An analysis on Variable Renewable Energy and the importance of Hybrid systems in India

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"Energy security based on clean & reliable sources is essential for India's future…"

- Mr. Narendra Modi, Prime minister, India

2014

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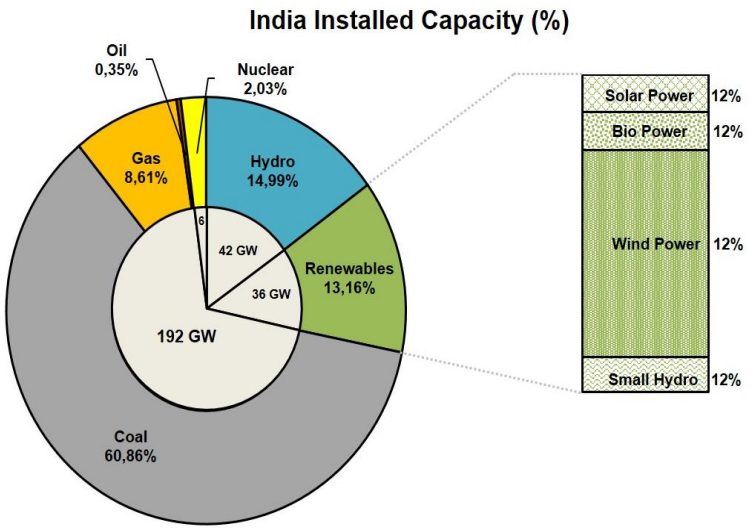
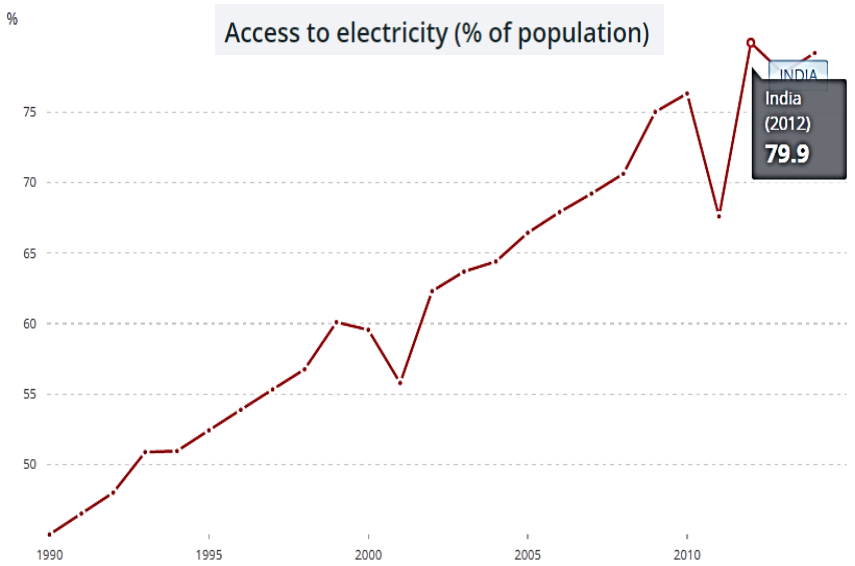
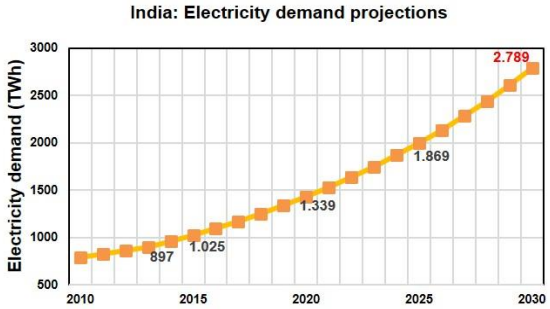
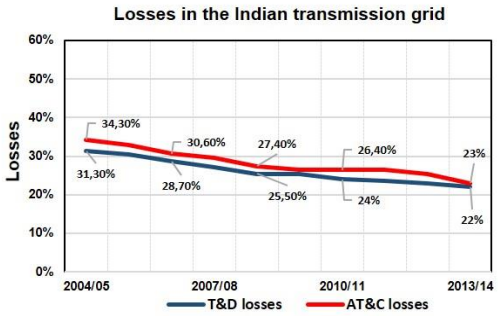
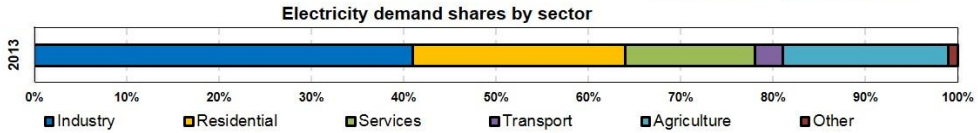
The Indian Electricity sector











