Analysis of LES options for the interconnected electricity system in the Indian subcontinent

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„ India is on track to be one of the largest developers of renewables globally “

- IEEFA.org

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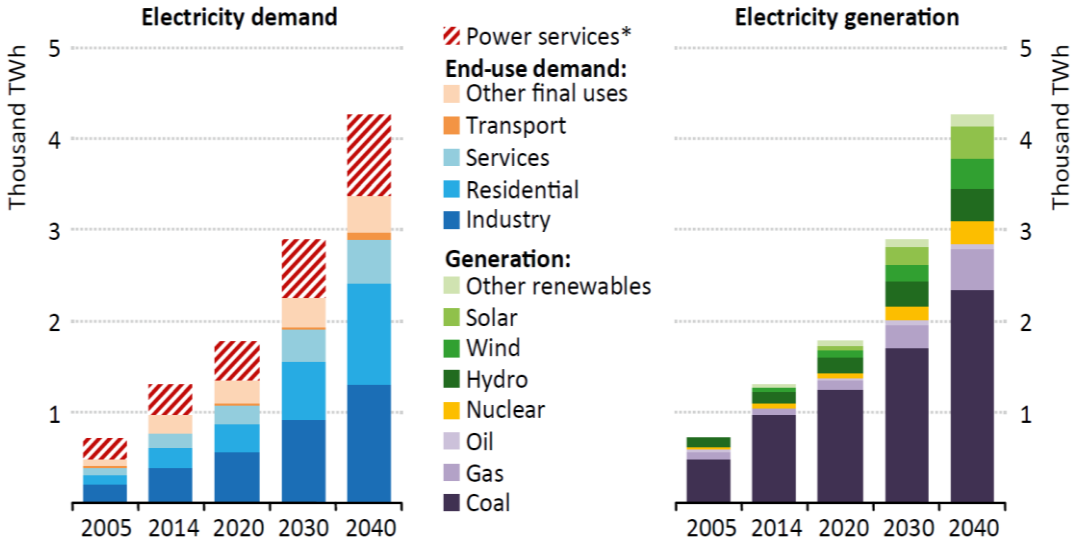
Introduction : Indian Electricity System

- Second most populated country
- Installed generating capacity : 370 GW (2019)
- Third largest electricity demand globally
- One of the highest rates of annual demand growth ~6 percent
- Economic development strongly coupled with energy usage
- One of the largest transmission networks in the world
- Leading installations of Solar PV – high development target

Introduction (2) : Indian Electricity System

- Promising onshore and offshore wind market
- ~40 percent of India yet to be built
- Several development programs: E-mobility, DSM, etc..
- Access to electricity (83 percent in 2016 → 98 percent in 2019)
- Energy storage capacity in 2019 : 5.8 GW

Development paths for the Indian Electricity System



Increase of electricity demand by 2040, NPS, WEO 2016

Challenges faced: Sustainable Renewable Transition

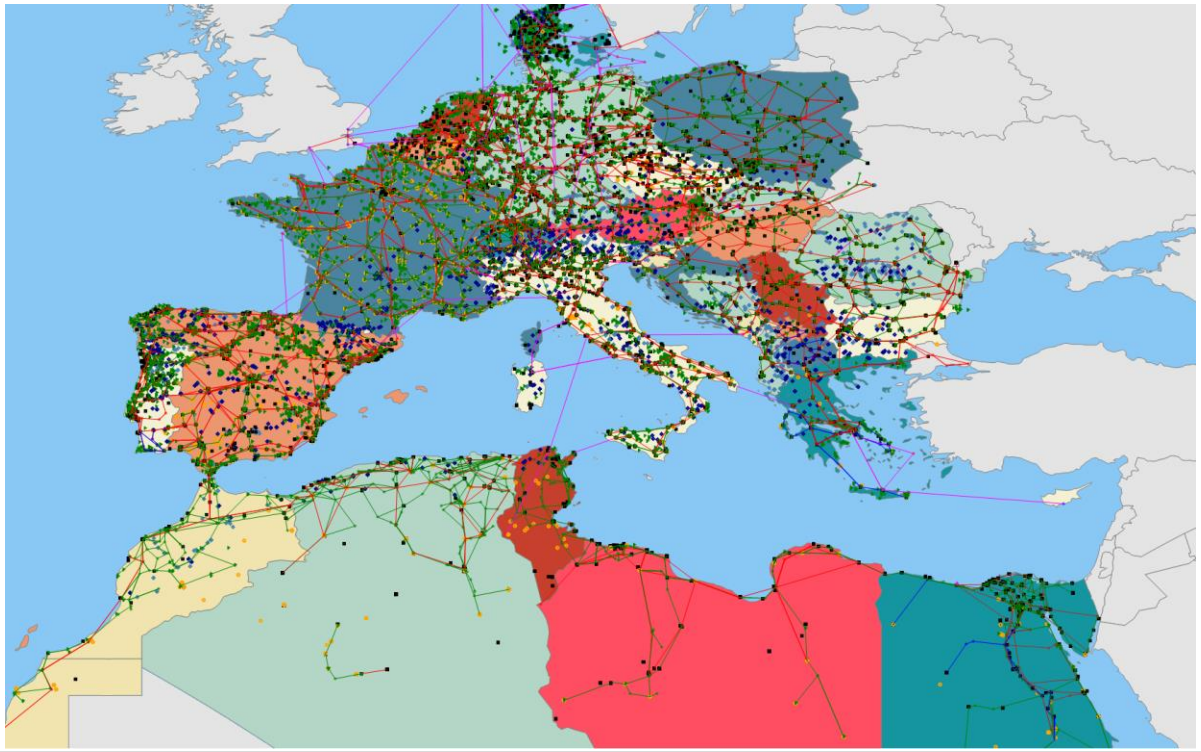
- Large RE shift expected, no prominent integration measures taken
- Transmission network development : Slow
- Energy storage severly lacking
- Base load mentality: still continues
- Stranding of assets: new thermal capacities
- Coal import dependency: will continue
- Large hydro power development : various issues within the country
- Several more…

