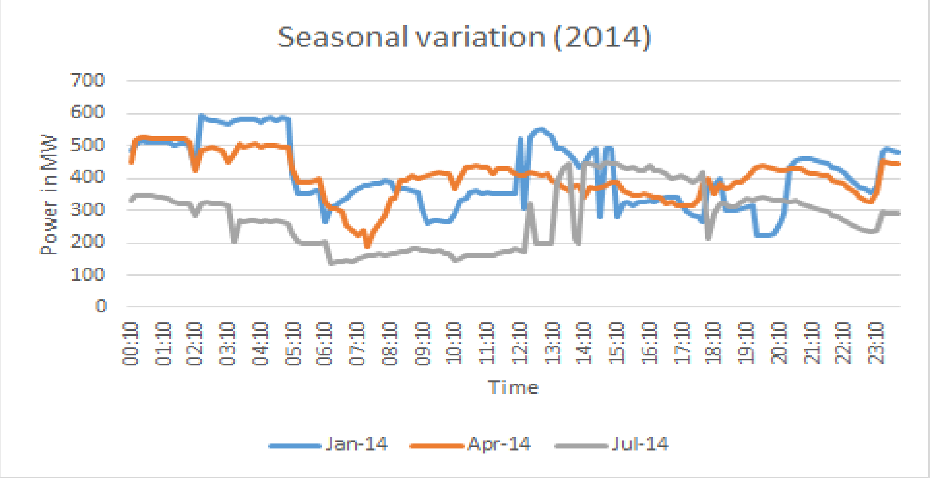


Figure 18: Seasonal Variation in Power in Rural Feeders under CESC (2014)

The following observations are made from the above analysis:

- *Rural load curve is relatively flat:* The number of feeders which have active 3-phase power supply is seen to be restricted to about 50% during the day (6 am to 6 pm)

- *Maximum load consumption is between 12 am to 6 am every day:* Since there is a drop in the number of feeders with a 3 phase supply between 6 am and 6 pm, many IPs are not energised during this time. Thus, IPs are operated during the night (6 pm to 6 am), leading to inefficient use of the electricity supplied.

- *Critical rural sectors don't have reliable access to 3-phase power during the day*: Rural sectors like small-scale industries, commercial establishments, public amenities, public and private institutions like schools and hospitals don't have reliable access to power during the day time.

Urban and Rural Power Availability across Karnataka

An analysis of rural and urban areas within various ESCOMs shows that there is a large variation in terms of the active 3-phase feeders (Figure 19 to Figure 22).

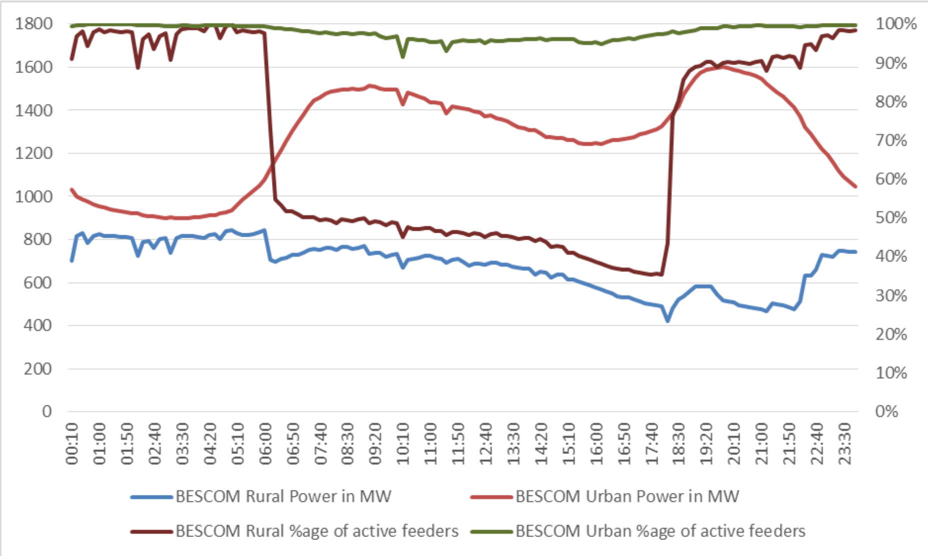


Figure 19: Urban and Rural Power Availability in BESCOM (FY2014)

For Bangalore Urban (Figure 19) , the urban feeder curve shows availability of three-phase the whole day, while for the rural feeders the activation rate dips to almost 45% during the afternoon corresponding to the time 9 am – 4 pm. Thus, it is observed that rural areas in Bangalore do not seem to get reliable 3-phase power supply for most of the afternoon, while the domestic sector gets uninterrupted 3-phase power supply.

