

Building Generating Capacity by 2022 Matching with GDP Growth

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Outline

- **Energy Transition for India**
- **Things that will be different**
- **ICF's proprietary power sector modeling tool**
- **Impact analysis: Short to medium term**
 - Electricity Demand growth
 - Plants under development and 175 GW RE
 - Declining CFs of coal plants
 - Domestic coal: Surplus situation
 - Gas requirement for integrating RE capacity

Energy Transition: India's vision will propel a changed landscape



- 175 GW target for renewables development by 2022
- Need for flexible generation for integrating RE capacity



- 24 x 7 power for all; greater grid connectivity and rural electrification
- Change in load shape; Potentially reducing load factor (From 85% to less than 75% in long-term)
- Increased electricity demand (6.41% growth 2016 to 2035)



- The commitments taken at COP21 for reducing emissions intensity of GDP by 33%-35% wrt 2005 levels by 2030
- Limiting GHG emissions (system wide cap of ~1700 Million tons of CO2 in 2030)
- Boost for non-fossil based generation and cleaner fuel generation options (Wind, Solar, etc)
- Improving efficiency of coal based generation; Clean coal technologies



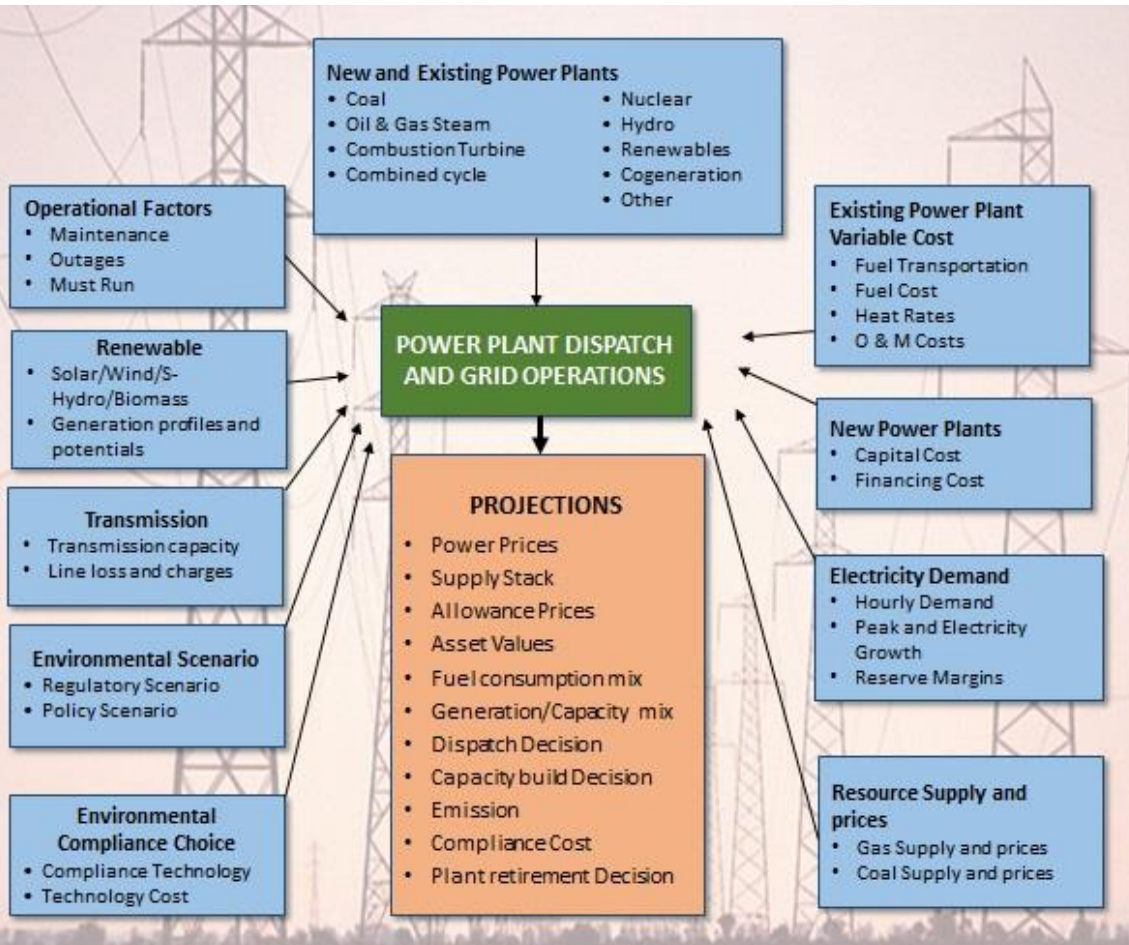
- Focus on manufacturing for job creation, particularly in MSME sectors
- Increased demand for reliable and high quality power
- Significant increase in per capita consumption (From ~900 units per person in 2015 to 1,900 units per person by 2030)



