What should we base the Baseload on?

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Today India's baseload is dominated by coal but in order to reduce emissions, the baseload has to shift towards more, non-polluting sources. Most of the candidates for new baseload aren't economical considering available technology and the variable output. In the case of solar, for instance, the expensive grid storage capability necessitated by its diurnal variability poses a huge hindrance in it becoming a baseload plant. Nuclear energy, on the other hand, stands out when reliability is considered. Thus, we need a new and clear focus on nuclear energy.

Background

In 2015, representatives from countries around the world came together for COP21 in Paris, to discuss the serious issue of the global challenge of climate actions. Every major country put down their targets to either cap or reduce their GHG emissions. This is to avoid the catastrophic and irreversible increase in global temperature of 2^oC. The decisions were voluntary and monitored.

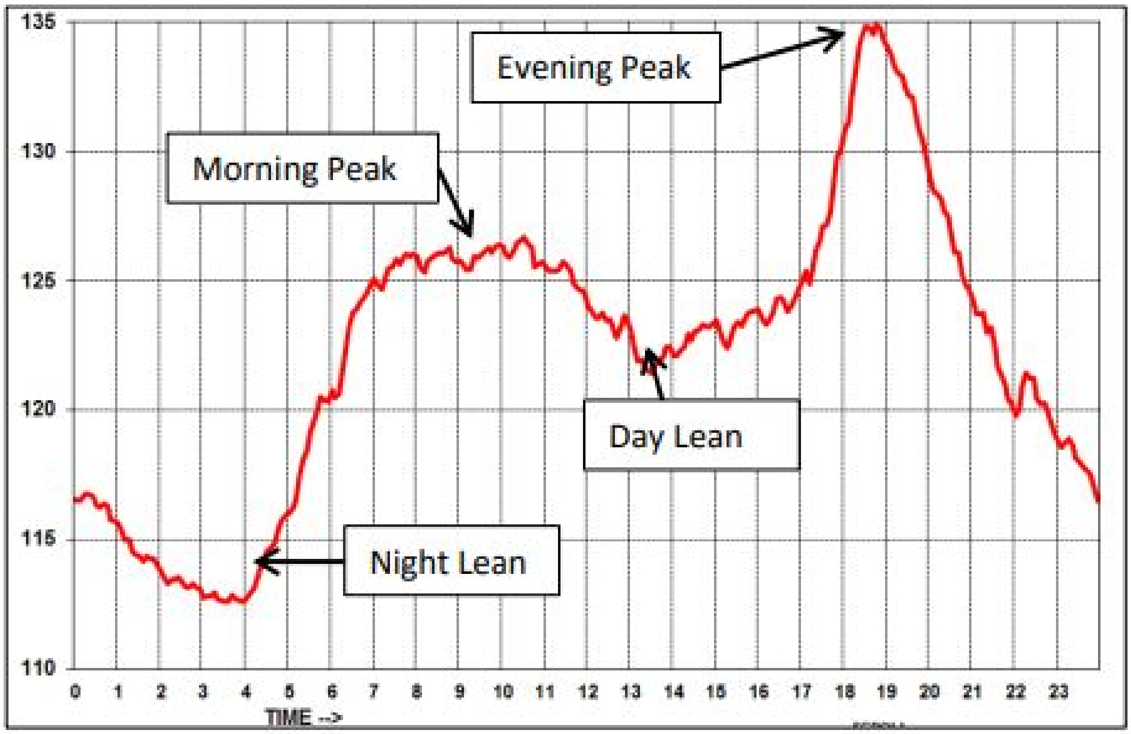
In India, the Electricity sector is dominated by the Coal with more than 75 % generation share. It is the main driver of the CO_2 emission in the country. The coal power plant by its nature is used as a baseload plant which is run continuously for power generation.

India's commitment

India has committed to reducing the greenhouse emission intensity of its GDP by 33 to 35% from the 2005 level by 2030 as one of its nationally determined contributions. It has also pledged to achieve installed power generation capacity of more than 40% from Non-fossil fuels. There are several options eg. Solar, Nuclear and other non-fossils power generation sources. In these Nuclear stands out due to several reasons: Capability to work as a reliable source for baseload power generation, High capacity factor and low operating cost.

Baseloads

In the figure given below, the load varies from 115 GW to 135 GW, with a minimum requirement of 115 GW power all the time, this is generally provided by a plant, with very high capacity factor. Rest intermediate supply is met by the use of low capacity factor plants, which have high running cost but also high ramping rate. It is evident that the energy sector of a country is dominated by the baseload generation mix. Considering projections (IESS) that the total demand of Electricity in India will grow up to 4697 TWh in 2047, nearly 4 times the current demand, there needs to be an effective solution to a less carbon-intensive baseload generation.