Similarly, the graphs (Figure 20 to Figure 22) indicate that in the three chosen districts the percentage of active feeders for the urban sector is the highest giving constant reliable power throughout the day.

In CESC, it is observed that percentage of active urban feeders is higher and flatter than the percentage of active rural feeders, which drops to nearly 50% during the day. On the other hand, in MESCOM, the drop in percentage of active rural feeders (to about 85%) during the day is much less significant.

In the case of Tumkur, where the percentages of active feeders for the urban sector are the highest, there are minor fluctuations as compared to the rural sector. The percentage of activation of agricultural feeders is higher than the rural sector.

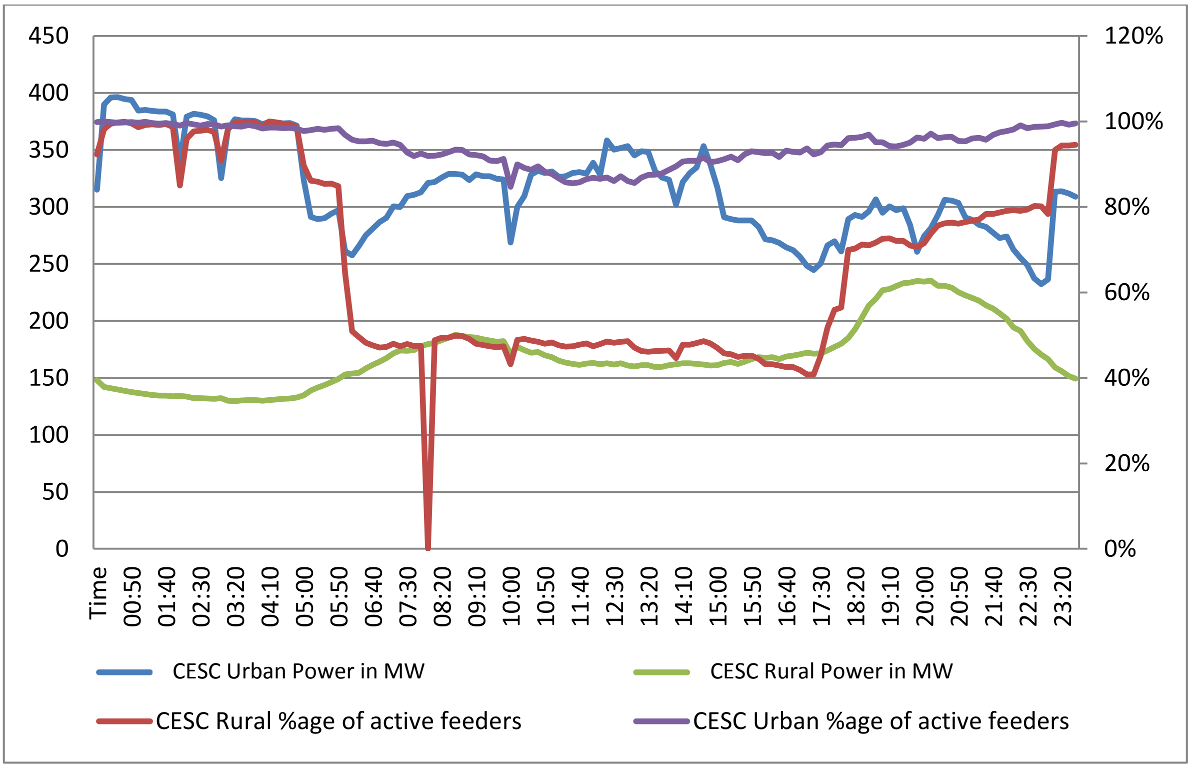


Figure 20: Urban and Rural power availability in CESC

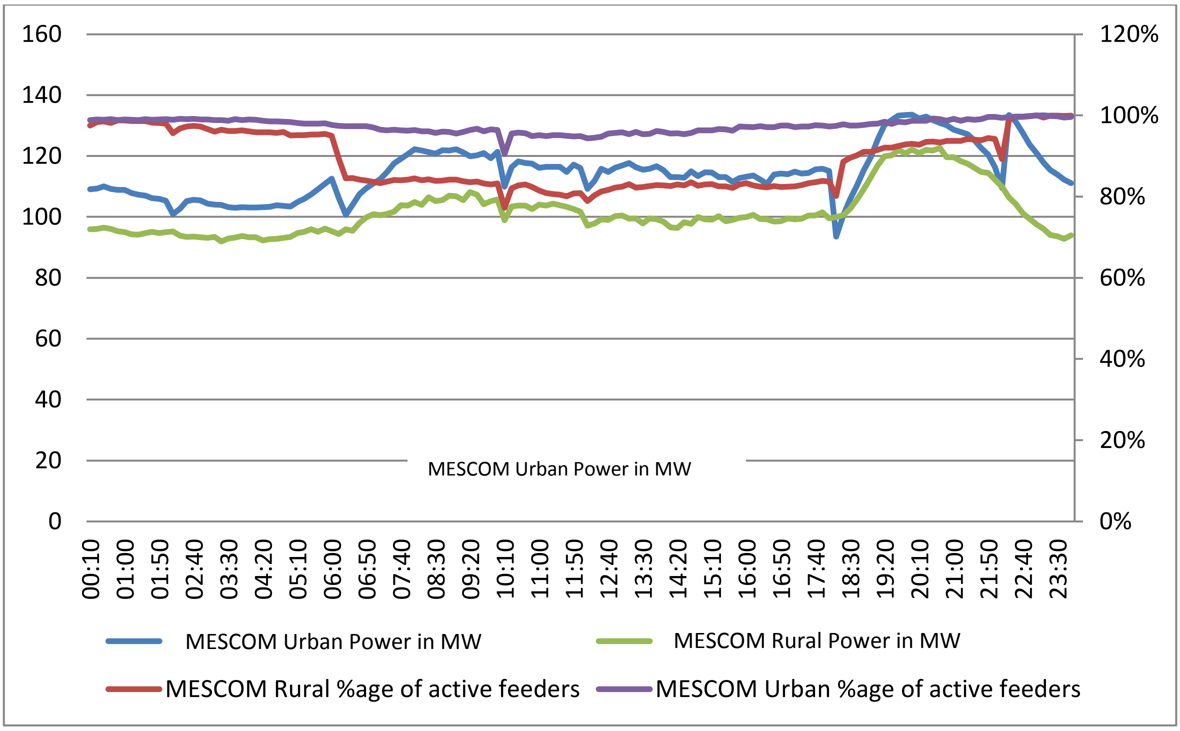


Figure 21: Urban and Rural power availability in MESCOM

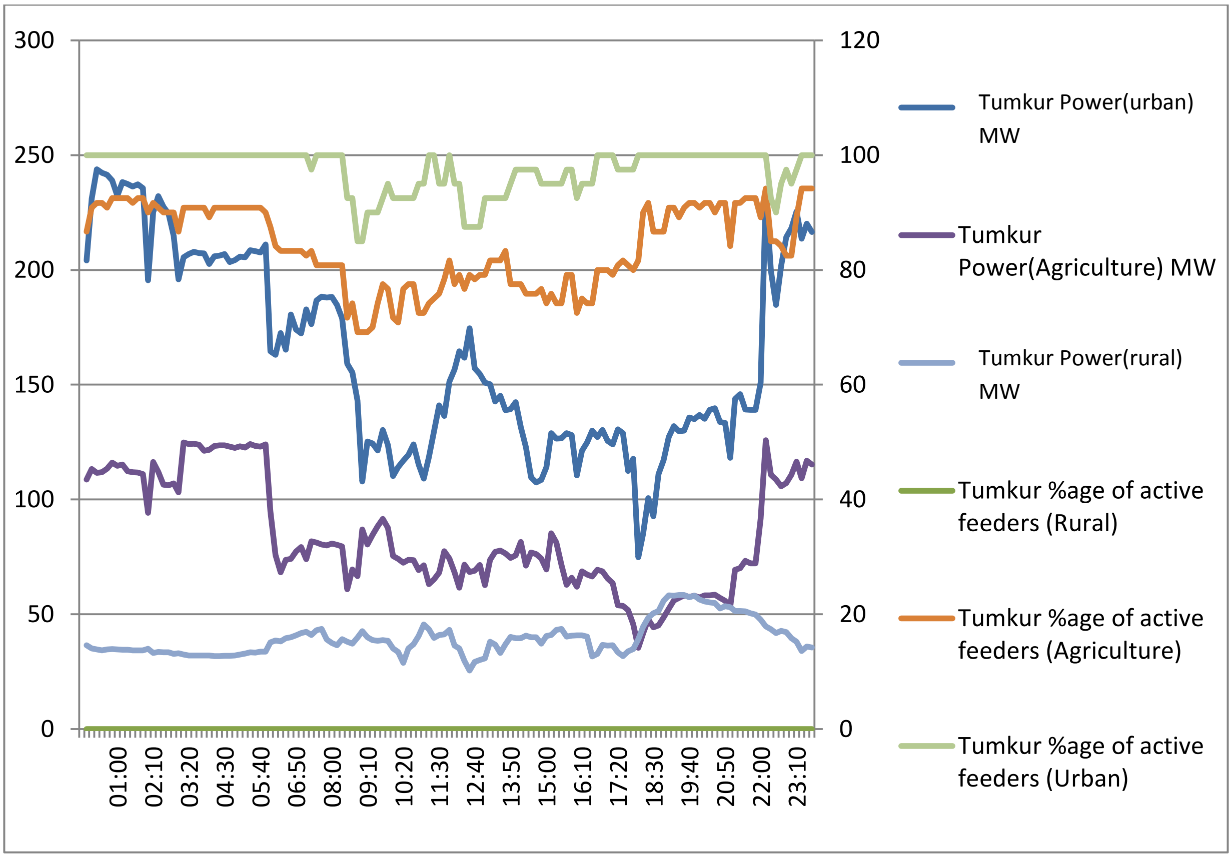


Figure 22: Urban and Rural power availability in Tumkur

Annexure 6: Power Reliability Measures

Other measures of reliability that are widely used by electric power utilities in the country include the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI). SAIDI measures the average outage duration for each customer served, while SAIFI measures the average number of interruptions a customer is likely to experience in a year.