Going Forward: Things that will be different

- **Need for flexible generation** like pump hydro, open cycle gas, battery storage, more cycling from coal based plants etc.
- Need for **gas generation** for (i) meeting variability in net demand, (ii) Meeting GHG emission targets
- Decline in year on year coal capacity addition as **focus shifts to** Solar, Wind and other **clean fuel technologies**
- Merit order dispatch to **Environment Order Dispatch** order: Improve air quality of cities
- **Evolving new market structures**: Ancillary service market, Peaking power market, Capacity market, Gas exchange for spot sales/purchase etc.

These changes can be analyzed using IPM®: ICF's proprietary power sector modeling tool

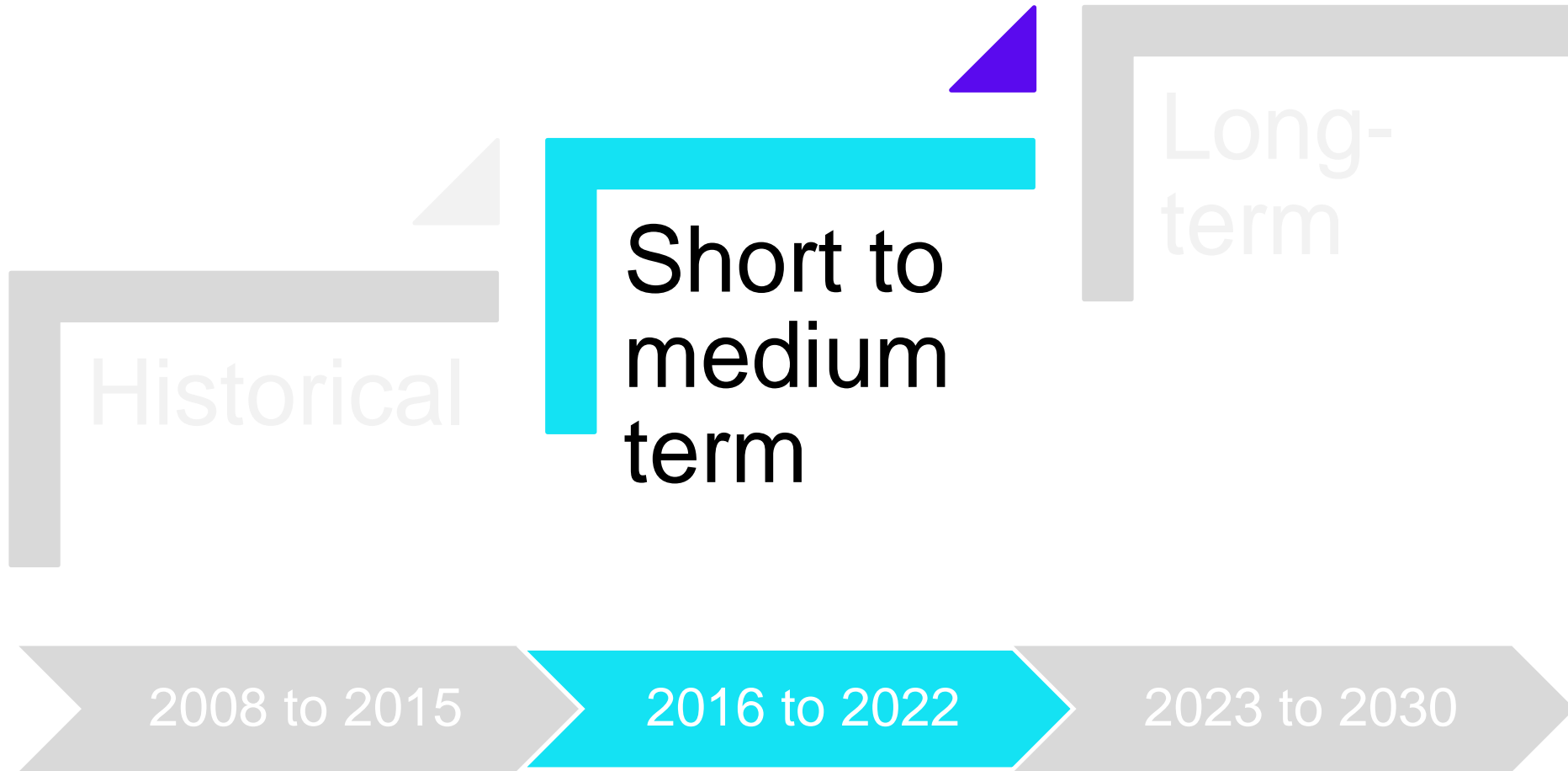


- Excellent and Versatile Long Range Planning Model
- Uses a Linear-programming based optimization approach
- Simulates least-cost plant dispatching and least-cost investments in generation capacity and interconnections to meet projected load in the region.
- Long-term capacity expansion and production costing model
- It is a multi-regional, deterministic, dynamic, linear programming model
- Utilizes Dynamic Optimization Framework with an Objective Function of Minimizing the Present Value of Total System Cost subject to various constraints
- Simulates rational expectations for perfect foresight providing the framework for inter-temporal decision making

What Future holds.....

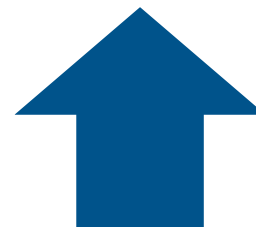


Impact analysis: Short to medium term

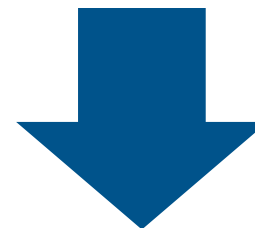


Electricity Demand growth will continue to show strong correlation with GDP growth

