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The Energy and Resources Institute

Transitions in Indian Electricity Sector

2017–2030

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Executive Summary

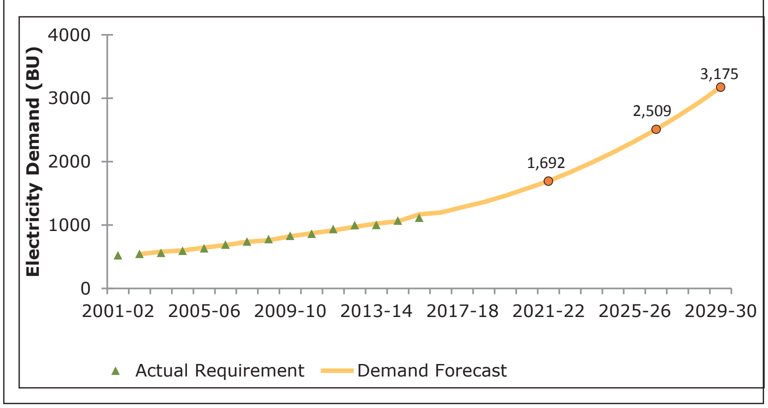
1. The Indian electricity sector is presently going through a major transformation. The accelerated pace of generation capacity addition over the past few years has led to a situation wherein the electricity supply potential is greater than the economic demand, a scenario witnessed never before in the history of the Indian electricity sector. We have also been witnessing changes in the energy mix due to enhanced policy focus on climate change, energy security concerns, etc., due to which the penetration of renewable electricity, especially from wind and solar energy, has been increasing steadily and is projected to grow much faster in the coming years. The demand patterns have also undergone changes due to *inter-alia* urbanization, increased space conditioning loads, and adoption of energy efficiency initiatives. Against this backdrop, The Energy and Resources Institute (TERI) has initiated a study to bring out possible transitions which could address the changing demand and supply scenarios.

2. We note that the assessment of electricity demand till 2030 would depend on a number of factors, primarily including economic growth, household connectivity, energy efficiency (including through reduced transmissions & distribution T&D losses) and the electrification of the transport sector. An analysis of electricity demand at the national level indicates that the demand in the current year depends on last year's electricity consumption (in other words, demand is 'sticky') and economic growth in the current year. An assessment of nature of electricity demand in the few states where almost universal connectivity exists and electricity supply shortages are marginal suggest that the electricity demand is dependent on economic parameters, including gross state domestic product and its components with the degree of dependence varying, contingent on the type of economic activity predominant in the state. This highlights the need for a detailed study in respect of each state at a more granular level.

3. Consequently, the electricity demand scenario is built on the basis of extrapolating past demand to the future, taking into account the current year consumption and future economic growth, and adjusting it to account for future end-use energy efficiency improvements, additional requirement for the newly electrified households (whose requirements are then assumed to grow with income and economic growth), and additional requirement for electrified road transport.

4. The present study indicates that the electricity demand is likely to increase from 1115 BU in 2015–16 to 1692 BU in 2022, 2509 BU in 2027, and 3175 BU in 2030 (Exhibit ES-1). In this context, it is underlined that with improving power supply position and reliability of supply, demand projections may undergo further increase as the industrial, commercial, and residential consumers, presently sourcing part of their requirements from captive power plants, would shift to grid power. On the other hand, there could also be a downward pull due to more rapid increase in energy efficiency in the future (as compared to past trends) due to programmes which increase market size for energy efficient products while simultaneously leading to price decreases due to increased competition. In general, we believe that the scenario presented here is a stylised scenario reflecting higher end of electricity demand.

Exhibit ES-1: All India Electricity Demand Scenario



5. The supply side has also been studied up to 2029–30. The capacity additions of non-RE power up to 2026–27 have by and large been taken from the draft National Electricity Plan (December 2016); with planned addition of coal, nuclear, hydro, and gas-based capacities of 50,025 MW, 7600 MW, 27,330 MW, and 4,340 MW, respectively. In case of coal-based power stations, the study has accounted for retirement of approximately 5.2 GW up to 2021–22 (as envisaged in draft NEP) and approximately 30 GW of capacity during the subsequent five years based on plant age, obsolescence of technology, and environmental considerations.

6. Two stylized supply scenarios have been considered - a **'High Renewables Scenario' (HRES)** and a **'Low Renewables Scenario' (LRES)**. In the High Renewables Scenario, the RE capacity increases from the prevailing level of about 50 GW to 175 GW and 275 GW in 2021–22 and 2025–26 respectively, & thereafter to 853 GW in 2029–30. For such a growth to be achieved, it is imperative that there is coordinated effort at the Central and State levels to ensure adequacy of balancing capacity, ancillary services, grid strengthening, and above all, requisite paying capacity of the electricity distribution companies. It is further assumed in the High Renewables Scenario that the price of firm electricity from intermittent renewables (i.e., weighted price of renewable and balancing electricity) would be about ₹5/kWh (USD 70/MWh) beyond 2027 which means that it would be competitive with coal-based electricity, and would account for all new capacity addition beyond that date. Considering the challenges in this regard and the capacity addition of only about 10.5 GW of wind and solar capacity having been achieved in the last 2 years, a 'Low Renewables Scenario' has also been considered. In this scenario, the RE capacity addition has been taken as 75 GW during the first 5 years and 100 GW in the 5 years thereafter. The aggregate RE capacity in this scenario reaches up to 125 GW in 2021-22, 225 GW in 2026–27, and 284 GW in 2029–30.

7. In both the scenarios, common assumptions have been made in regard to Plant Load Factor (PLF) and Capacity Utilization Factor (CUF) of electricity generation plants. PLF/CUF of nuclear and hydro plants has been considered as 75% and 35% respectively, based on past performance. An average CUF in respect of solar plants has been taken as 19% in line with CERC's order regarding levelised generic tariff for FY 2016-17. A reduction of 0.8% in generation from solar plants, reported by NCPRE and NISE as internationally acceptable benchmark[1], has been considered on a year on year basis. In case of wind-based plants, considering the present performance, technological improvements and the availability of wind potential in the sites which remain to be developed, a CUF of 25% has been considered. In case of coal, the energy that is likely to be met by the coal plants has been worked out as residual energy requirement after taking into account the availability from all other conventional and renewable energy sources.

8. These energy balance studies indicate that in the two scenarios, the average PLF of coal-based fleet is likely to decline initially from the current level of ~59% to ~50%-53% in the year 2018–19 and thereafter it follows an increasing trajectory touching ~ 78-80% in 2024–25/2025–26. The PLF of coal-based plants is capped at this level in view of needs to meet requirement of diversity of demand, planned maintenance, and forced outages. Consequently, existing and under construction coal capacity would be able to meet demand till 2025–26.

9. In the 'High Renewables Scenario', the remainder of the demand in the subsequent years of study is considered to be catered by renewables in view of the assumption that the price of renewable + balancing electricity would be about Rs.5 per kWh and competitive with the price of electricity from coal. In this scenario, the share of electricity generated from intermittent renewables would show a remarkable increase from the present level of ~ 5.6% to ~ 16%, 27% and 34% in 2022, 2027, and 2030, respectively, and the share of coal-based electricity generation would reduce from ~ 73 % in 2015-16 to ~ 70%, 61%, and 56% in the year 2021–22, 2026–27, and 2029–30, respectively.

10. In the 'Low Renewables Scenario', the additional requirement of supply beyond 2025–26 is assumed to be largely met by new coal capacity, and to a limited extent from new renewable capacity. In this scenario, 256 GW of new coal capacity is added by 2030 and the share of coal-based electricity generation in 2021–22,

[1] All India Survey of Photovoltaic Module Reliability : 2014 (NCPRE and NISE)

2026-27, and 2029–30 ranges from 74% to 76% as compared to 73% in 2015–16. The total installed capacity of renewable energy sources is likely to be 284 GW in 2030 and share of renewable would be 16% in that year.

Table ES-1

	Generation (BU)						Installed Capacity (GW)					
	High RE Scenario			Low RE Scenario			High RE Scenario			Low RE Scenario		
	2021-22	2026-27	2029-30	2021-22	2026-27	2029-30	2021-22	2026-27	2029-30	2021-22	2026-27	2029-30
Renewable Energy (W+S)	274	678	1102	186	379	511	160	470	853	110	210	284
Non RE excluding Coal	236	303	310	236	303	310	98	114	114	98	114	114
Coal	1182	1528	1763	1270	1827	2354	248	218	218	249	218	474
Total	**1692**	**2509**	**3175**	**1692**	**2509**	**3175**	**506**	**802**	**1185**	**457**	**542**	**872**

11. Table ES-1 shows the generation and installed capacity in the period till 2030 under the two scenarios.

12. There are many technical options for balancing demand and supply in view of the demand-side transitions as well as the changing supply mix due to likely level of achievement of Renewable Energy targets. Altering the flexibility of existing coal-based fleet to achieve faster ramp up and ramp down rates, utilization of the currently highly underutilized gas plants to provide peaking power if gas is available at cost effective rates, coordinated use of storage and pumped storage, creation of new storage capacity through advanced battery-based solutions are various alternatives for this purpose. Utilization of hydro power imports from the neighbouring countries would be yet another option to be looked into. The mix of choices will depend on their cost economics and grid friendliness. The evolving cost economics and consumers' paying capacity would also be a crucial factor in determining the extent of adoption of available options for balancing the intermittent renewable electricity supply. In the long run, the weighted cost of electricity supply from intermittent renewables and from the balancing/storage technologies, as compared to the cost of electricity from coal-based power plants, would determine the quantum of renewable electricity which could be absorbed in the grid and/or paid for by the electricity distribution companies. The success of current initiatives such as UDAY would create requisite environment for ensuring that electricity distribution companies operate on a commercial basis and take electricity procurement decisions within an economic framework.