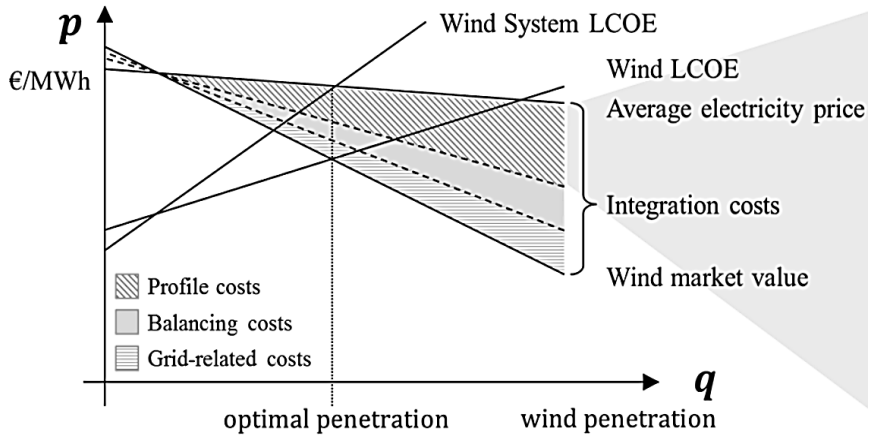
Source: CEA, Worldbank

The Indian Electricity sector

- Challenges:
  - Sustain economic growth along with energy transition.
  - Transmission and Distribution losses minimization.
  - Improve the financial situation of the energy sector.
  - Lose the dependence on coal imports.
  - 36% of emissions come from the power sector.
  - Improve energy access (20%, i.e. ~300 Mill. people without access)
- COP 21, Dec 2015 goals:
  - Decrease up to 33% carbon intensity from 2005 levels.
  - 175 GW of Solar PV and Wind energy expansion planned.

Variable Renewable energy (VRE)

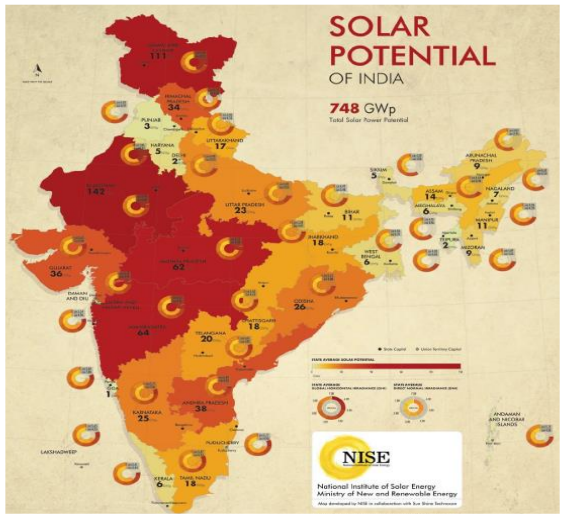
- Effective solution to India's energy goals.
- Variable and uncontrolled availability.
- Fluctuating generation, complex interplay of components.
- Integration costs tend to increase at a larger scale.
- Examples: Wind, Solar PV.