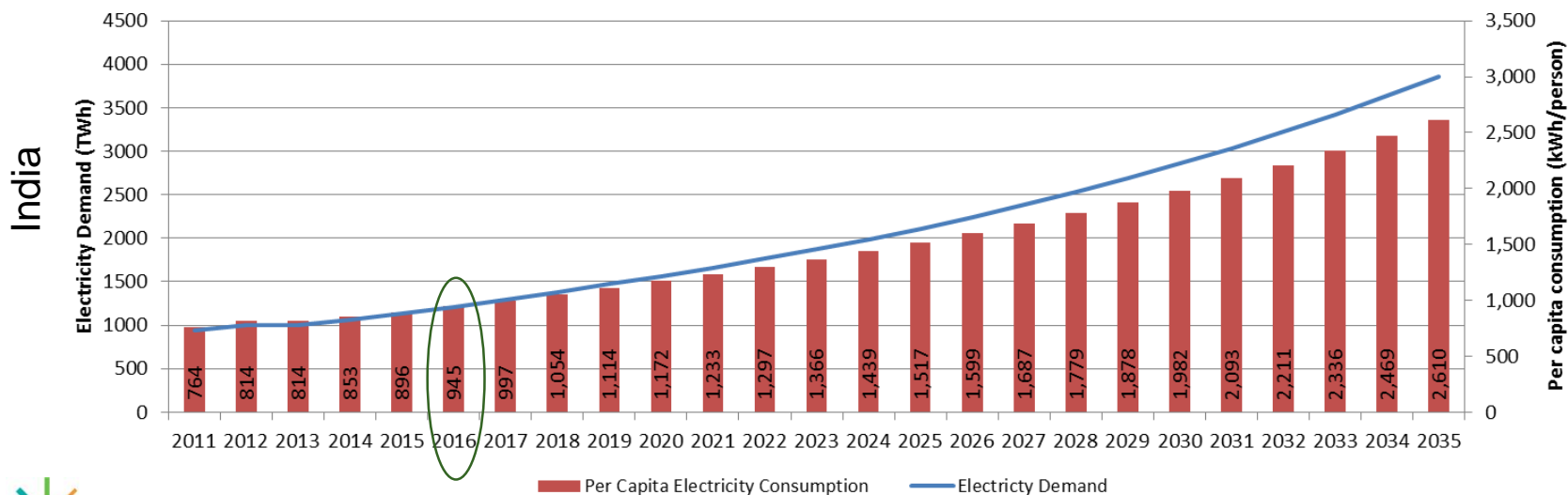
Electric power consumption in 2013 (kWh per capita)	Region Average
Latin America & Caribbean	2,045
Europe & Central Asia	5,496
Middle East & North Africa	2,880
East Asia & Pacific	3,495
North America	13,241



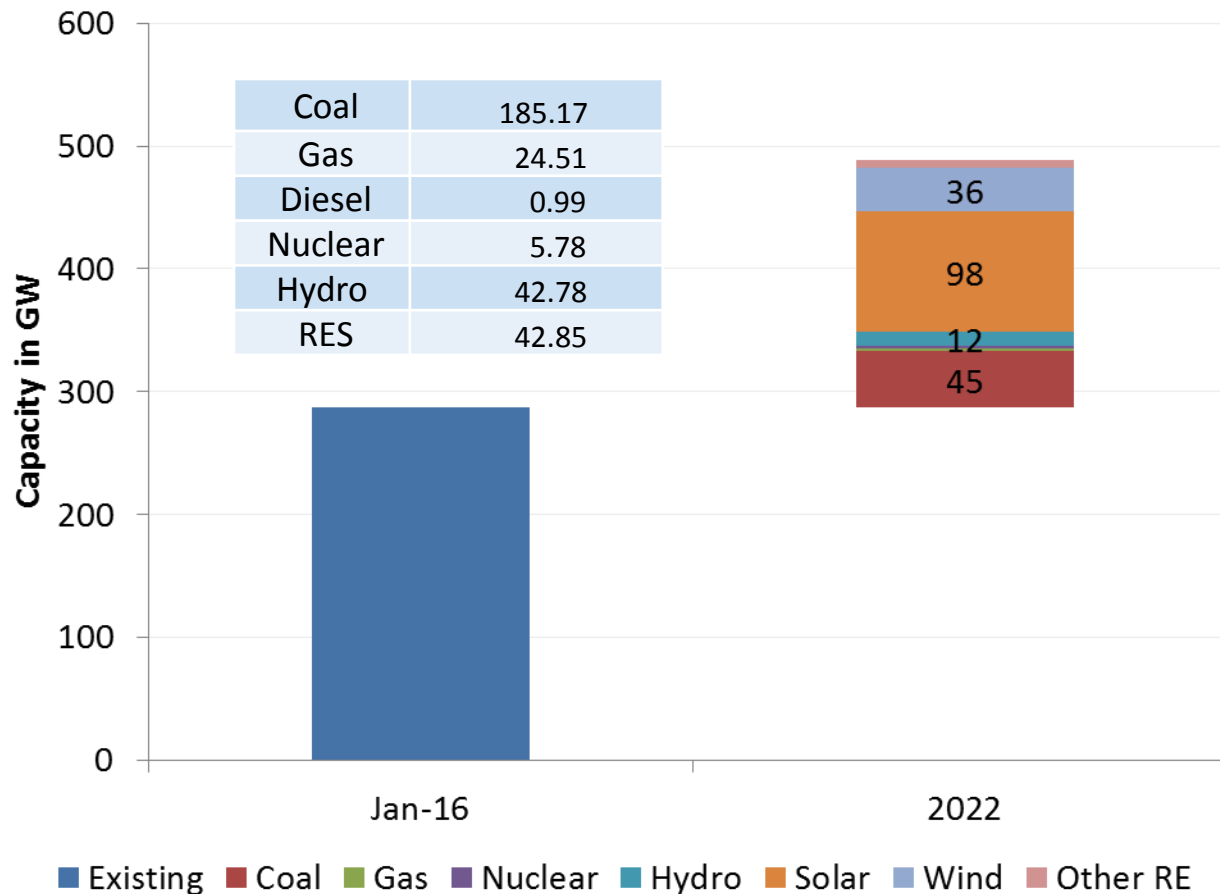
(i) 24X7 Power for all; (ii) Make-in-India; (iii) Rapid Electrification; (iv) Electric vehicles