A typical load curve of India (2015) (in GW) Source: POSOCO

Analysis

Two scenarios are taken for the year 2050- medium GDP growth (8.2 trillion USD) and high GDP growth (11.6 trillion USD). This will create a demand for 4250 TWh/yr and 5000 TWh/yr based on IESS forecast.

	Medium GDP growth	**High GDP growth**
GDP at 2050	8.2 trillion USD	11.6 trillion USD
Electricity Demand (at 2050)	4250 TWh/year	5000 TWh/year
Emission intensity target	0.48 kg CO_2/USD	0.32 kg CO_2 / USD
Capped CO_2 from coal	1764 $MtCO_2$	1665 $MtCO_2$
Baseload generation from non-coal scenarios	1406 TWh/yr	2193 TWh/yr

SHOULD WE GO FULL NUCLEAR?

	Scenario - 1 (Medium GDP growth)	**Scenario -2 (High GDP growth)**
Total Required Nuclear powerplant Capacity	200.6 GWe	313 GWe
Additional installation (including plants with in-principle approval)	175.72 GWe	288.12 GWe
Upfront Installation Cost	Rs 25.8 lakh crore	Rs 42.4 lakh crore

WHAT ELSE CAN WE DO?

Say that we achieve 100 GWe installed nuclear capacity and decide to meet the rest (705 TWh/yr, 1493 TWh/yr) of the generation using solar panels and grid storage facility. This can be done by scheduling the powerplants such that solar PV meets the entire load for some part of the day, thus, nearly eliminating the need for battery banks (except for reliability). The other way is to have battery banks like Powerpack to store the excess of solar-generated energy during the day and discharge it at night. Currently, the cost of Powerpack 2 is 398 USD/kWh.

Conclusion

Either way, there needs to be a holistic focus on nuclear energy, especially to ensure that there is proper information dissemination and myths are dispelled. International cooperation to ensure that nuclear energy remains a safe form of generation, and to ensure that reactors don't remain idle due to paucity of fuel is also an important matter to be dealt with. The source, possibly with solar, will form an important component of the country's baseload if India is to act responsibly in wake of climate change.

Section B

Historical data (1960-2017) for India's GDP was obtained from the World Bank. Forecasting of GDP up to 2050 was done by using Excel's in-built exponential smoothening model with two scenarios corresponding to medium (8.2 trillion USD) and high growth (11.6 trillion USD).

To project electricity demand, we used data from IESS - 2047 scenarios and extrapolated them to 2050, giving us demands of 4250 TWh/yr and 5000 TWh/yr for medium and high growth respectively. As per current trends, we can expect that 88.5 % of this demand is to be met by baseload plants.

Each scenario had a corresponding emission reduction target - medium and high growths with 25 % and 50 % reductions respectively by 2050 in emission intensity with respect to 2030. According to IEA, India's emission intensity in 2005 was 0.96 kg CO_2 / USD. Assuming India meets its NDC on emission reduction, emission intensity targets are 0.48 kg CO_2 / USD for medium growth and 0.32 kg CO_2 / USD for high growth scenarios.

From data published in the GHG platform India National Estimates (2005-2013) - 2017 Series, it is estimated that 45 % of all CO_2 emissions in India are from coal-based electricity generation. Thus, we can calculate the carbon dioxide emissions permissible from coal generation - 1764 $MtCO_2$ for the medium-growth scenario and 1665 $MtCO_2$ for the high-growth scenario. If the coal powerplants emit, on an average, 800g / kWh of electricity, we can set a ceiling on the amount of baseload demand that can be met by coal.

Capping the hydropower generation at 150 TWh/yr, we are left with 1406 TWh/yr and 2193 TWh/yr for medium and high-growth scenarios respectively.

NUCLEAR:

The data was obtained from NPCIL (current plants) and a 2019 DAE press release (planned) (http://pib.nic.in/newsite/PrintRelease.aspx?relid=187135). The estimate for the required nuclear capacity is done assuming India manages to achieve an 80% capacity factor - excluding the non-generating plants it is currently at 70.71%. To look at an indicative cost for setting up a new plant, the government has sanctioned Rs 14.71 crore / MW for 2 units of 700 MW each at Gorakhpur.

SOLAR:

We have assumed a capacity factor of 0.2 for calculating the required solar installation. To calculate the amount of grid storage, required we assume that 75% of energy generated from solar needs to be stored.

Comment and Critique:

Prabhat Ranjan

From the data, it is evident that India will likely achieve its GHG emission target specified in the INDC owing to its rapid growth of GDP. But this doesn't solve really curb absolute emissions. This policy brief analyses the probable baseload mix in the energy sector. Here other sources of energy are neglected other than nuclear which is consistent with the fact that all other sources renewables are inconsistent and have a very low capacity factor. Gas power plants are ignored due to its economical un-viability in India, but it could change the whole energy mix in future. In the case of Large hydro, they could be used as a baseload plant, but the potential of hydropower in India is limited due to several factors, also the environmental impact of large hydro is huge. Being a nuclear fuel deprived nation it will be a difficult transition for the country. And the view of the energy mix is very prone to the changes in public opinion, especially in case of nuclear energy. Investments has to be made and in the making new power plants. And the transition will take time since we already have a well-established coal-dominated power generation system.