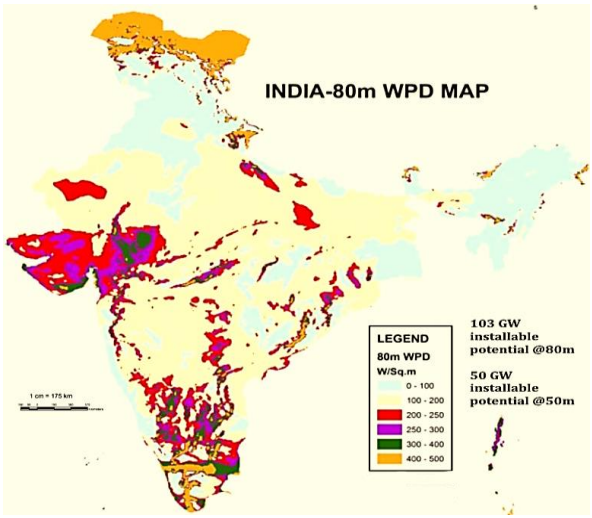


Source: Neon-energie

VRE in India

- Installed Capacity:
  - Solar PV: 20 GW
  - Wind (onshore): 35 GW
- Available Technical Potential:
  - Solar PV: 748 GW (estd. 5% shading area)
  - Wind (Onshore): 103 GW (@80m) and 50 GW (@50m)