The estimates for SAIFI and SAIDI for a few cities in Karnataka is shown in Table 24. One can see that even a city like Bangalore (with a SAIFI of 108), which receives very reliable power supply in comparison to smaller towns like Mangalore, Dharwad etc., faces several interruptions – nearly one interruption per day per customer. In contrast, Delhi has a very reliable SAIFI of about 9-16 while Mumbai has a SAIFI of about 3.

Table 24: SAIFI and SAIDI for 5 DISCOMs in Karnataka for FY2014

City	SAIFI (number)	SAIDI (minutes)
Mangalore	333	14735
Mysore	350	16920
Bangalore	108	3942
Dharwad	302	12774
Hubli	262	12151

Source: NITI Aayog

Annexure 7: Projects for Capacity Addition under 12th & 13th Plan

Table 25 presents a detailed list of projects for capacity addition in Karnataka, under the 12th and 13th plans from FY2012 to FY2017 and from FY2017 to FY2022 respectively.

Table 25: Projects for Capacity Addition under 12th & 13th Plans

List of New Projects scheduled for 12 & 13th Plan for Capacity Addition^ (under long term)						
Year	**Projects**	**Utility**	**% Allocation**	**State Share (MW)**	**Scheduled COD**	**Sector**
1	2	3		4	5	6