Energy efficiency in household, commercial establishments and agricultural pumps



45 GW of coal based plants are already in advance stages of development and expected to come online by 2022



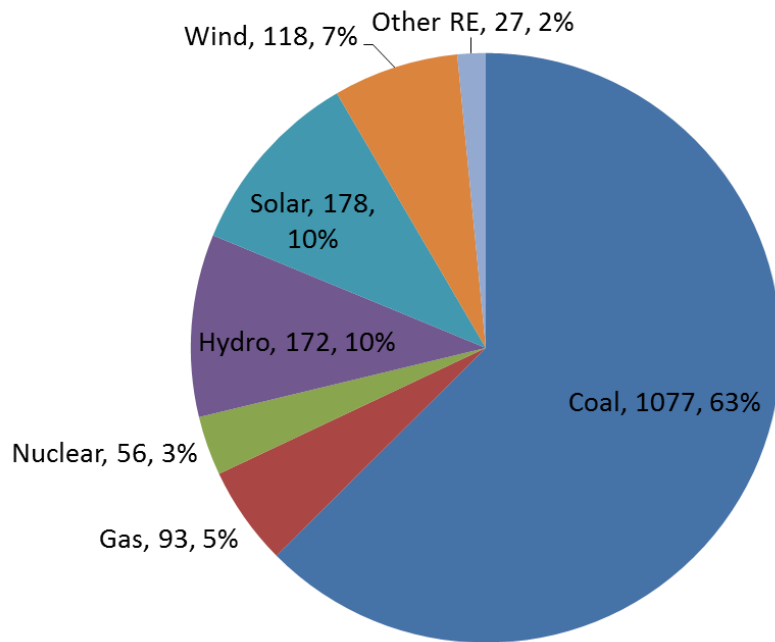
✓ Between 2016 and 2022, India will add ~200 GW of new capacity, of which ~140 GW will be RE

✓ Coal capacity addition has already slowed down from 17 GW YoY to 7 GW YoY in next 6 years