13. We believe that while the 'High Renewables Scenario' is not a certainty, it is indeed a reasonable probability. The challenges in this regard are well recognized and point out the need for ensuring timely implementation of transmission system expansion, including Green Energy Corridors, improved forecasting of renewable power as well as demand, supportive policies and regulations, alignment of national-and state-level policies and implementation plans, added emphasis on development and operational management of storage technologies, increased flexibility of generation fleet, demand-side management (including Demand Response Measures for rapid demand-side responses to address supply-side intermittency), developing domestic manufacturing capability and O&M support.

14. Considering the dynamic nature of the transitions that are taking place, it would be prudent to review the evolving scenario on a periodic basis, taking note of the incremental growth in electricity demand, changes in the structure of economy, technological developments in generation and storage technologies, balancing and ancillary services, grid infrastructure, and the associated techno-economic considerations.

15. India has a 10-year window of opportunity to overcome the challenges to large scale and economically preferential adoption of renewable energy. The prime consideration for utilization of renewable energy thereafter would be whether the price of 'despatchable renewable electricity' i.e. renewable + balancing

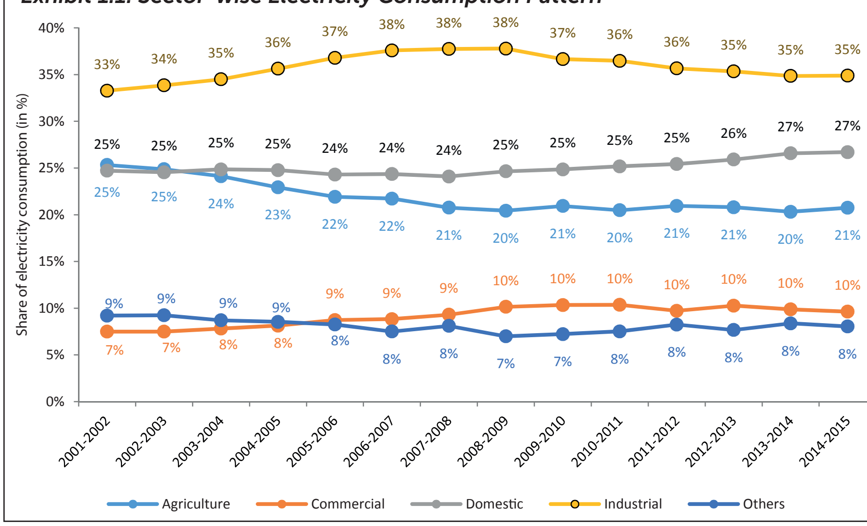
electricity reaches a level of ₹5 per kWh. Further, while the growth in electricity demand, policy, regulatory measures, and initiatives would lead to a "pull factor", the dovetailing of international technological cooperation and financial support so as to overcome the "humps of challenge" would enable its realization. This could provide a paradigm shift to the future of Indian electricity sector wherein all the new generating capacity addition would come from the renewables, thereby reducing the dependence of the sector on fossil fuels and avoiding incremental carbon dioxide emissions.

1. Introduction

1.1 The structure and complexion of the power sector in India has undergone radical changes in recent years in the context of various reform measures introduced by the government and evolving socio-economic conditions. Substantial growth in installed generating capacity, transmission, and distribution system coupled with open access, power trading, and power exchanges have led to reduction in energy and peak shortages and surplus generation capacity. A competitive power market is evolving and there is increased focus on access, efficiency, quality, and affordability of supply and on decarbonizing the sector. While these are noteworthy efforts, the per-capita consumption of electricity in the country (1,075 units in 2015–16) remains much less than the world average. For example, as per IEA statistics, per-capita consumption of electricity in India in 2011–12 was 884 units compared to the world average of 3,024 units. Of late, we are also witnessing a rather paradoxical situation of stranded generation capacity and pockets of shortages.

1.2 The electricity consumption in the country presents a picture of steady growth over the years. The relative consumption of various consumption categories has shown changes. During the period from 2001–02 to 2014–15, there was an increase in the share of domestic consumption (25% to 27%) as well as commercial consumption (7% to 10%) and a decline in agricultural consumption (25% to 21%). The share of industrial consumption, after witnessing an increase (33% to 38%) during 2001–12, reduced and has remained around 35% (2012–13 to 2014–15). Exhibit 1.1 presents the share of electricity consumption in major consumption categories from 2001–02 to 2014–15. Electricity consumption pattern in the country is set to witness further transition because of Government Initiatives, such as 'Power for All', 'E-mobility', 'Make in India', Demand Side Management, Energy Efficiency, and Energy Conservation measures.

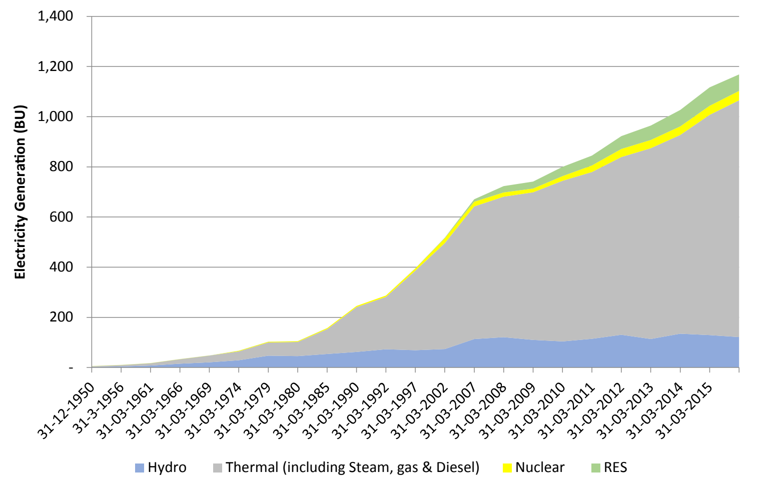
Exhibit 1.1: Sector-wise Electricity Consumption Pattern



1.3 The electricity generation in the country has also witnessed increased growth during the last few Plan periods with CAGR of 5.16% in 10th Plan (2002–07), 5.77% in 11th Plan (2007–12) and 6.0% in 12th Plan (2012 to 2015–16). The generation mix has also been witnessing a change with increasing penetration of renewables; the contribution of renewables becoming noticeable during the last five years and constituting about 5.5% of the total generation in 2015–16 (Exhibit-1.2).

1.4 The supply side scenario in India is set to witness a major transition in view of India's recent climate pledge underlining the country's commitment to a growing role for low-carbon sources of energy, led by solar and wind power. The energy choices in the country in the coming years are to be governed by INDC commitments, energy security, long-term sustainability, enhanced electricity access, reliability of power, and environmental and social considerations. Target of achieving 175 GW of renewable energy up to 2021-22 which is now seen as an 'article of faith' by the government and quantum jump in capacity addition in renewable energy sources in the next decade is likely to significantly alter the energy mix. This would also impact the operation of coal-based power plants, which currently contribute to bulk of the power requirement in the country. The tightening of environmental norms is also a factor to be reckoned with.

Exhibit 1.2: Growth of Electricity Generation-Sourcewise



Source: - CEA General Reviews

1.5 The development strategy for the future should consider these radical changes taking place on the demand and supply side as well as the market requirements. Realistic forecast of demand considering the changes in consumer behaviour, impact of GDP on demand growth, etc., would be a primary and important requirement for this. It will also be necessary to factor in the pattern of generation availability from different resources, the flexibility in their operation, etc. In the long-term perspective, one would also have to look at the technological improvements taking place on the power generation front, developments in storage technologies that could increase the despatchability of variable energy resources and effective load management techniques. Such an exhaustive study would no doubt require integrated and dynamic planning through appropriate modelling frameworks. The present report is an initial step in this direction.

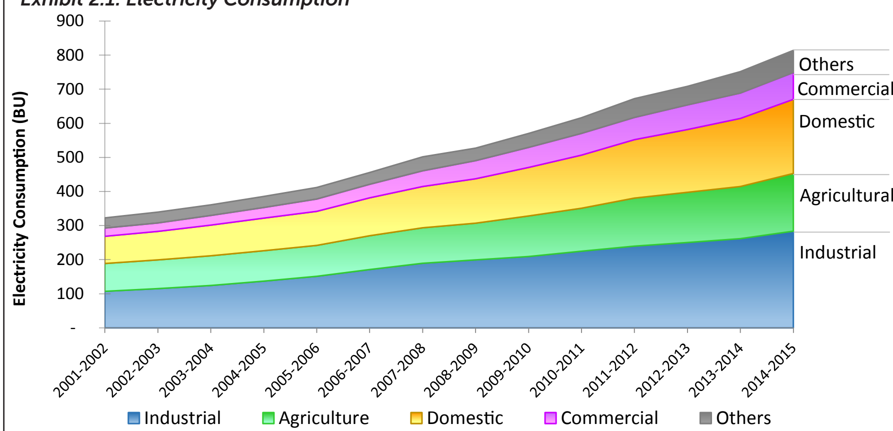
1.6 In Section 2, an analysis of the demand and various influencing factors has been carried out in different sectors at All India level as well as for a few states. The supply side scenario and the likely contribution from different fuel types to meet the projected demand based on energy balance studies has been worked out in Section 3. The study covers two stylised scenarios, a High Renewables Scenario and a Low Renewables Scenario. The major findings and recommendations based on the study are presented in Section 4.