2014-15	NLC Expansion Stage II (Unit-1) (1X250)	NLC	22%	55	U1: Jan-2015 (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	NLC Expansion Stage II (Unit-2) (1X250)	NLC	22%	55	U2:Jan-2015 (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Tuticorin (Unit-1) (1X500) (JV with TNEB)	NLC	16%	79	U1: Feb-2015 (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Kudamkulam Unit-1 (1*1000MW)	NPCIL	22%	221	Assuming CoD Delcaration by 22nd January -2015 (First synchronized to Grid in Oct-2013)(As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Tuticorin (Unit- 2) (1X500) (JV with TNEB)	NLC	16%	79	U2: Mar-2015 (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Vallur (Unit-3) (1X500) (JV with TNEB)	NTPC	7%	37	Unit # 3 is already Sychronized and the COD of the unit is planned by the end of 2014 (31st Dec-2014). (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Jurala (Unit-1 to 6) (6X39)	JV	50%	117	PPA signed in May-2014	Joint Venture
	Kalpakam PFBR - 500 Mwe	BHAVINI	17%	84.4	March-2015; (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	BTPS Unit-3 (700 MW)**	KPCL	50%	350	March-15, Ref: KPCL Letter Dated: 21-10-2014	State
	Yermarus (1X800MW) Unit-1*	KPCL	80%	640	Unit-1: Mar-2015; Ref: KPCL Letter Dated: 21-10-2014	State
	NCE	KREDL		300	2014-15	State
	Sub-Total			**2,017**		