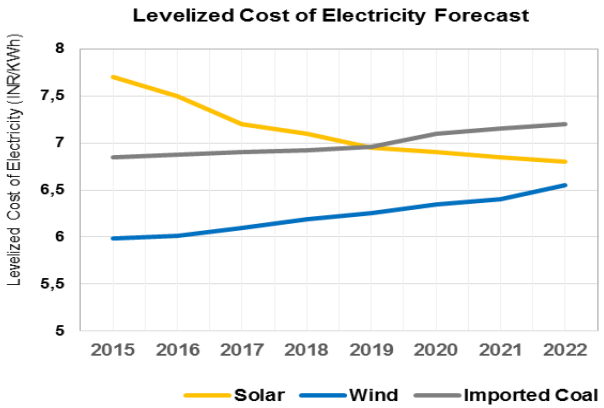


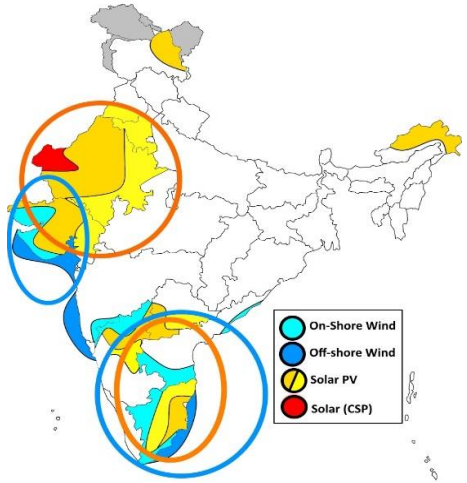


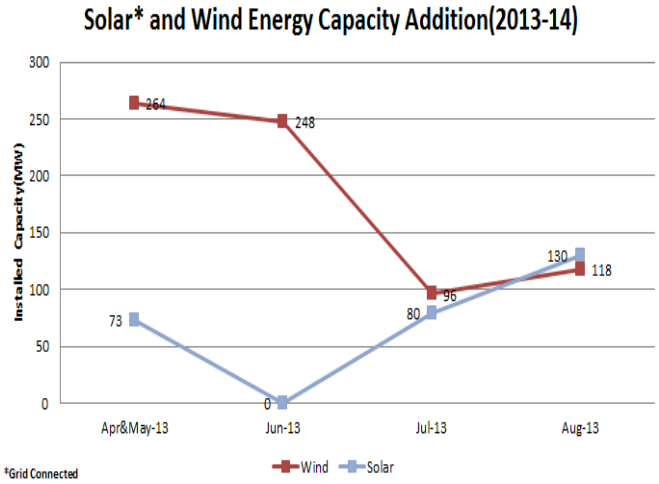
Source: NISE, MNRE, CEA

VRE in India

- LCoE for Solar PV: Expected to decrease in 2019.
- Several development zones for PV and onshore Wind.
- Increase in Capacity addition for Solar PV and Wind.
- Expected increase in ‘Integration’ costs.
- Policies directed at VRE support.







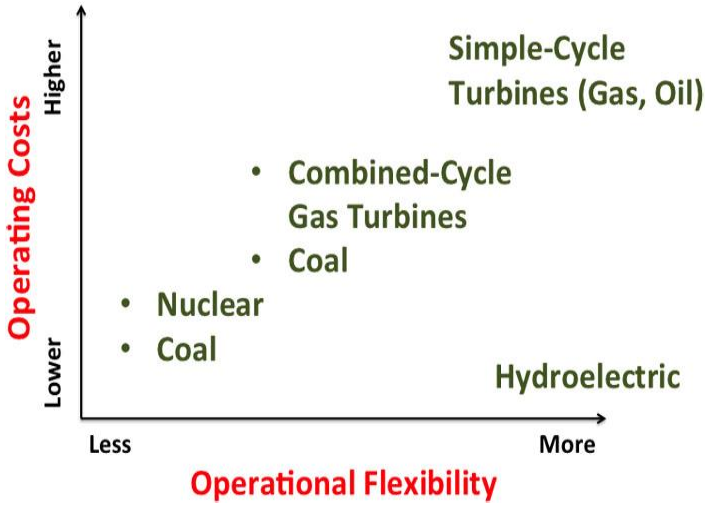
Hybrid systems

- A system consisting of two or more sub-systems with different system behaviours, usually complementing each other.
- With Electricity systems: proven effective ‘island systems’.
- Fluctuating nature of VRE : can be compensated.
- With integration costs in mind : Large scale expansion.
- Sustainable VRE expansion in India: Solution.

Flexibility of power plant types

- Possibility to combine power plant types as a hybrid system.
- Higher Flexibility : Easier integration, lesser ‘integration’ costs.

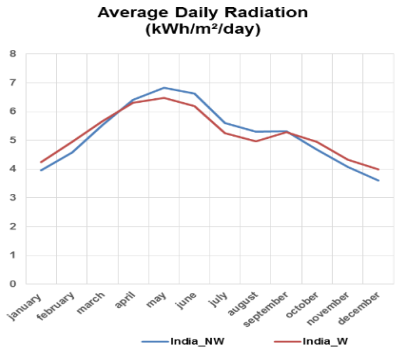
Technology	Ramp Time (To Full Capacity)	Min. Run Time
Combined-cycle combustion turbine	hours	hours to days
Nuclear	days	weeks to months
Steam cycle combustion turbine	hours	Hours to a day
Simple-cycle combustion turbine (gas/ oil/ biomass)	minutes to hours	minutes
Hydro-electric (includes pumped storage)	minutes	None
Wind Turbine (includes offshore wind)	minutes	none

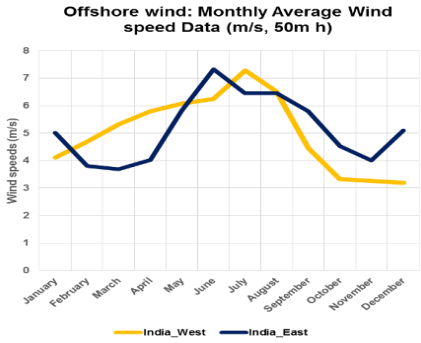


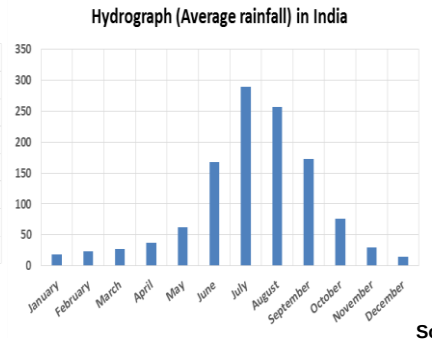
Source: Energy markets, Policy and Regulation