2. Demand Pattern Analysis and Future Scenario

2.1 The electricity sector in India has experienced considerable growth in the last two decades encompassing all consumer sectors from residential to industrial as well as agricultural. Growth in average per capita income levels, urbanization levels, improved electricity access, increased economic activity, and greater electrification impacting end use demands, such as agricultural practices, are some of the factors that have contributed significantly to the growth in electricity demand as well as changes in patterns of electricity consumption across the country. At the same time, the last decade has seen the introduction and implementation of several measures towards enhancing energy efficiency. The introduction of Star Labelled Appliances, standards, the PAT scheme, etc. are some of the additional measures that were initiated during the last decade. India's electricity demand across sectors is therefore a complex function of the growth resulting from increasing aspirations, economic growth, and higher electrification of activities on the one hand, and the reduction in electricity requirements due to efficiency improvements across different sectors on the other.

2.2 Total electricity consumption in the country grew at a CAGR of more than 7% between 2001 and 2015 reaching 814.3 BU in 2014–15 from 322.5 BU in 2001–02.[2] (Exhibit 2.1). This 151% growth in total consumption was a result of 177% growth in residential consumption, 241% rise in commercial consumption, 148% growth in industrial consumption, and 112% growth in agricultural consumption. This escalation in power consumption occurred in tandem with economic development as the GDP also grew at a CAGR of 7.3% over this period.[3]

Exhibit 2.1: Electricity Consumption



Source: CEA General Reviews

2.3 As the country aspires to maintain a high and robust economic growth as well as to provide a thrust to infrastructure– and manufacturing-led growth, the growth and pattern of electricity consumption in future is also expected to change significantly. The change in consumption patterns and likely trajectories of electricity demand in the short term and long term are therefore crucial aspects that need to be examined in planning for optimal and efficient use of resources.

2.4 Given the importance of studying the drivers of power demand across various electricity consumption sectors and evaluating the implications on future demand levels and patterns, TERI undertook this study to identify and examine various factors that influence electricity demand across different sectors at the national as well as state level. Using some of these explanatory factors, a forecasting exercise was carried out to obtain power demand till 2030. Reduction in transmission & distribution (T&D) losses, energy efficiency improvement, accelerated rural household electrification, and electric mobility additionally, were accounted for in order to incorporate these incremental changes, since the effects of these elements would not be adequately captured in the past trends of deemed electricity consumption, as used in our estimation.

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2 CEA, 2015. *Growth of Electricity Sector in India from 1947-2015*

3 RBI, 2016. *Handbook of Statistics on Indian Economy*

2.5 Forecasting of electricity demand is always a challenging task, especially for fast developing economies. It is especially so in case of countries such as India considering the expanse, large variations in agro-climatic and socio-economic conditions, fast changing consumption patterns, purchasing capacity of consumers, shortage caused by infrastructure constraints, and progress in implementation of various government programmes to promote efficiency, e-mobility and energy access.

2.6 The present study is a first step towards understanding electricity demand patterns at the state and national level and projecting the demand up to 2030 based on select key drivers. It will be modified and strengthened as further research is undertaken.

Demand Analysis

2.7 In the present study, econometric and statistical analysis of electricity consumption since 2001–02 has been carried out with a view to establish significant factors influencing electricity consumption. The relationship of electricity consumption with factors such as GDP, per capita GDP, industrial GDP, agricultural GDP, agricultural pump-sets energized, gross area sown, gross area irrigated, etc. was examined. The data was analysed using statistical methods, such as correlation and regression, to determine the dependence of electricity demand on these parameters. The study was undertaken at the national level and for some select states, which had marginal shortage of power and high connectivity, in order to capture the measured electricity consumption as unrestricted demand for these states.

2.8 The analysis revealed that, in the past 15 years, electricity demand at the national level was strongly correlated with total GDP and its components and derivatives including industrial GDP, agricultural GDP, and per capita GDP. The results are shown in Exhibits 2.2–2.4. Analysis at state level, however brought out findings which varied widely from the national-level results. This is particularly true at the sectoral level as the socio-economic parameters, and therefore, the sectoral activity level varies across states and leads to diverse demand patterns.

Exhibit 2.2: Analysis of all India total electricity consumption with total GDP

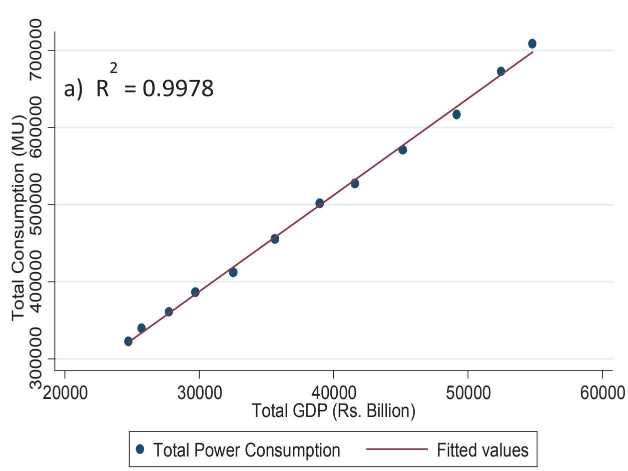
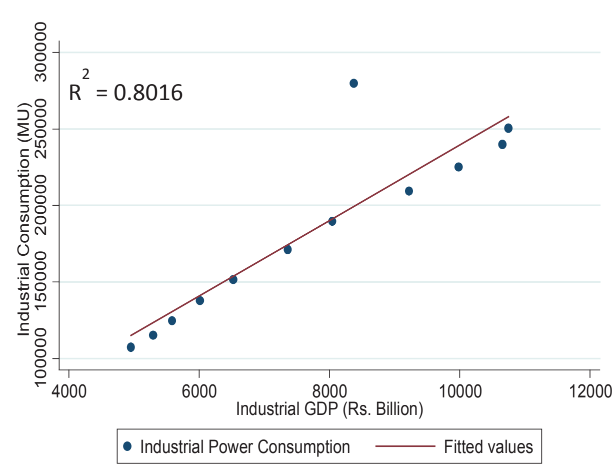


Exhibit 2.3: Analysis of all India industrial electricity consumption with industrial GDP



2.9 Incase of Gujarat, total electricity consumption indicated statistically significant correlation with Gross State Domestic Product (GSDP) with R^2 = 0.9632, industrial GSDP (R^2 = 0.928), and agricultural GSDP (R^2 = 0.8057). However, when sectoral electricity consumption is analysed with sectoral GSDP, a different picture emerges. While the industrial electricity consumption is highly correlated with industrial GSDP with R^2 of 0.9269, the agricultural consumption does not have a significant relationship with agricultural GSDP, as shown in Exhibit 2.5. While electricity consumption in the agriculture sector did not indicate a correlation with gross sown area and gross irrigated area, agricultural consumption between 2005–06 and 2012–13 showed a strong correlation with number of pump-sets energized in the same period (R^2 = 0.9087), as depicted in Exhibit 2.5. It was also observed that agricultural electricity consumption declined from 2001–02 till 2005–06 and then increased steadily till 2014–15 with CAGR of 4.62%. The growth in agricultural consumption was outstripped by demand growth in other sectors leading to decline in contribution of agriculture to total demand. Industrial consumption increased at a higher rate as compared to other sectors, resulting in an increase in its share in total consumption from 32% in 2001–02 to ~53% in 2014–15. Therefore, while projecting demand for Gujarat in the future, further qualitative research needs to be undertaken to closely examine the factors influencing consumption in each of the sectors and determining the causalities and their implications.

Exhibit 2.4: Analysis of all India agricultural electricity consumption with agricultural GDP

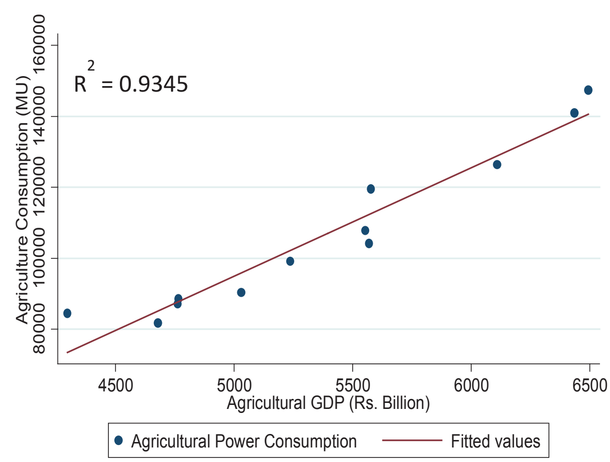
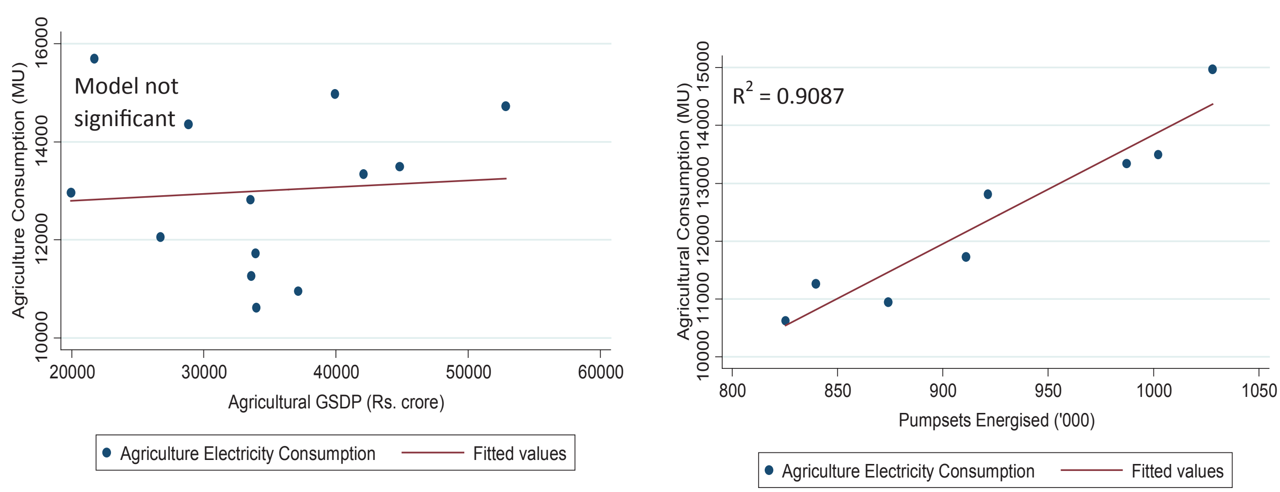