2015-16	Yermarus (1X800MW) Unit-2*	KPCL	80%	640	Unit-2:June-2015; Ref: Ref: KPCL Letter Dated: 21-10-2014	State
	Kudamkulam Unit- 2 (1*1000MW)	NPCIL	22%	221	U2:July-2015; (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Guledagudda in Bagalakote district-100 MW	NTPC	100%	100	Assuming 2015-16 (COD shall be worked out after placement of order for the project; Ref: NTPC letter Dated: 26-09-2014)	CGS
	Munirabad (1X10 MW)-Hydro	KPCL	80%	10	April-2015; Ref: KPCL Letter Dated: 21-10-2014	State
	450 MW from Damodar Valley Corporation	PCKL	100%	450	Assuming LTA will be obtained from June-2015	State
	NCE	KREDL		300	2015-16	State
	Sub-Total			**1,721**		
2016-17	Kudgi Unit- 1 (1X800 MW)	NTPC	50%	400	Assuming April-2016 (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	Kudgi Uni-2 (1X800 MW)	NTPC	50%	400	Assuming Oct-2016, 6 months from First Unit COD (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	NCE	KREDL		300	2016-17	State
	Sub-Total			**1,100**		
2017-18	Krishnapatnam UMPP Unit-1 & 2 & 3 (3X660)	UMPP	0%	0	Due to Court Case, Not Considered	CGS
	Kudgi Unit- 3 (1X800 MW)	NTPC	50%	400	Assuming April-2017, 6 months from Second Unit COD (As per 26th SRPC Meeting held on 20th Dec-2014)	CGS
	NLC New TPP-U#1 (1X500)	NLC	7%	35	U-1 :Oct-2017,Ref: NLC Letter Dated: 08-10-2014 and As per 26th SRPC Meeting held on 20th Dec-2014	CGS
	NCE	KREDL		300	2017-18	State
	Sub-Total			**735**		
2018-19	Bidadi -Gas- (700 MW)	KPCL	80%	560	Projected:2018-19; (Ref: KPCL Letter Dated: 21-10-2014, 30 months from Zero Date.)	State
	Yelahanka Gas based Power Plant (1X350 MW) Phase -I	KPCL	80%	280	2018-19; Projected (Ref: KPCL Letter Dated: 21-10-2014, 30 months from Zero Date.)	State

	GHEP Additional Unit (1X20 MW)	KPCL	80%	16	Projected:2018-19; (Ref: KPCL Letter Dated: 21-10-2014, NIT under issue. 30 months from Zerio Date)	State
	NLC New TPP U#2 (1X500)	NLC	7%	35	U-2:Apr-2018,Ref: NLC Letter Dated: 08-10-2014 and As per 26th SRPC Meeting held on 20th Dec-2014	CGS
	Krishnapatnam UMPP Unit-4 & 5 & 6 (3X660)	UMPP	0%	0	Due to Court Case, Not Considered	CGS
	NCE	KREDL		300	2018-19	State
	Sub-Total			**1,191**		
2019-20	Pudimadaka- Unit-1 (1X800MW)	NTPC	15%	120	April-2019-20 ; Projected; (NTPC Letter Dated 26-09-2014, CoD is anticipated in 13th Plan)	CGS
	Pudimadaka- Unit-2 (1X800MW)	NTPC	15%	120	Oct-2019-20 ; Projected; (NTPC Letter Dated 26-09-2014, CoD is anticipated in 13th Plan)	CGS
	Shivanasamudram Seasonal Powe House	KPCL	80%	276	Projected:2019-20; (Ref: KPCL Letter Dated 21-10-2014, 54 months from Zero Date)	State
	Chattisgarh (Godhana) Unit-1 (1X800MW)	KPCL	0%	0	Projected: April-2019-20; Ref: KPCL Letter Dated: 21-10-2014,1st Unit 51 months from Zero Date;	State
	Chattisgarh (Godhana) Unit-2 (1X800MW)	KPCL	0%	0	Projected: July-2019-20; Ref: KPCL Letter Dated: 21-10-2014,1st Unit 48 months from Zero Date;	State
	Edlapur-800MW*	KPCL	80%	640	Projected:2019-20; (Ref: KPCL Letter dated 21-10-2014, MOEF Clearnce is awaited)	State
	Case-2 Gulbarga Unit-1(660 MW)	PCKL	100%	660	Projected:2019-20; Awaiting Coal allocation	State
	Cheyyur UMPP U-1 (1X800 MW)	UMPP	20%	160	Projected:2019-20 (Ref:RFP-Bid Due date is 22nd Dec-2014, as per CTNPL Amedment to RFP)	CGS
	Cheyyur UMPP U-2 (1X800 MW)	UMPP	20%	160	Projected:2019-20 (Ref:RFP-Bid Due date is 22nd Dec-2014, as per CTNPL Amedment to RFP)	CGS
	Kaiga Expansion Unit-1(700 MW)	NPCIL	50%	350	Projected: 2019-20	CGS
	NCE	KREDL		300	2019-20	State
	Sub-Total			**2,786**		