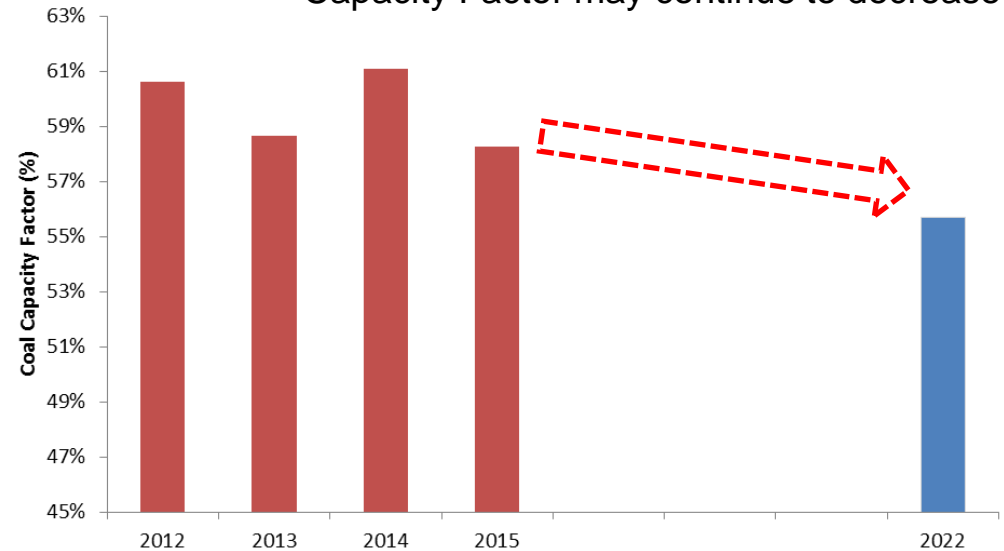
Coal continues to be the mainstay of power in India (63% of total mix), however average capacity factor reduces to 56%