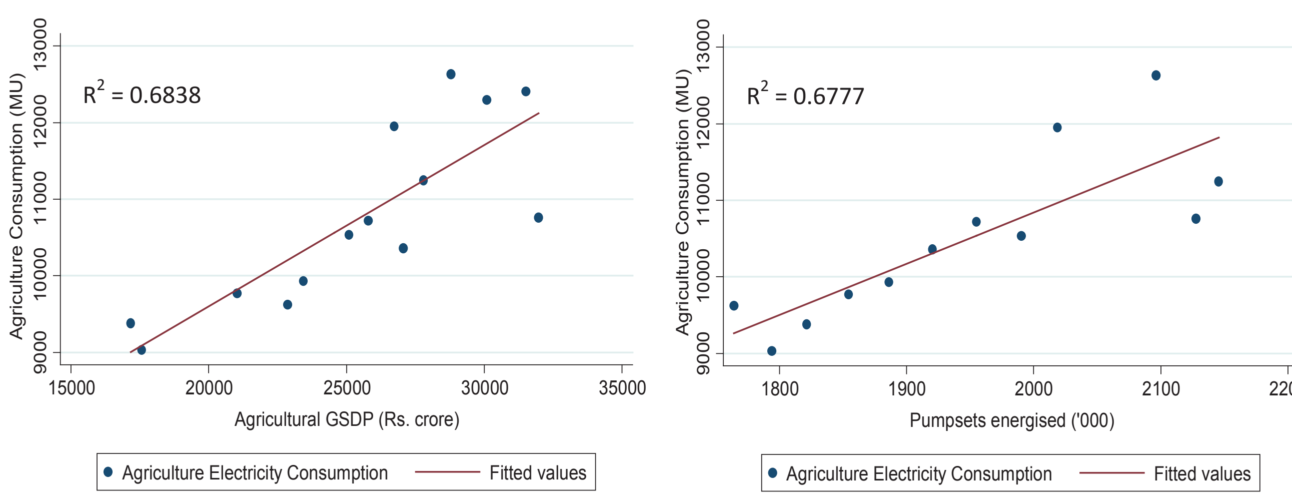
Exhibit 2.5: Regression of agricultural power consumption in Gujarat with agricultural GSDP and number of pumpsets



2.10 In case of Tamil Nadu, not only did total electricity consumption have high correlation with total GSDP—industrial and agricultural GSDP—but consumption from different sectors was also correlated with the GSDP of the respective sector. Agricultural power consumption had statistically significant correlation with agricultural GSDP (R^2 = 0.6838), which is shown in Exhibit 2.6. Furthermore, agricultural consumption was also correlated with number of pumpsets energized (R^2 = 0.6777). As in case of Gujarat, agricultural consumption in Tamil Nadu increased at a much lower rate (2% CAGR) as compared to that in other sectors (more than 6%) in the state, resulting in a decline in the contribution of agricultural electricity consumption to total electricity consumption. As the gross irrigated area remained relatively unchanged in the study period, it can be inferred that the growth in agricultural electricity demand was largely on account of increased use of electric pumpsets for irrigation purposes, and this causality may therefore need to be accounted in future projections of agricultural power demand for Tamil Nadu.

2.11 The analysis of electricity consumption in Delhi revealed that the residential and commercial sectors account for more than 75% of the states' total electricity consumption. Agricultural consumption has declined consistently in both magnitude and share in total consumption, and industrial consumption, while growing

Exhibit 2.6: Regression of agricultural power consumption in Tamil Nadu with agricultural GSDP and number of pumpsets



marginally in magnitude, has declined in terms of their contribution to total consumption. Therefore, future growth in demand in Delhi is likely to depend more on per capita income and standard of living of its future populace.

2.12 The analysis of the state-level case studies demonstrate that there is no one-size-fits-all model of electricity demand across states. An in-depth study for each state needs to be conducted to understand the changes in their underlying causal factors; the end-use activities; and also policies, programmes, and developments that might impact their electricity demand in the future.

Demand Scenario

2.13 In the present study, accessment of electricity demand has been made on the rationale that the total electricity consumption in a year will depend on that year's GDP as well as previous year's consumption of electricity. This is supported by the results of statistical analysis of past years' consumption with GDP as well as the following reasoning. Electricity consumption and GDP are closely inter-related and consumption of electricity has been seen to increase over time across economies—both due to consumption of new economic agents in various consumption categories as well as the increase in consumption of existing agents. Empirically, data on total electricity consumption and GDP in India also confirms this relationship—correlation coefficient is more than 95%. Apart from the existence of a strong correlation between electricity consumption and economic activity, we are likely to see an increased electrification on account of enhanced access of electricity to sections that were earlier not in a position to get access either on account of connectivity and/or affordability. In countries like India, the current year's consumption is expected to be higher than that of the previous year—the degree of increase depending on structural shifts in activity levels or end uses, introduction of specific policies or measures, etc.

2.14 Accordingly, at the All-India level, using historical data for the period 2001–16, a statistical model was developed using GDP and lagged electricity consumption as independent variables. The resultant model explained more than 99% of the variation in electricity demand in the past with R^2 value of 0.9941. It can be expressed as:

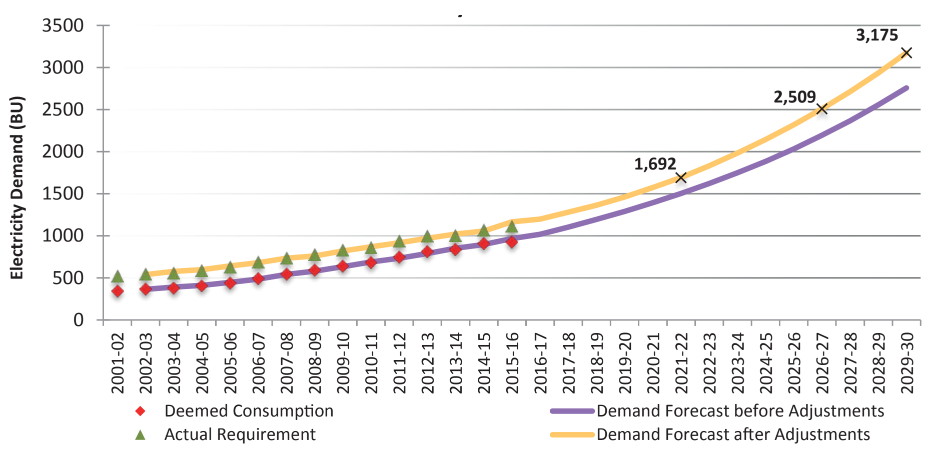
$$\log E_t = \alpha + \beta \times \log GDP_t + \gamma \times \log E_{t-1}$$

2.15 In this model, the GDP was forecasted using a 1st order auto-regressive model. Accordingly, the value of GDP in the current year was based on the GDP in the previous year. Past data was used from 1990-91 to 2015-16. The CAGR of GDP from 2001—02 to 2015—16 was 7.35% while that of the forecasted GDP was 7.5% between

2016—17 and 2029—30. This model inherently assumes that the relationship between GDP and electricity demand remains the same in the future as it was in the past, and addtionally consideres electricity demand in the preceding year than those farther back in time. However, there are certain aspects of electricity demand that are expected to change considerably in the near future which may cause the future growth trend to be different from that in the past. These factors, therefore, need to be accounted for separately.

2.16 One such factor is energy savings due to energy efficiency improvement. While there has been some autonomous energy efficiency improvement even in the past, the initiation of various specific energy saving programmes by BEE such as Standards & Labelling (S&L), PAT Scheme, and Energy Conservation Building Code (ECBC) have provided an impetus to energy conservation and efficiency measures since 2007. As a result of these measures, a substantial amount of energy consumption has been avoided during the last ten years which is regarded as energy savings[4]. The deemed consumption (total electricity requirement adjusted for T&D loss) was then adjusted using the energy savings, as available from BEE, to reveal the consumption that would have occurred in the absence of the energy-efficiency measures. Using the model already specified (based on the current year GDP and previous year consumption), deemed consumption was projected for 2016-17 to 2029-30 to reflect the actual consumption if there were no additional energy conservation and efficiency measures, such as those that have been recently initiated. Projected energy saving values, as available from BEE, were then netted out from the projected demand to account for energy efficiency and technological improvements in the future.

Exhibit 2.7: All India Electricity Demand Scenario



2.17 Similarly, adjustments were also made for likely growth in electric mobility and an increased electricity demand on account of rapid electrification of un-electrified households as these changes are also not expected to be captured fully in the past electricity consumption data. In case of electric mobility, electricity consumption of road transport has been considered to grow with a CAGR of 16.6% from 2016–17 to 2029–30. As demand for traction was assumed to grow at the same rate as in the past, no external adjustment was applied for it as the model already captures the past trend[5]. Further, additional energy consumption due to accelerated electrification of existing un-electrified households was separately captured by assuming that all existing un-electrified households would be electrified by 2022 with an initial basic consumption[6] of 1,000 kWh per annum and subsequently following the average growth rate of electricity consumption by the residential sector (8.03%[7]) in successive years. The forecasted final demand was then duly adjusted with future expected T&D loss to arrive at a forecasted total requirement of electricity at the national level. Keeping in view the trend of reduction in T&D losses during the last 15 years, T&D losses have been considered to reduce from the current level of 21.78% (2015–16) to 15% by 2021–22 and remain at the same level till 2029-30.