2020-21	Pudimadaka Unit-3 (1X800 MW)	NTPC	15%	120	April-2020-21 ; Projected; (NTPC Letter Dated 26-09-2014, CoD is anticipated in 13th Plan)	CGS
	Pudimadaka- Unit-4 (1X800MW)	NTPC	15%	120	Oct-2020-21 ; Projected; (NTPC Letter Dated 26-09-2014, CoD is anticipated in 13th Plan)	CGS
	Kudgi Unit 4 (1X800)	NTPC	50%	400	April-2020-21; Projected, NTPC Letter 26-09-2014, Unit#4 &#5 shall be taken up in Kudgi Stage-II	CGS
	Kudgi Unit 5 (1X800)	NTPC	50%	400	Oct-2020-21; Projected, NTPC Letter 26-09-2014, Unit#4 &#5 shall be taken up in Kudgi Stage-II	CGS
	Sirkali Power Project Unit-1 (1X660)	NLC	20%	132	Apr-2020; Ref: NLC Letter Dated: 08-10-2014	CGS
	Sirkali Power Project Unit-2 (1X660)	NLC	20%	132	Oct-2020; Ref: NLC Letter Dated: 08-10-2014	CGS
	Case-2 Gulbarga Unit-2(660 MW)	PCKL	100%	660	Projected:2020-21; Awaiting Coal allocation	State
	Cheyyur UMPP U-3 (1X800 MW)	UMPP	20%	160	Projected:2020-21 (Ref:RFP-Bid Due date is 22nd Dec-2014, as per CTNPL Amedment to RFP)	CGS
	Cheyyur UMPP U- 4 (1X800 MW)	UMPP	20%	160	Projected:2020-21 (Ref:RFP-Bid Due date is 22nd Dec-2014, as per CTNPL Amedment to RFP)	CGS
	Kaiga Expansion Unit-2(700 MW)	NPCIL	50%	350	Projected: 2020-21	CGS
	NCE	KREDL		300	2020-21	State
	Sub-Total			**2,934**		
2021-22	Pudimadaka Unit-5 (1X800)	NTPC	15%	120	April-2021-22 ; Projected; (NTPC Letter Dated 26-09-2014, CoD is anticipated in 13th Plan)	CGS
	Sirkali Power Project Unit-3 (1X660)	NLC	20%	132	Apr-2021; Ref: NLC Letter Dated: 08-10-2014	CGS
	Cheyyur UMPP U-5 (1X800 MW)	UMPP	20%	160	Projected:2021-22 (Ref:RFP-Bid Due date is 22nd Dec-2014, as per CTNPL Amedment to RFP)	CGS
	NCE	KREDL		300	2020-21	State
	Sub Total			**712**		
Grand Total				**13,197**		

Source: KERC

NOTE
* Percentage allocation for the KPCL Power Plants are taken as per PPA
^ KPCL Vide letter Dated 21-10-2014 has provided the Scheduled CoD Dates for BTPS-U#3, YTPS (U#1&2), Addn. unit at Munirabad PH , R, M&U of NPH and Solar Power at Belakavadi. For the remaining projects it has been mentioned 30/48/51 months from zero date. Therefore for these Projects, Dates are Projected. Also, KREDL has provided capacity additon of of 80 MW solar power projects during 2015 vide their letter dated 27-09-2014. However for considering other RES, NCE Projects from FY 2014-15 onwards average 300 MW is taken.
Orissa 2nd UMPP-4000 MW from which State is having a share of 350 MW for which still no bidding process started; Not considered in Projections
Wind Power Project of 36 MW in Maduragudda in Hassan district is likely not to be taken up in near future as per NTPC letter dated: 17-06-2013; Not considered in Projections
Krishnapartnam Power Project is not considered due to pending court case
Only Fifty percentage of the total energy for the first Three months after the commissioning is considered
Gundia, Tadadi, Chhatisagh Projects of KPCL are not considered

Annexure 8: Existing Methods for Load Management in Rural Areas

Nirantar Jyothi Yojana (NJY)

Feeder separation is an idea that a dedicated agriculture feeder supplies to only irrigation pump sets and a dedicated non-agriculture feeder supplies to all loads except IPs. The objective is to ensure 24x7 power supply to all non-agricultural loads, and a minimum of 6-8 hours of quality power supply to IPs for agricultural use during system off-peak hours. The main advantage of feeder separation is the fact that it is a hard-wired conventional scheme and does not involve any electronics or communication technologies.

The state of Gujarat has taken a lead in feeder separation and has implemented a scheme called Jyothi Grama Yojana (JGY). As a result, a round the clock supply is provided to all non-agricultural consumers including residential loads, and a restricted (6-8 hours) quality power supply to agriculture loads has been ensured. It has been reported that the project made a significant contribution to different social groups and that the lives of large numbers of poor people also improved with the use of very modest amounts of electricity for lighting, fans and (less so) even cooking.

GoK also launched the feeder separation scheme under the NJY scheme in 2009 which is being implemented in two phases. The first phase consists of 70 Taluks with a total cost of INR 1,203 Crore, while in the second phase 56 Taluks with a total cost of INR 920 Crores have been covered. The financing of the scheme was done by internal resourcing in ESCOMs and raising loans through nationalised banks. Due to the financial crisis of ESCOMs to fund this project, and keeping in mind the repayment of capacity of ESCOMs, 40% of the cost was covered with a grant and 60% through a loan that was approved. The loan will be raised by the ESCOMs from the banks.