1. VRE + DRE

- DRE : ‘Dispatch’-able Renewable Energy.
- Examples : Hydro power, Biomass energy.
- Output: Can be ‘controlled’ to a certain level.
- No ‘integration’ costs : No problems related to balancing, grid and profiles.
- DRE capital stock: Higher than most power plant types.
- India : Hydro electric technical potential ~150 GW untapped.



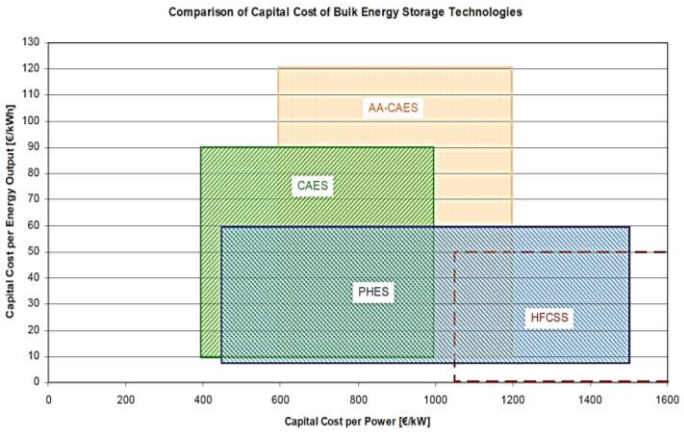


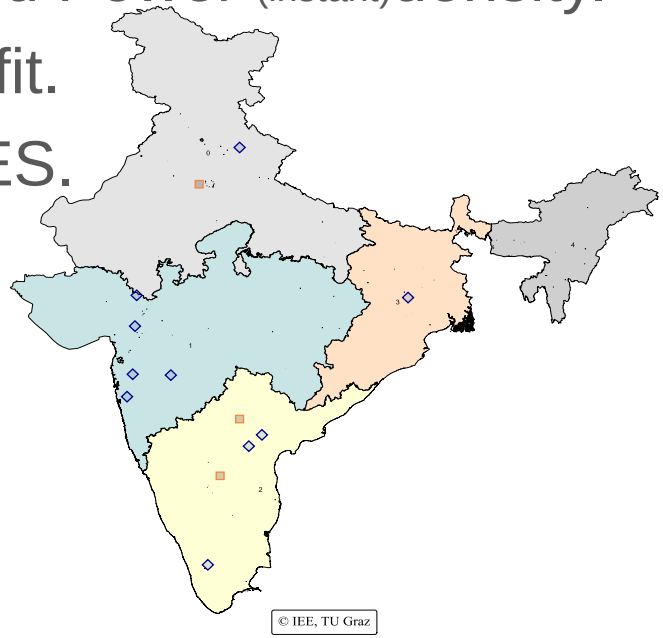


Source:CEA, GoI

2. VRE + LES

- Large-scale Energy Storage : complementary with VRE.
- Function like a battery:
  - Charge : during excess VRE generation.
  - Discharge : during low VRE generation.
- Favorable: High energy (over time) and Power (instant)density.
- Control Reserve: additional benefit.
- Pumped Hydro,Battery tech, CAES.