4 BEE, 2016. https://www.beeindia.gov.in/content/programmes
5 CEA, 2015. Growth of Electricity Sector in India From 1947-2015
6 Average consumption per connection in 2014-15 as calculated from CEA data. Number of un-electrified households as on April 30th, 2016 was obtained from DDUGJY website
7 CAGR of average domestic consumption in recent years (2001-02 to 2014-15)

2.18 The results of the forecasting exercise are depicted in Exhibit 2.7, which presents the forecasted values before and after adjustments for external factors like energy efficiency, T&D losses and electrification. As indicated, the total electricity requirement has been assessed to increased from 1,115 BU in 2015–16 to 1,691 BU in 2021–22 and 2,509 BU in 2026-27 with a CAGR of 7.66%. The per capita consumption increases from the prevailing level of 1,075 kWh to 1,490 kWh in 2021–22, 2,121 kWh per annum in 2026–27 and 2,634 units per annum in 2029–30.

Way Forward

2.19 The present study focused on assessment electricity demand based on GDP forecast and lagged electricity consumption. While these factors have been responsible for shaping demand in the past, and continue to do so in the future, there may be additional factors that influence electricity demand and must, therefore, be further examined in an in-depth manner to obtain a more holistic picture. To begin with, a deeper analysis needs to be done at the sectoral level for each state, as the drivers of growth in these sectors will vary across states. The simultaneous play of reduction in T&D losses, energy efficiency initiatives, increased electrification and growth in electricity consumption due to socio-economic factors make it imperative to study future electricity demand patterns closely.

2.20 Furthermore, policies and programmes that impact electricity demand, directly or indirectly, will have to be studied including impact of programmes, such as the National Mission for Enhanced Energy Efficiency, Make in India, LED Penetration and Streetlight National Programme, National Electric Mobility Mission, etc. Such an analysis will not only provide insights into the electricity consumption patterns across the country but will also give the foundation for projecting this demand into the future. TERI would, therefore, continue to refine and build upon the demand forecast done in this study through further detailed and disaggregated state-and sector-level analysis, using appropriate forecasting methods.

3. Supply Side Analysis and Demand – Supply Scenario

3.1 The power sector in India has been heavily dependent on fossil fuels (mainly, coal, lignite, gas and diesel). In 2016, coal-fired power plants had a share of more than 60 per cent in the country's installed capacity mix, followed by hydro and renewables constituting ~ 14.2% each. Going ahead, it is expected that the share of renewable in the generation mix will significantly increase, given the programmed capacity addition of renewables. The aggregate capacity of renewales is envisaged to increased 175 GW (PIB, 2015). As per this target, solar capacity is expected to increase from 5 GW in 2016 to 100 GW in 2022. Of this, 60 GW capacity is expected to be installed as ground mounted solar power plants and 40 GW is expected to be installed as rooftop solar. Installed wind capacity is expected to increase from 26.8 GW in 2015-16 to 60 GW in 2022. Moreover, capacity addition is also expected in bio-power (10 GW) and small hydro-power (5 GW). Apart from renewables, capacity additions are also expected in other sectors in the period between 2017-22. As per the draft National Electricity Plan (NEP), installed capacity of coal plants is expected to increase by ~ 50 GW; installed capacity of hydro, gas-based and nuclear power plants is expected to increase to ~58.1 GW, ~29.9 GW, and 9.5 GW respectively by 2022 (CEA, 2016). Moreover, in the case of nuclear and hydro power, further capacity addition of 4.8 GW and 12 GW is envisaged in the draft NEP between 2022 and 2027. Renewables energy sources too are expected to see an increase in capacity addition from 175 to 275 GW in 2027 (Table-3.1).

Table -3.1: Installed Capacity (MW)

Sources	Existing	Anticipated	
	2016	2022	2027
Solar	6763	1,00,000	1,50,000
Wind	26,867	60,000	1,00,000
Other RE*	9220	15,000	25,000
Coal	1,85,172	2,48,513	2,48,513
Gas	25,503	29,969	29,969
Nuclear	5,780	9,580	14,380
Hydro	42,801	58,131	70,131

***** *Includes bio-power, small hydropower and waste-to-energy***

Source: (CEA, 2016)

3.2 The capacity addition in various categories, especially renewables, is expected to have a substantial impact on the generation mix. RE-based generation currently contributes just about 5.6% of the total generation. With the planned capacity addition, renewables would have a significant share in the generation mix. The variability and intermittency of renewable generation and net demand incident on the grid due to emerging generation mix as well as electricity consumption patterns call for a detailed study at the micro level as well as macro level. The present exercise is an energy balance study at macro level looking at the contribution of renewable energy, other sources of energy put together and coal in meeting the assessed demand; the focus is primarily on coal and renewables (wind and solar). Considering the wide scope and complexity of the issues, this exercise starts by assessing the energy balance at the national level to understand the supply scenario until 2030. A more detailed analysis on the supply side will follow.

Methodology

3.3 Two stylised scenarios have been considered to assess energy balance from 2017 to 2030. The first scenario takes into consideration higher capacity addition of renewables. Keeping in view the challenges associated with quantum jump in renewable capacity addition contemplated by the Government of India , another scenario with a lower trajectory of RE capacity addition has been considered. The study takes into consideration capacity addition and generation from wind and solar sources only, considering that the generation from bio power, small hydro and waste-to-energy is not substantial in the energy mix.

High Renewable Growth Scenario (HRES)

3.4 Under this scenario, renewable capacity addition is given higher priority than other sources of power. Considering the quantum of renewables planned to be added to the grid, it is here in that by 2027, issues pertaining to managing the variable and intermittent nature of renewable generation would get addressed. It is also assumed that energy storage technology would become viable beyond 2027 such that the price of electricity from renewable energy storage achieves parity with the price of electricity generated from domestic coal sources at prices below INR 5/kWh.

Capacity Addition

3.5 The high renewable energy scenario is based on the premise that capacity from renewable energy meets target capacity addition of 175 GW by 2022. Beyond 2022, a capacity addition of 25 GW per year has been assumed for renewables (wind and solar) until existing capacity meets anticipated demand. To meet unmet demand beyond 2026, this scenario assumes capacity addition in both wind and solar, presuming that storage technology has become viable. It is also assumed that more capacity will be added in the country in solar than wind. Therefore capacity addition of wind to solar beyond 2026 has been assumed at 1:0.6 (based on the proportion of the capacity in 2022).

3.6 Capacity of coal and lignite plants is expected to increase from ~185 GW in 2015–16 to ~248 GW in 2021–22, after accounting for retirement of 5200 MW inefficient coal-based thermal power plants which are more than 25 years old. Between 2022 and 2027, a further retirement of approximately 30 GW of similar coal-based capacity is expected. In this exercise a constant reduction of approximately 6 GW every year after 2022 has been assumed, such that total installed capacity reduces to ~218 GW in 2026-27. There may be capacity additions of supercritical thermal power plants to make up for the plants which will retire but this has not been considered in the scenario.

3.7 Gas-fired thermal power plants are expected to see a capacity addition of 126 MW in 2016-17 and a further capacity addition of ~4.3 GW. Commissioning of this capacity has been assumed in 2019-20. This is considering various gas infrastructure capacities (in terms of LNG terminals as also gas pipelines, especially in eastern India) are expected to be made available by 2020 (PIB, 2015). Nuclear capacity is expected to witness an increase to ~9.5 GW in 2021–22 and thereafter capacity addition has been assumed at 1000 MW every year such that total installed capacity increases to ~14.3 GW by the end of 2026–27. In respect of hydropower, the capacity addition until 2022 is ~15 GW. As per draft NEP a capacity of 12 GW is likely to be added by 2027. For the purpose of the present study the same has been phased evenly in each year.

Table 3.2: Installed Capacity under HRES (MW)

Sources	Anticipated		
	2022	**2027**	**2030**
Solar	1,00,000	2,94,109	5,33,538
Wind	60,000	1,76,466	3,20,123
Coal	2,48,513	2,18,207	2,18,207
Gas	29,969	29,969	29,969
Nuclear	9,580	14,380	14,380
Hydro	58,131	70,131	70,131

Plant Load Factor

3.8 Based on a review of the Plant Load Factor (PLF)/Capacity Utilization Factor (CUF) for nuclear and hydro power plants since 2008-09, an average PLF/CUF of 75% and 35% respectively has been assumed for the period between 2016-17 and 2029-30. For gas-based plants, prevailing PLF of about ~22% has been considered. In view of limited availability of gas, operation of these plants has been contemplated for 6 hours in a day. In the case of solar PV, a CUF of 19% has been assumed as per the Central Electricity Regulatory Commission (CERC) tariff order (CERC, 2016). A degradation of 0.8% has been assumed on the generation (NCPRE & NISE , 2014). As per the CERC tariff order (2016), the CUF for wind energy ranges between 20% and 32%, depending on the zones. Since most of the new wind plants to be set up to meet the target of 60,000 MW are expected to be installed in zone 3, a CUF of 25% has been assumed.

New Capacity Addition

3.9 It has been assumed that once existing generation capacity meets the anticipated demand and the PLF of coal plants increases to ~80%, entire unmet demand will be met via capacity additions in renewables. To bifurcate sourcing of demand between wind generation and solar generation a weighted average of the CUF and the capacity in 2022 has been assumed.

Low Renewable Energy Scenario (LRES)

3.10 In this scenario, a lower trajectory renewable capacity has been assumed in view of the challenges to be addressed and lack of certainty about solar plus battery prices achieving grid parity.