The project has a large capital outlay, and hence being implemented in stages. Therefore, regular monitoring is necessary to advise any mid-course correction. The impact of the scheme is under evaluation by different ESCOMs. However, more than the economics of the scheme, NJY helps in achieving the utility's obligation to serve consumers with uninterrupted power supply.

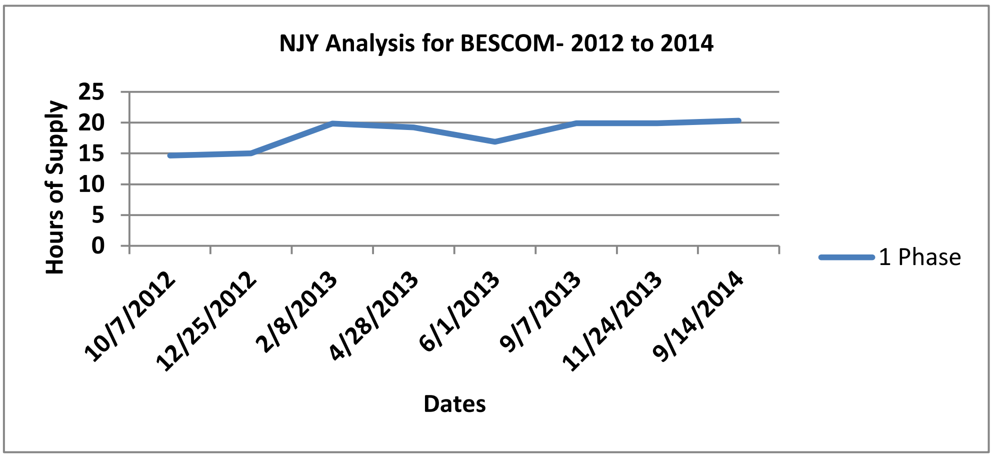


Figure 23: NJY analysis for BESCOM across Selected Dates from 2012-2014

The data analysis carried out in 14 randomly selected feeders under BESCOM on selected dates between 2012-14, shows that there has been an improvement in power supply after the bifurcation, with average supply hours reaching 20 hours in 2014 (Figure 23). But this claim needs to be checked with an analysis of 3-phase power availability in the rural feeders so as to arrive at conclusions regarding the actual impact of NJY. Moreover, there can be factors other than feeder separation that can contribute to increased power availability in these feeders.

Cyclic Rostering of Power Supply to Feeders

In rural areas, a cyclic rotation of 3-phase power supply is being carried out to make sure that all the areas under this supply system get at least the minimum number of hours required to carry out pumping activities. But often the unpredictable nature of this scheduling makes it difficult for the farmers to plan their pumping activities.

Potential savings from the above existing schemes require further analysis, which is out of the scope of this study due to lack of availability of data.

Annexure 9: Illustrative Costs of DRE Systems

Solar IPs:

Table 26 outlines the approximate costs of installation of solar IPs of different capacities:

Table 26: Approximate Costs of Solar Pump Installations

Pump (HP)	Solar Pump Controller	Panel Bank (Varies as per design requirements)	Cost INR (Approximate)
2	2 HP	1800 Wp	3,22,000/-
3	3 HP	3000 Wp	4,40,000/-
5	5 HP	4800 Wp	6,07,000/-

Current provisions under the JNNSM allow a 40% subsidy for solar pumps at the following benchmark costs (Table 27):

Table 27: JNNSM Subsidies for Solar Pumps

Type of Pump	Technical Specifications	Maximum Subsidy (INR/HP)
DC Pumps (INR / HP)	upto 2 HP	57,600
	>2 HP TO 5 HP	54,000
AC Pumps (INR / HP)	upto 2 HP	50,400
	>2 HP TO 5 HP	43,200
For pumps above 5HP – 10HP, subsidy amount is fixed at INR 1,94,400 per pump		

Source: NABARD Circular dated 17 December, 2014[33]

The remaining cost after the deduction of 20% margin money can be covered by arranging lower interest loans with banks to accelerate promotion of such renewable technologies which would decrease dependence on the grid and minimise power deficits. Also, under the Surya Raitha Scheme it is possible for farmers to supplement their income by selling back the surplus power they might generate from solar IP sets at the rate of INR 9.4/unit which would also provide additional income for them and recover their costs of installation over a period of time.