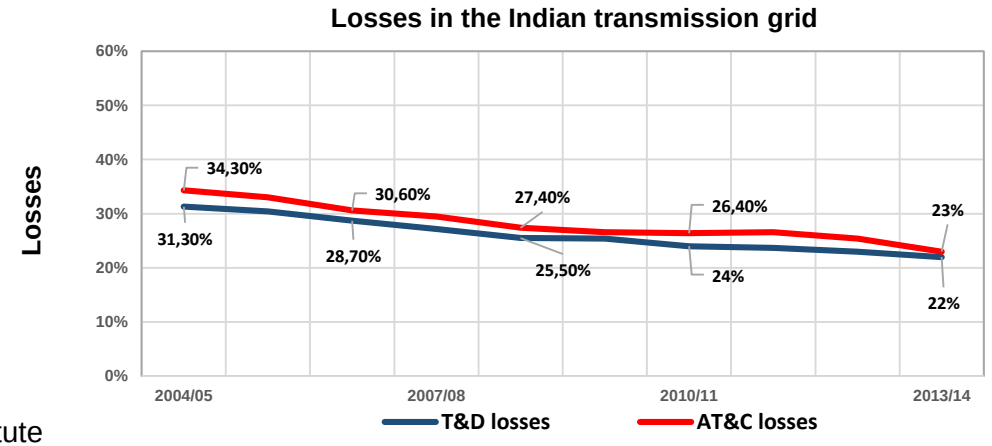




Source: Wietschel, 2011; Atlantis,IEE

3. VRE + Smart Grids

- ~50% of India yet to be built: Scope for infra. Development.
- Reduction of distribution losses:
  - 20% loss in T&D => 1 unit in 5units generated lost.
  - T&D losses : negligence in maintenance.
  - Smart grids: improvement of flexibility and maintenance.
- EPRI* estimate, cost of deploying smart grid : $17 -$24 billion a year.

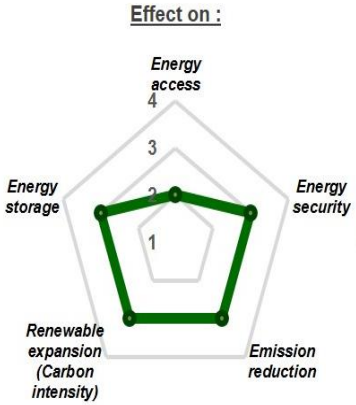


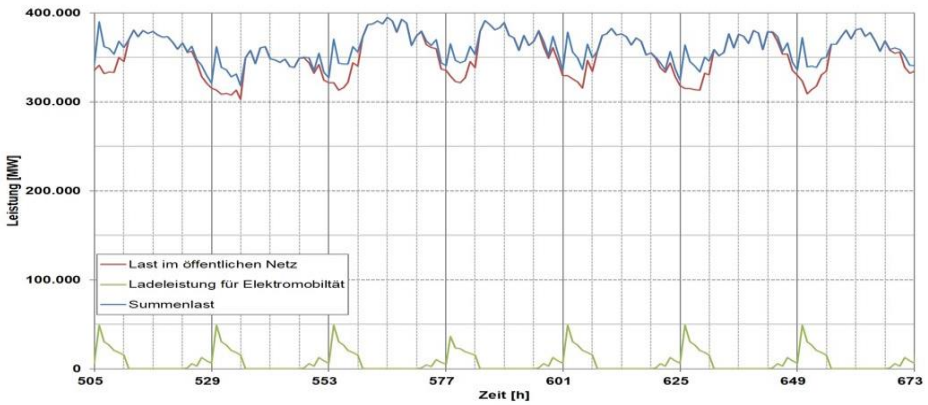
*EPRI - Electric Power Research Institute

Source: IEA, Buckley, T.

4. VRE + E-Mobility

- Goes hand-in-hand with smart grids
- E-Mobility energy storage: V2G and G2V, only for small power systems
- Might effectively work if VRE generation is de-centralized
- Off-Peak charging: 10% increase in overall load
- Negates integration charges of VRE





Source: IEE, TUG

5. VRE + Clean conventional technology

- Most feasible hybrid system for India.
- 60% of installed capacity : Coal Power plants **(avg. life: ~23 years)**
- Prevents ‘stranded’ coal power assets.
- Saves the Private electricity sector financially.
- India Policy : 1MW of new Clean Coal must be accompanied by 20% RE capacity.
- Clean Conventional : base and intermediate loads
  VRE : intermediate and peak loads.