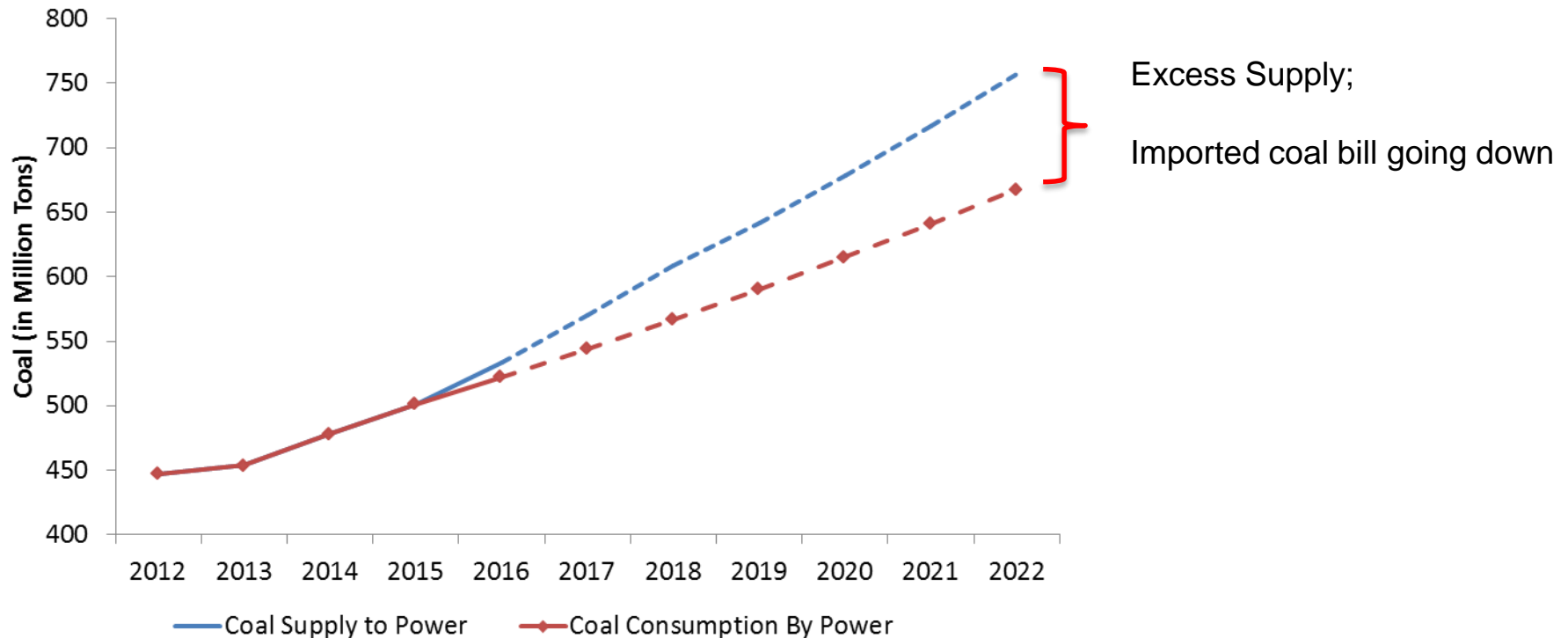
Coal in generation mix (63%) - 2022



Capacity Factor may continue to decrease



India could end-up with surplus domestic coal