Capacity Addition

3.11 In this scenario, aggregate capacity of renewables has been considered as 125 GW by 2022. This is consistent with one of the scenarios mentioned in the draft NEP. Beyond 2022, renewable capacity addition at the rate of 20 GW per year has been considered until 2027, with proportion of solar to wind capacity being 1.2:1 in line with their relative proportion considered in 2022. With such an assumption, cumulative wind and solar installed capacity totals to 170 GW in 2025. Beyond 2027 and until 2030, the capacity addition has been assumed at 25 GW per year in such a manner that the proportion of solar capacity to wind capacity is 1.6:1.

3.12 The trajectory for coal installed capacity in this scenario is similar to that in the HRES, until its PLF increases to ~77% (in 2025). Beyond 2025, generation from renewables is capped and all unmet demand is met through capacity addition in coal-fired thermal power plants. The installed capacity as well as additions for gas, nuclear and hydropower remain the same as in the HRES.

Table 3.3: Installed Capacity under LRES (MW)

Sources	Anticipated		
	2022	**2027**	**2030**
Solar	60,000	1,14,545	1,61,420
Wind	50,000	95,455	1,22,727
Coal	2,48,513	3,19,628	4,74,855
Gas	29,969	29,969	29,969
Nuclear	9,580	14,380	14,380
Hydro	58,131	70,131	70,131

Plant Load Factor

3.13 The assumptions on Plant Load Factor and Capacity Utilization Factor remain the same as in HRES scenario for all the energy sources.

New Capacity Addition

3.14 Once the PLF of coal based thermal power plant reaches ~77% it is assumed that all unmet demand will be met from new coal capacity.

Assessment of Coal Demand

3.15 By assuming the total generation needed from non-coal sources, the results of the exercise lead to generation needed from coal-based generation. The PLF of the entire coal fleet as well as the coal requirement till 2030 has been worked out taking in to consideration the efficiency of the coal plant, PLF and grade of coal.

Efficiency

3.16 During the 12th Plan, capacity addition from super-critical technology is likely to contribute about 39% of the total capacity addition (33,490 MW) in the coal-fired thermal power plants (CEA, 2016). Further, with the addition of 50, 025 MW, the share of super-critical plant capacity is expected to increase to 31% of the total coal-based installed capacity. This share could be even higher if capacity additions based on super-critical plants are made to make up for the plants which will be retired between 2022 and 2027. In the past, the subcritical technology of Indian coal-fired fleet had an average efficiency of ~31% as compared to the world average of 35.1% (CEA & AF Mercados EMI, 2013). Moreover, the high ash content in Indian coal inevitably leads to efficiency loss. There has been some efficiency improvement in 2013-14 (34%) (CEA, 2016). Considering these factors, an efficiency of 34% has been assumed which increases to ~37% in 2022 and remains constant thereafter.

Specific Coal Consumption

3.17 The specific coal consumption in the country varies depending on the grade of coal being used, age, technology, and size of the plant and efficiency of the operations. To assess the grade of coal, the exercise took note of various grades of non-coking coal which were despatched by coal companies during 2014-15 and 2015-16. The two grades with the most quantity of domestic coal despatched during the last two years were G11 grade (4000 kCal/kg-4200 kCal/kg) and G12 grade (3700 kCal/kg-4000 kCal/kg) (CCO, 2016) (CCO, 2015). In view of this, the GCV of 4000 kCal/kg which is the upper bound of the G12 grade and the lower bound of the G11 grade was assumed.

Findings

High Renewables Scenario

Impact on Renewables

3.18 In HRES, the share of coal-based installed capacity decreases from 49% of the total installed capacity in 2022 to ~18% in 2030, while the share of installed capacity of renewables increases from 32% in 2022 to 72% in 2030. The share of installed capacity of solar plant alone in 2030 comes to ~45% of the total capacity. The share of wind installed capacity meanwhile increases from 12% in 2022 to 27% in 2030 (Exhibit 3.1 & 3.2). Considering that unmet demand from 2027 is met from renewables, there is a sharp spike in growth of installed capacity of solar and wind plants between 2026 and 2027 of about 81%. The rate of capacity addition for both sources though taper after the sharp spike in 2027.

Exhibit 3.1: Installed Capacity of Solar Plants under HRES

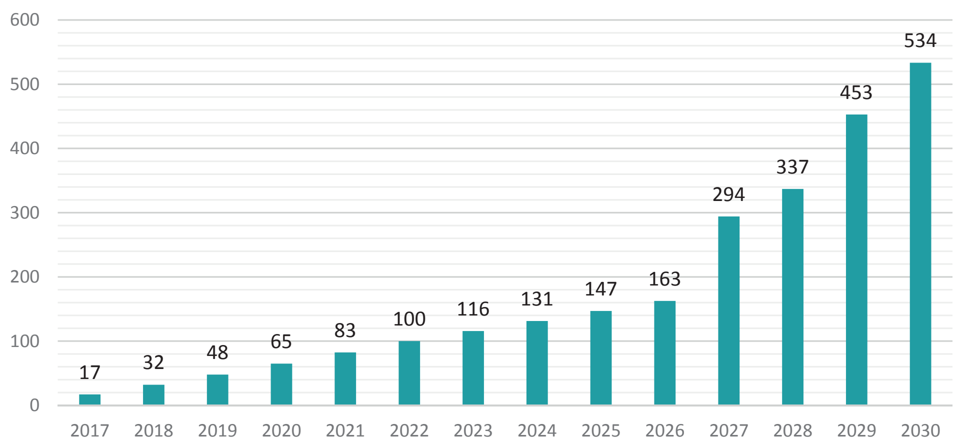
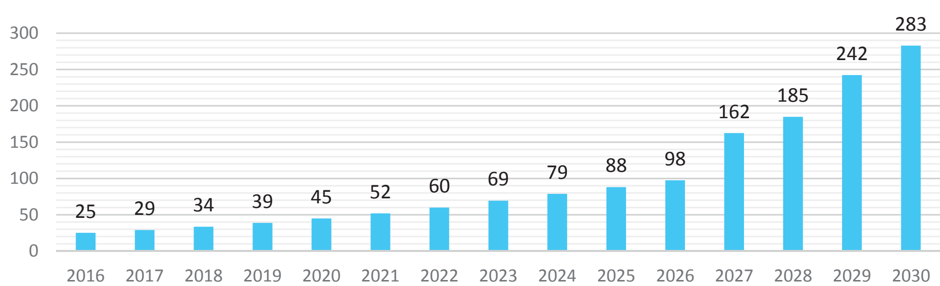


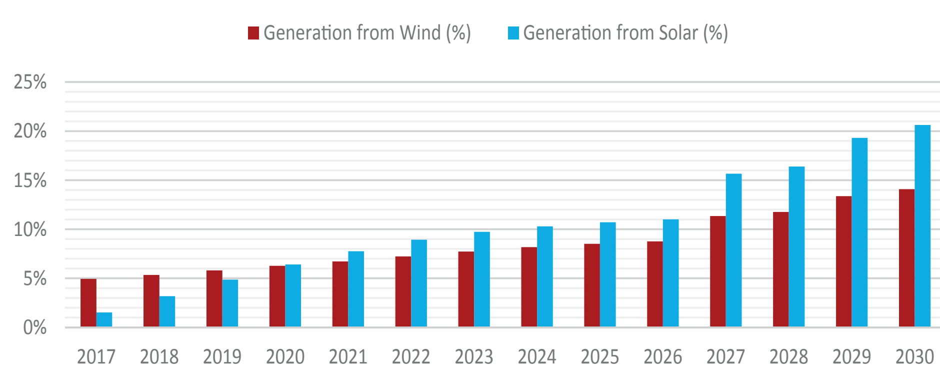
Exhibit 3.2: Installed Capacity of Wind Plants under HRES



****2015-16 are based on actual numbers***

3.19 Consequently, generation from wind and solar power plants also increase from 6.47% in 2017 to ~34% in 2030. Solar generation increases from ~18 BU in 2017 to ~614 BU in 2030. While wind-based generation increases from ~59 BU to ~488 BU (exhibit 3.3).

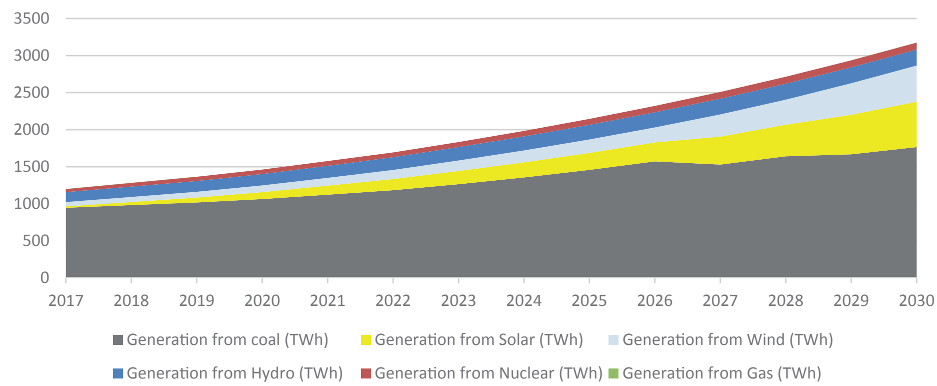
Exhibit 3.3: Share of Generation from Renewables



3.20 Generation from non-coal sources in the HRES increases from 21% in 2017 to ~44% in 2030. Post 2026, a sharp spike is seen in the share of generation from non-coal sources, given increasing RE capacity (Exhibit 3.4). Given such a situation in the non-coal generation, coal-based generation is seen decreasing from ~79% 2016-17 to ~56% in 2030 (Exhibit 3.5).