Bhagya Jyothi vs. Solar Home Systems:
Table 28 lists the costs incurred and beneficiaries for the BJ scheme in FY2013:

Table 28: Costs and Beneficiaries for Bhagya Jyothi scheme (FY2013)

Number of consumers	Sanctioned load	Total consumption (MUs)	Fixed charges (INR Crores)	Energy charges (INR Crores)	Total charges (INR Crores)
713132	7589	128	0	63	63

Source: **(Harish & Tongia, 2014)**

[33] Available at https://www.nabard.org/uploads/Circular%20No.252WEB.PDF

Table 29: Cost Comparion of BJ Connection and Solar Home System

Expenditure per connection in the BJ scheme	Total cost of Solar Home system (containing 1 CFL bulb + mobile charging port)	Amount of subsidy to be given (Cost borne by Government under the JNNSM @ 270 INR/Wp)
878[34]	8,000[35]	1728

Table 29 compares the amount which will have to be spent for per household connection under the BJ scheme as well as for the cheapest solar home systems. Even though solar home systems might involve huge installation costs initially, this is only a one time investment for the State and the beneficiary and there is always flexibility to limit the load. Additionally, within the provisions of the JNNSM, even if the whole cost of the solar home system is not covered, the 40% capital subsidy can be provided by the government while the remaining amount can be covered through interest-free or low-interest loans for BPL households.

[34] Not including cost of provision of light and installation and connection to the grid

[35] Approximate cost obtained from a solar service provider

Annexure 10: Estimation of Savings from Energy Efficiency in Appliances

The following appliances (listed in Table 30 and Table 31) have been modelled in the study for estimating savings from uptake of energy efficient appliances:

Table 30: Domestic Appliances Modelled in the Study

Consumer	Appliance	Life (Years)	Cost (INR)	UEC (kWh/year)
Residential	Fan (3-star)	12	1,880	209
	Fan (5-star)	12	2,040	180
	Fan (SEA)	12	2,420	126
	Direct-cool refrigerator (3-star)	12	9,030	400
	Direct-cool refrigerator (5-star)	12	11,700	260
	Frost-free refrigerator (3-star)	12	15,800	555
	Frost-free refrigerator (5-star)	12	19,300	364
	Television set (3-star)	12	13,020	108
	Television set (5-star)	12	13,390	91
	Split air conditioner (3-star)	12	28,209	2,244
	Split air conditioner (5-star)	12	38,100	1,884
	Window air conditioner (3-star)	12	25,320	2,261
	Window air conditioner (5-star)	12	32,640	1,860
Commercial	Split air conditioner (3-star)	12	28,209	2,244
	Split air conditioner (5-star)	12	38,100	1,884

Table 31: Lighting Appliances Modelled in the Study

Consumer	Appliance	Life (Years)	Cost (INR)	UEC (kWh/year)
Residential	Incandescent bulb	1	12	72
	CFL	5	150	13.2
	LED bulb	20	649	7.2
	Tube light (3-star)	3	47	54
	Tube light (5-star)	3	75	43.2
	LED tube light	10	1,019	16.8
Commercial	Incandescent bulb	1	12	144
	CFL	3	150	26.4
	LED bulb	10	649	14.4

Refrigerators comprise frost-free and direct-cool variants while air conditioners consist of split and window variants. Data incorporated into the model includes appliance cost, UEC, and life of the appliance. The life and UEC of each appliance is based on data published by BEE. The approximate cost has been determined based on online and telephonic survey of appliances.

In commercial sector, bulbs are taken as proxy for lighting demand (which may be met through point lighting, linear lighting, luminaires, etc.) and split air conditioners are used as proxy for HVAC demand (which may be met through fans, coolers, air conditioners, etc.) as appliance-wise breakup is not available.

Table 32 presents the various available technologies for efficient street lighting:

Table 32: Technologies Available for Street Lighting

Luminaire Type	Rated Power (W)	Lumens	Input Power (W)
Incandescent	375	5,630	375
Tungsten halogen	300	5,590	300
Compact fluorescent	64	5,670	89
Light emitting diode	100	9,400	110
Mercury Vapor	250	10,270	285
High Pressure Sodium	194	18,890	243
Metal Halide	468	39,220	585
Linear fluorescent	39	7,410	112
Efficient linear fluorescent	38	17,750	187
Next Gen LEDs	100	22,040	110
Future LEDs	100	35,880	105

Source: Lawrence Berkeley National Laboratory

A switch to LED lighting can result in savings of at least 30%. Even linear fluorescents can provide savings of above 30% at a lower initial investment.

Center for Study of Science, Technology and Policy
18, 10th Cross, Mayura Street,
Papanna Layout, Nagashettyhalli, RMV II Stage,
Bengaluru-560094
Karnataka, INDIA
www.cstep.in