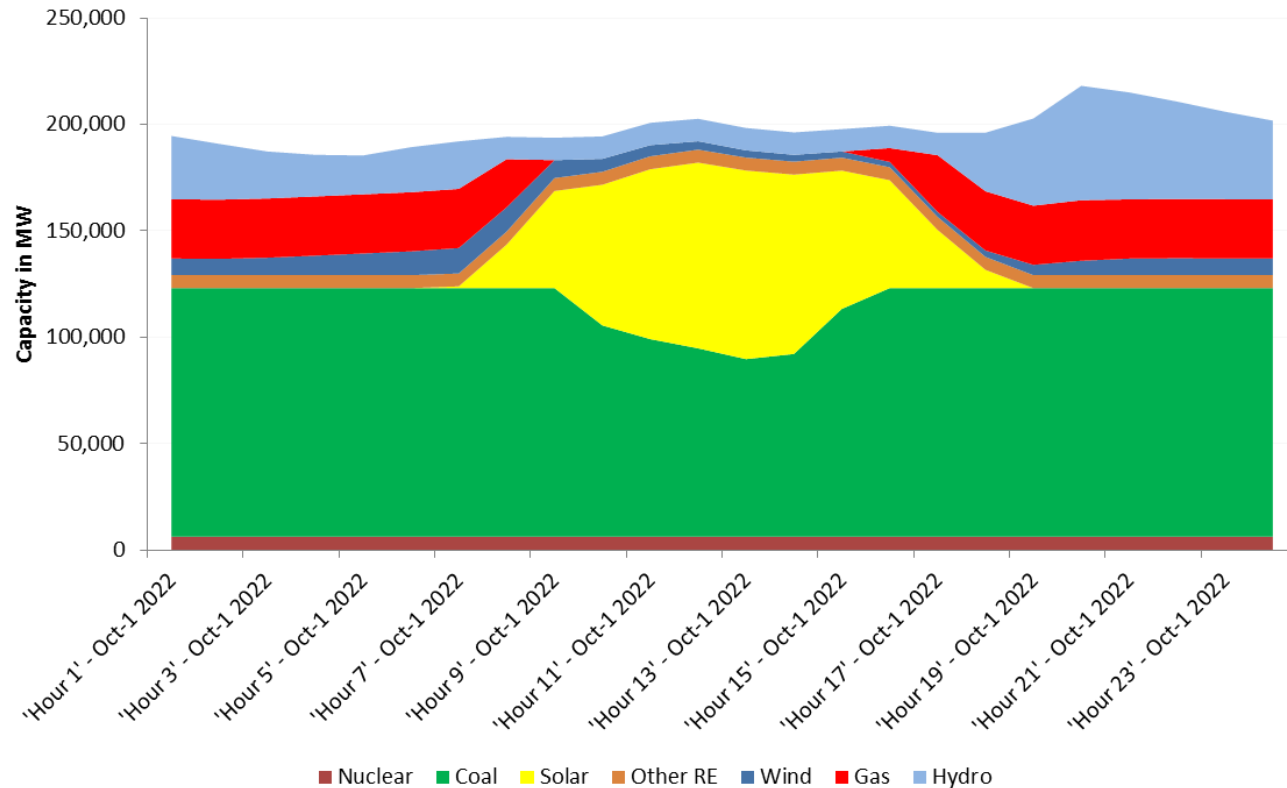
- ✓ Assumed 750 MT production by CIL: quite short of Government's target of 1 Billion Tons

India RE capacity is readying for a massive build-up...