Overview

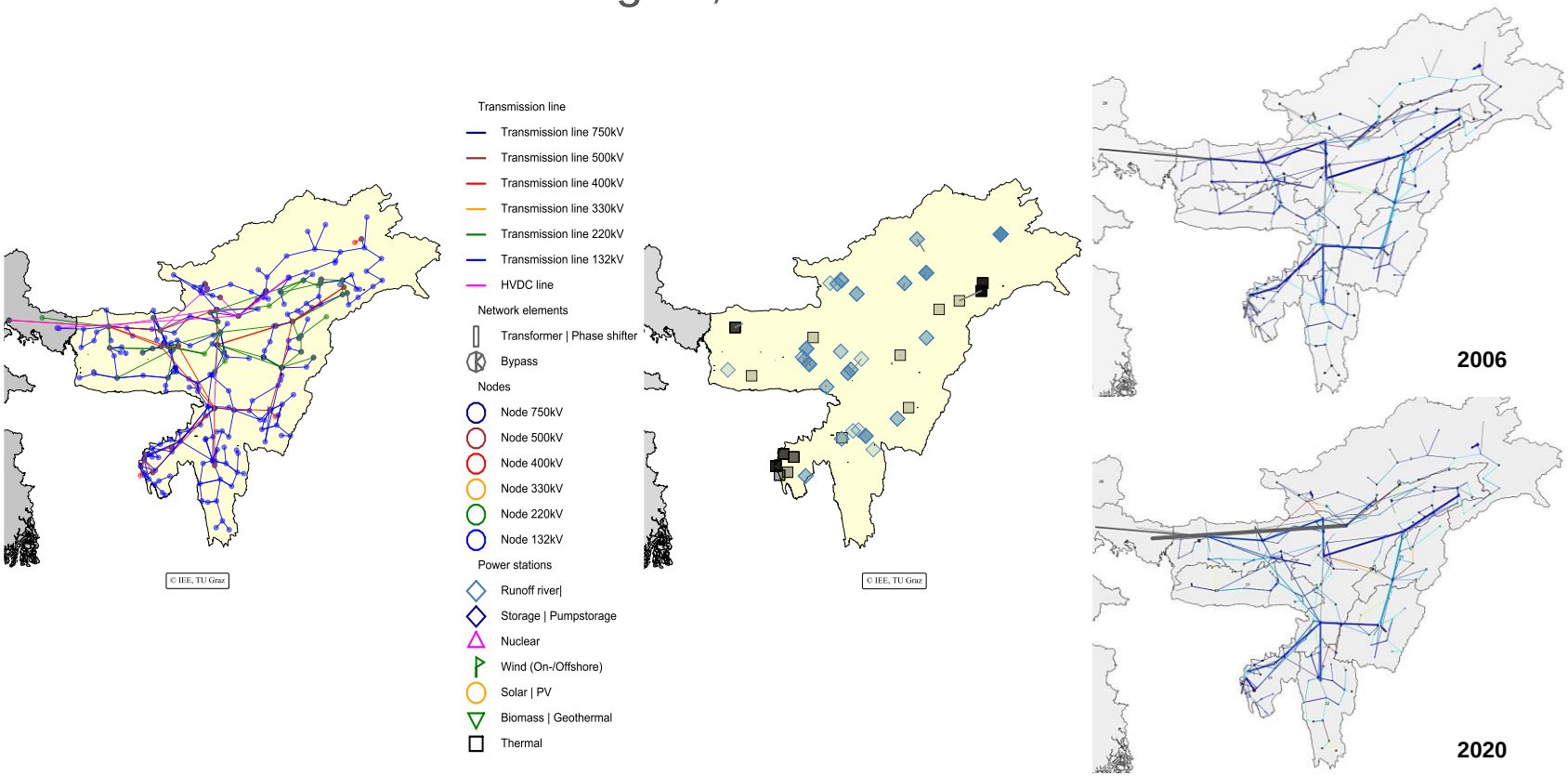
Hybrid System	Complexity	Capital Intensity	Added benefits	Effectiveness
VRE+DRE	Low	Relatively Low	Agriculture, Biomass	Short and Long term
VRE+ LES	Relatively Low	Very High	Back-up Power, Water Management	Long term
VRE+Smart Grids	Relatively High	High	Energy Efficiency, Reduced financial loss	Long term
VRE+E-Mobility	Very High	Relatively Low	Transport sector – Pollution reduction	Long term
VRE+ Clean Conventional	Low	Low	Avoid stranded assets	Short term