Krishna Bansal

We can see from our calculations that we are not able to meet the emission regulation if we want to cater the energy demand. To cater to energy demand we should look for non-polluting energy sources. Energy indeed to complete our daily requirement. If we consider total emission or pollution generation is a key hurdle to meet the energy requirement by coal and nuclear. We know that emission from the transportation sector a major share. We can go for EVs to reduce pollution formation. Although the cost of EVs is high because of the price of the battery.

We can not phase out coal or nuclear from our system. Because as the high energy generation scenario comes in the picture, then during some days of the there are the chances of hype of demand. To cater to this boost of demand we should keep nuclear-based power plant as a backup.

Appendices

1) Per unit electricity generation cost by Coal based power plant

To calculate the per unit electricity generation we are taking all power plant of 600 MW generation capacity. The total cost of a unit generation considers two part of cost fixed cost and variable cost. Following are the data for the 600 MW coal-based power plant.

Table1:- Parameter used in the cost calculation

Sr. No	Parameter	Parametric value
1	Capital cost [1]	18.38 Lac/MW
2	Debt equity ratio	70:30
3	Rate of equity (ROE)	15.5 %
4	Interest on loan	11 % (SBI bank rate)
5	Interest on working capital	10 %
6	Depreciation	5.28 %
7	O&M	18.38 Lac/MW
8	The calorific value of coal [2]	3765 kcal/kg
9	Station heat rate	2375 kcal/kWh
10	Coal consumption	4780 ton/MW-Annum
11	Cost of coal [3]	886 Rs/kg
12	Power consumed by auxiliary	6.5 % of electricity generation
13	Plant capacity factor	70 %

1.1) Fixed cost calculation [4,5]

1) *Return on equity*

- Capital cost = Plant capacity * Capital cost
  $= 600*18.38*10^5$
  $= 11028*10^5$ Rs.
- Equity = Capital cost*Equity
  $= 18.38*10^5*0.3$
  = 551400 Rs.
- Debt = Capital cost * Debt
  $= 18.38*10^5*0.7$
  = 1286600 Rs.

- Return on Equity= Equity * ROE
  $$= \frac{15.5*0.3*18.38*100000}{100}$$
  = 85467 Rs.

2) *Interest on loan*

= Interest rate*Debt
= 0.11*1286600
= 141526 Rs

3) *Interest on working capital*

= Interest rate*ROE
$= 0.1*11028*10^5$
$= 11028*10^4$ Rs.

4) *Depreciation*

= Capital Cost * Depreciation Rate
$$= \frac{5.28*1102800000}{100}$$
= 58227840 Rs.

5) *O&M Cost*

= Plant Capacity * O&M Rate
= 600*20.43
$= 12258*10^5$ Rs

6) *Power generation in a year*

= Plant capacity * Hours in a year * Plant capacity factor
= 600000(kw)*24*365*0.7
$= 36792*10^5$ kwh

Total fixed cost = *Return on equity* + *Interest on loan* + *Interest on working capital* + *Depreciation* + *O&M Cost*

= 1102800000+1141526+110280000+58227840+1225800000
= 2497249366 Rs.

Fixed cost per unit = *Total fixed cost / Total electricity generation*
= 2497249366/36792*10^5
= 1.473 Rs/Unit

1.2 Variable cost calculation

1. *Cost of coal consumption*

= Cost of coal * Coal required for per unit electricity generation
= 0.886 * 0.545
= 0.4827 Rs/kwh

2. *Variable cost per unit as bus bar*

= 0.4827/(1-0.065)
= 0.51625 Rs/kwh

Total cost = Per unit fix cost + per unit variable cost
= 1.473 + 0.51625

Total cost = 1.98925 Rs/kWh

2) Emission generation to produce one unit of electricity

We are considering that the power plant is using coal which has a calorific value of 3765 kcal/kg. In technical language, we say that it a G12 grade type of coal. Following are the properties of the G12 grade coal.