Exhibit 3.4: Share of Generation from Renewables

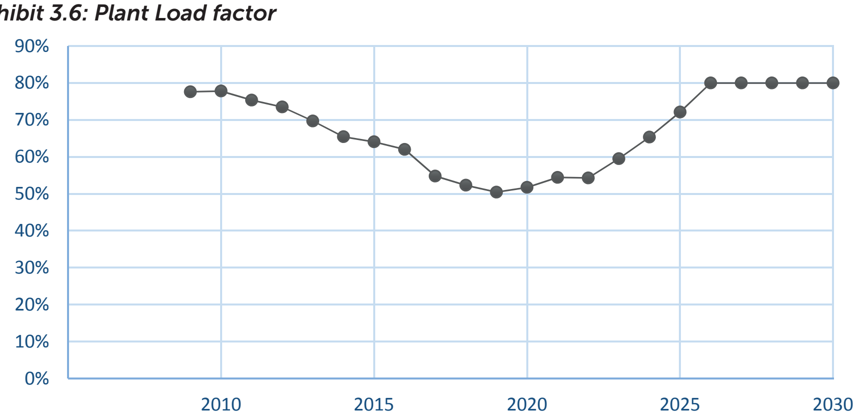
Exhibit 3.5: Source-wise Energy Supply



Impact on coal

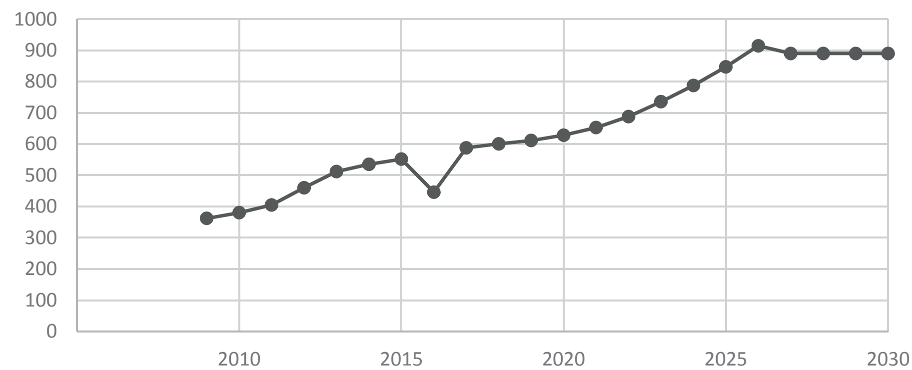
3.21 Considering the decreasing share of generation from coal-based power plants and the expected capacity addition until 2022, the PLF of coal power plants is seen falling from 62% in 2015-16 to ~54% in 2022. Beyond 2022, the PLF is seen increasing given the retirement of coal plants which are older than 25 years (CEA, 2016). Thus, the PLF increases to ~60% in 2023 and further to 80% in 2026, after which it has been assumed to be , without any new coal-capacity additions until 2030 (Exhibit 3.6).

Exhibit 3.6: Plant Load factor



3.22 The plant load factor has a direct impact on coal demand. In the next fifteen years, under this scenario, coal requirement for power generation from utilities is expected to increase at a CAGR of ~5%. Coal demand is seen increasing from 446 MT in 2015-16 to 688 MT in 2022 and ~915 MT in 2026. After 2026, there is slight dip in coal demand to 890 MT in 2027 until 2030, considering plants being retired and it remains constant thereafter given the capacity addition in RE (Exhibit 3.7).

Exhibit 3.7: Coal Requirement (MT)



Low Renewables Senario

Impact on Renewables

3.23 In the LRES the share of total installed capacity of RE increases from ~24% in 2022 to ~39% in 2027 and then decreases to ~33% in 2030. Solar-based installed capacity increases to ~161 GW in 2030 from ~114 GW in 2027 and 60 GW in 2022. Wind-based capacity meanwhile reaches ~122 GW in 2030 from ~95 GW in 2027 and ~50 GW in 2022 (Exhibit 3.8). In comparison to the HRES, the share of RE in the generation mix increases from ~6% in 2017 to only 11% in 2022. Beyond 2026, considering additions in coal-based capacity, the share of RE generation increases to ~16% (Exhibit 3.9).

Exhibit 3.8: Installed capacity of wind and solar-based capacity

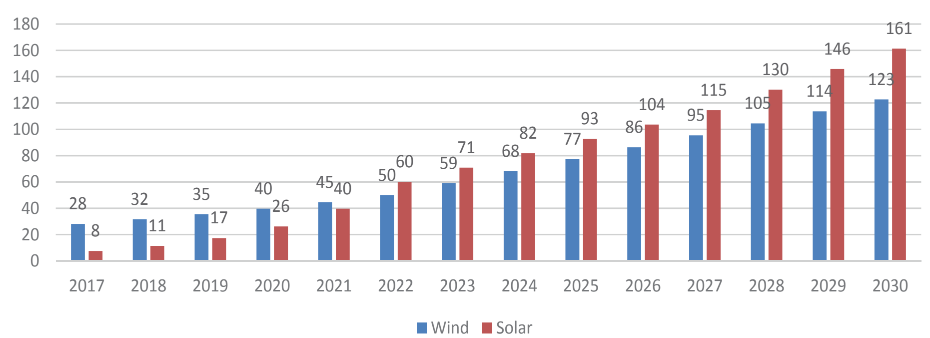
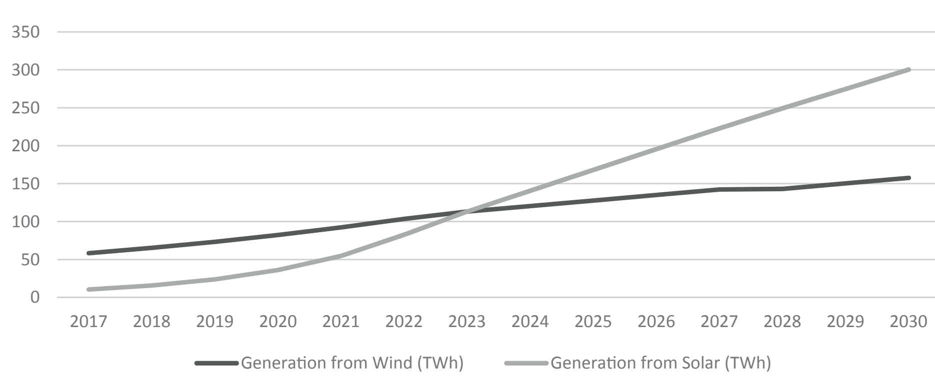


Exhibit 3.9: Total generation from wind and solar capacity



3.24 The share of non-coal sources in the generation mix ranges between ~20% and ~26%. Considering the capacity addition in RE, it forms the bulk of non-coal generation. The share of coal-based installed capacity increases from ~40% in 2027 to ~56% in 2030 due to capacity additions (Exhibit 3.10 and 3.11). Generation from coal increases from 954 BU in 2017 to about 2354 BU in 2030.

Exhibit 3.10: Generation from coal and non-coal sources

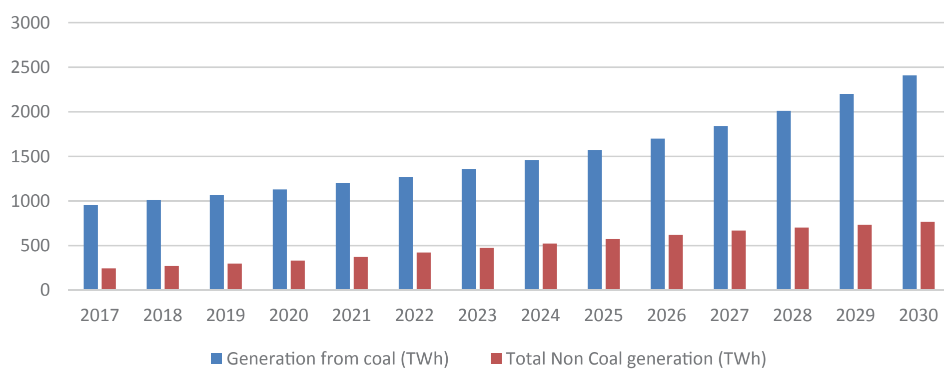
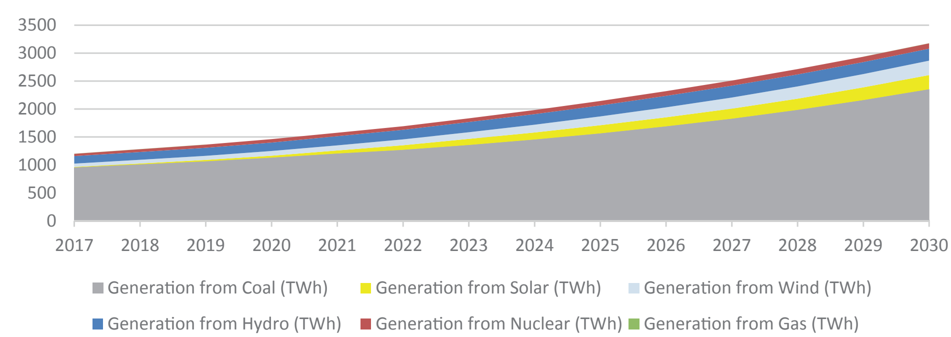


Exhibit 3.11: Source-wise Energy Supply



Impact on Coal

3.25 As per the calculations of this exercise, by 2025-26, existing coal capacity would not be adequate to meet the demand, especially considering that some amount of coal-based capacity is being retired between 2022 and 2027. Thus, to meet the demand, coal-based generation capacity is likely to increase to 230 GW in 2024–25 to 474 GW in 2029–30. (Exhibit 3.12). Thus, the PLF of coal-based power plants follows a declining trajectory from 64% in 2014-15 to 53% in 2018-19 and thereafter shows an upward trend, reaching upto 78% in 2025 (Exhibit 3.13). It is then capped at 78% in view of diversity of demand, planned maintenance and forced outages. The lowest PLF attained during this period is ~53% in 2019.