Conclusion:

- Electricity from VRE : defines India's electricity future.
- Increasing electricity demand + energy access.
- Priority for VRE integration : utmost importance.
- Hybrid systems: Answer for sustainable VRE integration.
- Several options for Hybrid systems in India.
- DRE along with VRE : the most viable long term solution.
- DRE with clean conventional tech : viable short term.
  (buying 'time' while saving money)

Ongoing work

- Modeling, validation and Analyisis of the Indian Electricity system at the IEE, TUGraz
  Ex: North East Indian Region, initial simulations



Thank you for your Attention!

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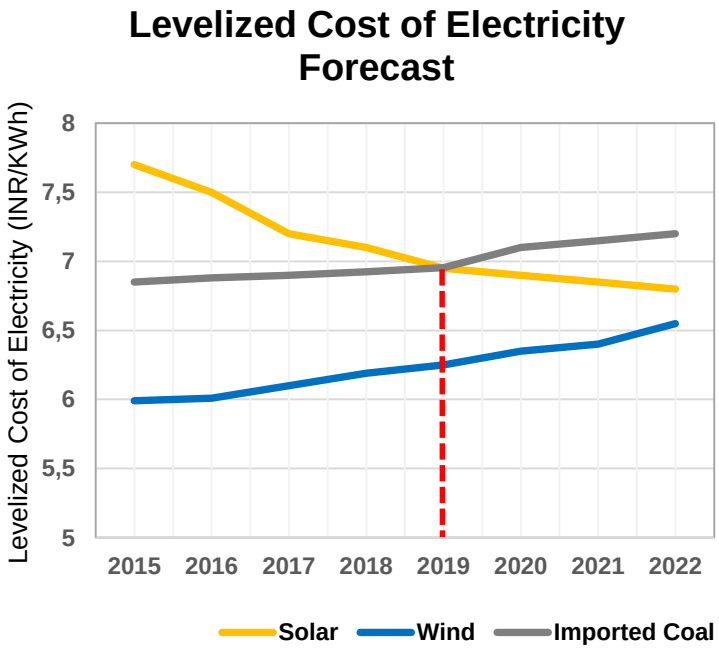
Economic aspects



Technology	Capital Cost ($/kW)	Operating Cost ($/kWh)
Coal-fired combustion turbine	$500 — $1,000	0.20 — 0.04
Natural gas combustion turbine	$400 — $800	0.04 — 0.10
Coal gasification combined-cycle (IGCC)	$1,000 — $1,500	0.04 — 0.08
Natural gas combined-cycle	$600 — $1,200	0.04 — 0.10
Wind turbine (includes offshore wind)	$1,200 — $5,000	Less than 0.01
Nuclear	$1,200 — $5,000	0.02 — 0.05
Photovoltaic Solar	$4,500 and up	Less than 0.01
Hydroelectric	$1,200 — $5,000	Less than 0.01

Source: Energy markets, Policy and Regulation