- RE capacity (wind and solar) in June 2016 stood at 42,850 megawatts, overtaking hydropower that stood at 42,783 mw
 - India is on track to becoming one of the world's largest producers of green energy and will surpass many developed countries in this endeavour.
 - India has a target of adding 175 GW of RE capacity by 2022
 - Solar - 100 GW of solar,
 - Wind - 60 GW
 - Bio-power - 10 GW
 - Small hydro - 5 GW (≤ 25 MW each)
 - Government considering adding large hydro in the definition of RE and with this
- the target RE capacity can be 225 GW
- What this will mean is increased variability of generation and balancing the grid will be a challenge in future
 - Various options for balancing will need to be explored for millisecond response to seasonal response
 - Batteries
 - Flywheels
 - Thermal storage (phase change materials)
 - Pumped hydro
 - Compressed Air
 - Open cycle gas
 - Cycling from coal plants

... causing disruption to conventional base-load dispatch order

- Graph below shows overall system load curve for a typical day in the month of October 2022
- To meet demand and RE generation variability, system requires average of 20 GW of gas based capacity during 0000 hours to 0800 hours and 1600 hours to 0000 hours (with peak requirement of 28 GW)
- The load curve summararily assumes interventions to the dispatch order (RES purchase obligation, solar/wind integration) tenable by 2022



In summary

Demand for electricity will rise

With rising GDP growth (further boosted by current demonetization)

As more people get connected to grid

We may be close to achieving 24X7 reality in few states of India in next few years

UDAY benefits will start kicking in and it can be a real game-changer if DISCOMs become more professional

Supply mix with change considerably

Coal will continue to be the mainstay of Indian power sector providing baseload power but PLFs are likely to further reduce

Renewables will form a very significant chunk of generation capacity required flexibility in the system

Storage technologies (including open cycle gas and cycling of coal plants) will have a key role to play

Hydro will also develop but at a slow pace due to various environmental and construction related issues

Gas will get increased support due to its environment friendliness

Key policy changes will need to happen to

- Ensure 24X7 supply
- Support variable generation to balance renewables



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India's operating Nuclear Plants

Reactor	State	Type	MWe net (each)	Commercial operation
Tarapur 1&2	Maharashtra	GE BWR	150	1969
Kaiga 1&2	Karnataka	PHWR	202	1999, 2000
Kaiga 3&4	Karnataka	PHWR	202	2007, 2012
Kakrapar 1&2	Gujarat	PHWR	202	1993, 1995
Madras 1&2 (MAPS)	Tamil Nadu	PHWR	202	1984, 1986
Narora 1&2	Uttar Pradesh	PHWR	202	1991, 1992
Rajasthan 1&2	Rajasthan	Candu PHWR	90, 187	1973, 1981
Rajasthan 3&4	Rajasthan	PHWR	202	1999, 2000
Rajasthan 5&6	Rajasthan	PHWR	202	Feb & April 2010
Tarapur 3&4	Maharashtra	PHWR	490	2006, 2005
Kudankulam 1&2	Tamil Nadu	PWR (VVER)	917	December 2014, (2017)
Total (22)			6219 MW	

Madras (MAPS) also known as Kalpakkam
 Rajasthan/RAPS is located at Rawatbhata and sometimes called that
 Kaiga = KGS, Kakrapar = KAPS, Narora = NAPS