Exhibit 3.12: Expected Coal-based capacity (2024-25) & additions beyond 2025

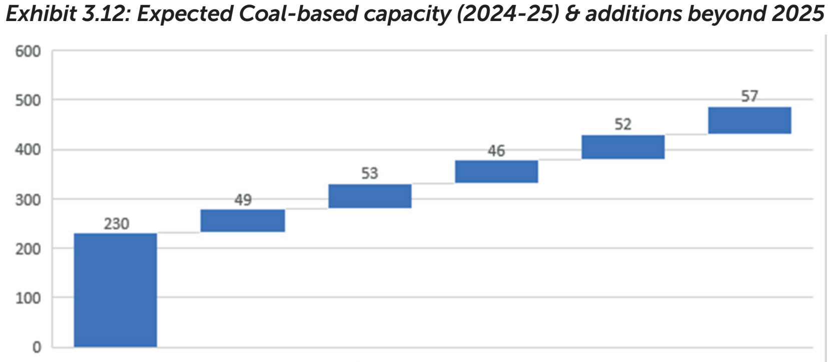
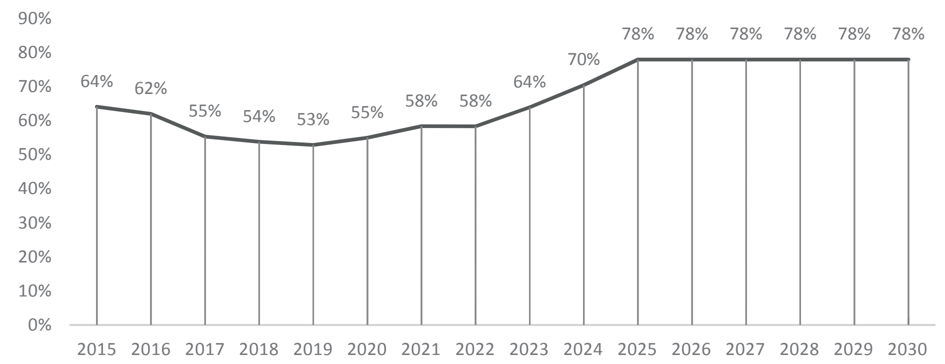
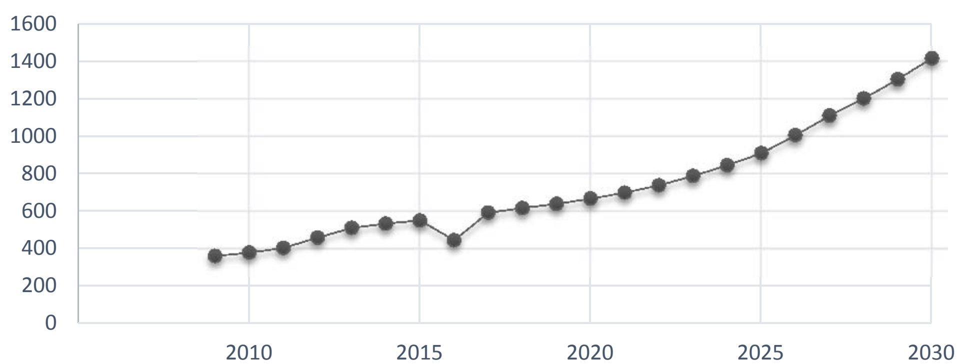


Exhibit 3.13: Plant Load Factor



3.26 The coal requirement is seen increasing at a constant rate of 9% for the next fourteen years, rising from 446 MT in 2015-16 to 739 MT in 2022 and reaches about 1 BT in 2026, finally coming to about 1.4 BT in 2030 (Exhibit 3.14). This coal requirement is subject to change depending on improvement in plant efficiency and quality of coal.

Exhibit 3.14: Coal Requirement (MT) for generation of power by utilities



Way Forward

3.27 The present exercise is an energy balance study at macro level looking at the contribution of renewable energy, other sources of energy put together and coal in meeting the assessed demand; the focus is primarily on coal and renewables (wind and solar). Considering the wide scope and complexity of the issues, this exercise starts by assessing the energy balance at the national level to understand the supply scenario until 2030. A more detailed analysis on the supply side will follow.

4. Conclusions

1. The Indian electricity sector is witnessing a major transformation in respect of demand growth, energy mix and market operations. Various socio-economic factors and technology developments are contributing to this. A detailed and critical assessment of the emerging scenario is of paramount importance for the sustainable development of the sector. A macro-level assessment in stylised scenarios up to 2029–30 are covered in the present study.

2. Analysis of the demand during the past 15 years shows that the demand is strongly influenced by various economic factors. These are also found to vary among states, depending upon the economic activity predominant in that state warranting detailed econometric studies for the states. The present study has focussed on assessment of electricity demand at all India level on the premise that the total electricity consumption in a year will depend upon that year's GDP along-with previous years' electricity consumption. Empirically, data on all India electricity consumption and GDP has shown a high correlation coefficient of more than 95%.

3. Based on the above, all India level demand projections in the stylised scenarios upto 2029–30 have been carried out using the electricity demand and GDP data from 2001–02 to 2015–16. The impact of future end-use energy efficiency improvements, electrification of new households and additional requirement for electrified road transport, which may not follow the past trend has been accounted for exogenously. The study shows that the demand is likely to grow from 1115 BU in 2015–16 to 1,692 BU in 2021–22, 2,509 BU in 2026–27 and 3,175 in 2029–30 representing a CAGR of 7.2%, 7.7% and 7.8% respectively. Per-capita consumption of electricity is projected to increase from the prevailing level of 1,075 kWh to 1,490 kWh in 2021–22, 2,121 kWh 2026–27 and 2634 kWh in 2029–30. These demand projections may go up or down depending on the success of the UDAY programme, Make in India initiative, deceleration in the use of captive power, energy efficiency, DSM programs, etc.

4. The energy mix is also projected to undergo radical changes with increased focus on RE (especially solar and wind) and considering the operational and environmental issues related to coal power plants. The increasing penetration of solar and wind (which have inherent high intermittency and variability) would no doubt present a number of challenges in respect to planning and operation of power systems. Timely strengthening of the grid infrastructure, provision of adequate balancing and storage capacity, ensuring requisite flexibility in ramping up and down, improved forecasting of RE power as well as demand, improved financial health of utilities would be key factors in this context. Taking these into account two scenarios of RE development have been considered in this study. The HRES considers capacity increase from the prevailing level of about 50 GW to 175 GW in 2021–22 and 275 GW in 2025-26. The LRES considers capacity addition of 75 GW during the first 5 years (reaching a level of 125 GW) in 2021-22 and 100 GW in the next 5 years (reaching a level of 225 GW) in 2026–27.

5. The results indicate that the energy that would be available from RE sources, storage hydro, nuclear and gas plants (existing as well as those planned/committed) would suffice for meeting the remainder of the demand for electricity at the national level during the next 7-8 years. This would in other words mean that no new coal plants would be needed and the plant load factor (PLF) of coal based plants would be in the range of 78-80% in 2024–25 and 2025–26.

6. The type of new capacity which will be required in the following years would depend upon how the aforementioned challenges get addressed and cost economics of storage technologies (which could increase the dispatchability of RE plants). In the HRES, it is assumed that the remainder of the demand in the subsequent

years (over and above what can be met from plants already considered up to 2016–27) would be through RE capacity additions, on the premise that the price of RE+ balancing electricity would be about ₹5 per kWh and competitive with the price of electricity from coal. In this scenario, the share of electricity generated from RE would increase from the present level of ~ 5.6% to ~34% in by 2030 and the share of coal-based electricity generation would reduce from ~ 73 % to ~56%. In the LRES the additional requirement of supply beyond 2025–26 is assumed to be largely met by new coal capacity (and other conventional sources including gas depending upon the cost economics at that time), and to a limited extent from new RE capacity.

7. The evolving scenario being dynamic, periodic, preferably annual, assessment is imperative to take stock of the emerging scenario by evaluating the evolving demand and supply trajectories, technological developments, learning from global and Indian experiences in the ensuing period as well as factoring in various techno-economic considerations and above all the financial health of the utilities.

Abbreviations

BEE	Bureau of Energy Efficiency
BkWh/BU	Billion kilo-Watt hours/ Billion Units
CAGR	Compound Annual Growth Rate
CCO	Coal controller's Organization
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CUF	Capacity Utilization Factor
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
ECBC	Energy Conservation Building Code
GDP	Gross Domestic Product
GSDP	Gross State Domestic Product
GW	Giga Watt
HRES	High Renewables Scenario
IC	Installed Capacity
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
INR	Indian Rupees
kCal/kg	Kilocalorie/kilogram
kWh	Kilo Watt-hour
LED	Light Emitting Diode
LRES	Low Renewables Scenario
MT	Million Tonne
MU	Million Unit
MW	Mega Watt
MWh	Mega Watt-hour
NCPRE	National Centre for Photovoltaic Research and Education
NDCs	Nationally Determined Contributions
NEP	National Electricity Plan
NISE	National Institute for Solar Energy
O&M	Operations & Maintenance
PAT	Perform Achieve Trade
PIB	Press Information Bureau
PLF	Plant Load Factor
RBI	Reserve Bank of India
RE	Renewable Energy
S&L	Standards & Labelling
T&D	Transmission and Distribution
TERI	The Energy and Resources Institute
UDAY	Ujwal DISCOM Assurance Yojana
USD	US Dollar
Vs	Versus
W+S	Wind + Solar

The Energy and Resources Institute