Table 2 : Coal constituent

Sr. No.	Constituent	
1	Moisture	2.66
2	Sulphur	1.03
3	Size	200 - 325
4	Calorific value	3765 kcal/kg
5	Fixed carbon	54.20
6	Volatile matter	36.58
7	Ash content	6.74

%C = 0.97C+0.7(VM-0.1A)-M(0.6-0.01M)
= (0.97*54.2)+0.7*(36.58-0.1*6.74)-2.66*(0.6-0.01*2.66)

%C = 76.183 %

%H= 0.036C+0.086(VM-0.1A)-0.0035M^2(1-0.02M)

= 0.036*54.2+0.086(36.58-0.1*6.74)-0.0035*2.66^2(1-0.02*2.66)

%H = 5.01%

%N=2.10-0.02VM

= 2.1-0.02*36.58M

%N = 1.3684

2.1 Fuel Composition

Table 3: Fuel constituent

Sr. No.	**Constituent**	**%**
1	C	76.183
2	H	5.01
3	N	1.3684
4	S	8.03
5	Moisture	2.66
6	Ash	6.74

3) Theoretical air required for combustion

=[11.6C+34.8(H_2-O_2/8)+(4.35S)]/100 kg/kg of fuel

=[(11.6*76.183)+34.8(5.01-0)+(4.35*8.03)]/100

= 10.93 kg/kg of fuel

- Let excessive air required is 30% of theoretical air requirement

Air required for combustion of 1 kg oil is = (1+ EA)*Theoretical air

Air required = 1.3*(10.93)

Air required = 14.209 kg/kg of fuel

$C+O_2=CO_2$

12 kg of carbon produces 44 kg of CO_2

So 0.76183 kg produces 2.7933 kg of CO_2

4) CO_2 emission for one unit of electricity production

Calorific value of coal = 3765 kcal/kg
Coal consumption = 4780 ton/MW Annum
Per unit coal consumption = 0.5456 kg/kwh
CO_2 emission for per unit = 2.7933*0.5456
= 1.524 kg

5) Total coal available resources in India

As per the ministry of Coal India, India coal reserve of 319020 Million Tonnes*[6]*. From the previous calculations, we know that there is a requirement of 0.4 kg of coal for per unit of electricity generation. If we want to consider coal-based power plant as a base load then we need to produce 120.89 GW of electricity in the year 2050. Here we are calculating the amount of coal required to cater to the .

Unit of electricity generation = 120.89*24*365
=1058996.4 GWh
Coal need to produce 1058996.4 GWh is = 0.4*1058996.4
= $423598.56*10^6$ kg
Coal available as on $287951*10^9$ kg.
If we consider the present availability of coal is equal to the availability of coal available in the year 2047, then excessive coal would be equal to

Fig 1: Past data for coal consumption and coal production in India

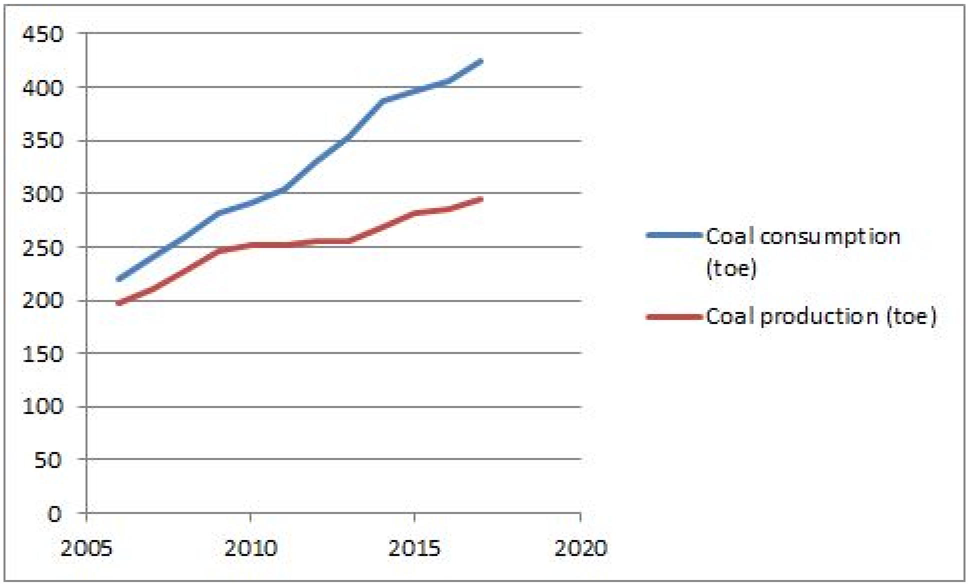


Table 4:- Coal consumption data of India *[7]*

Year	Coal consumption (toe)
2006	219.297
2007	240.032
2008	259.271
2009	280.832
2010	290.382
2011	304.628
2012	329.988
2013	352.782
2014	387.544
2015	395.273
2016	405.644
2017	423.967

Table: Coal production data on India *[7]*

Year	Coal production (toe)
2006	198.159
2007	210.346
2008	227.463
2009	246.047
2010	252.353
2011	250.815
2012	255.048
2013	255.728
2014	269.452
2015	281.006
2016	284.933
2017	294.241

Reference

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2) *http://www.cea.nic.in/reports/others/thermal/tppd/coal_cons_norms.pdf*
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