ATLANTIS_India: Introduction

- Techno-economic simulation model developed at the IEE, TUG
- Technical model + economic model
- 5 power regions in India : East, North East, North, South and West
- 4 neighbouring countries: Bangladesh, Bhutan, Nepal and Sri Lanka
- Node-specific demand distribution model
- Input data validated until the year 2018
- Various studies already conducted – RE integration scenarios, Hydro power scenarios, Nuclear power scenarios etc..

ATLANTIS: techno economic simulation model

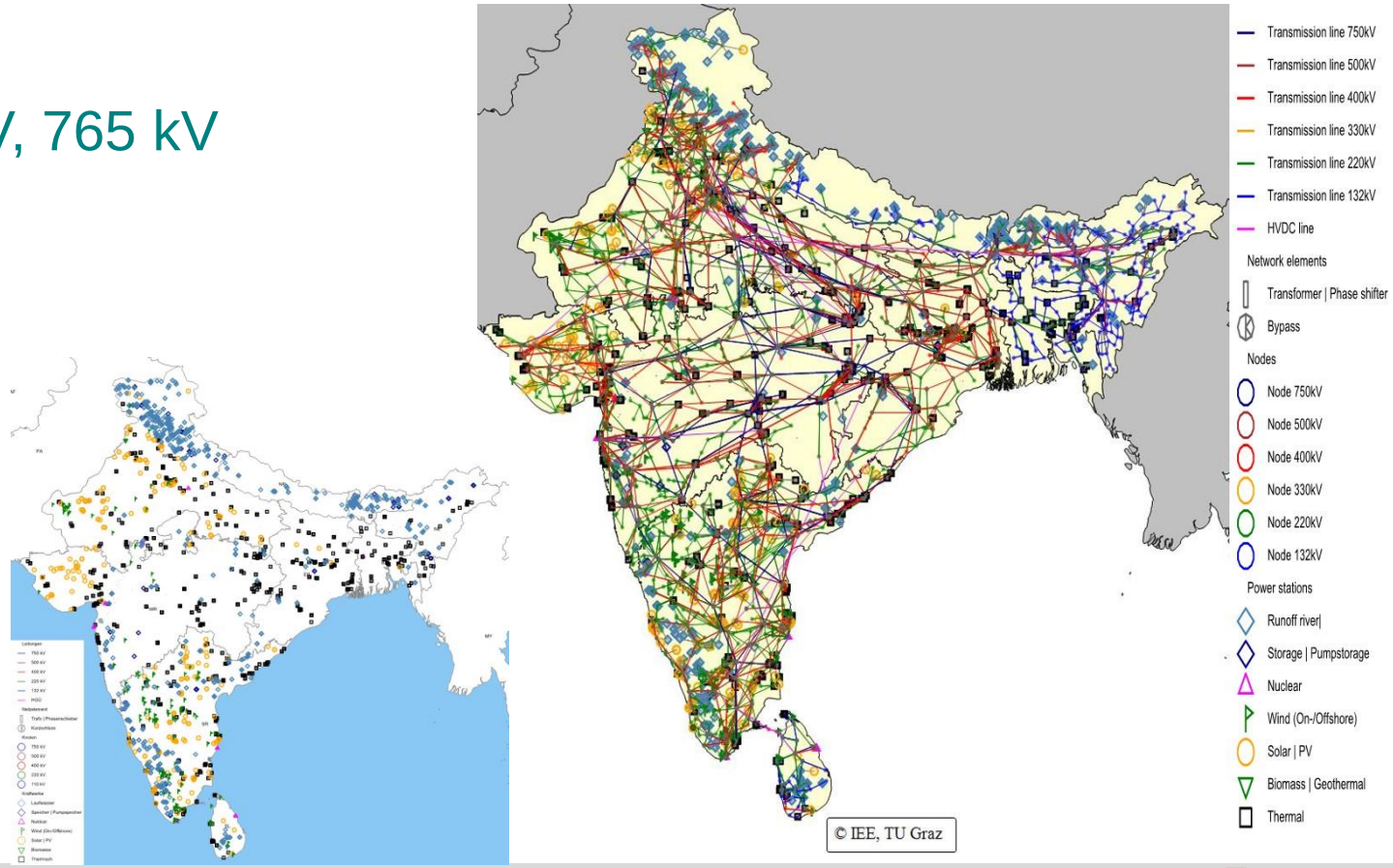
- ATLANTIS_India is based on ATLANTIS simulation model
- Techno-economic simulation model for European and African Electricity economics
- Developed at the IEE, TUG
- > 50 man-years in development



ATLANTIS_India: Physical Model

- Physical model: Nodes, transmission lines, transformer stations and power plants
- 5 Voltage levels:

  132 kV, 220 kV, 400 kV, 500 kV, 765 kV
- Over 1500 nodes
- Over 6000 transmission lines
- Over 4200 power plants



ATLANTIS_India: Market Model

- **4** market models, based on simulation requirements
- **Cu-Plate ‚Stock' market model**
  – no restrictions to power flow between regions
- **Zonal pricing model (ZP)**
  – NTC trading restrictions without load flow calculations
- **Total Market model (TM)**
  – Load flow calculations (inter-regional), ignores NTC calculations
- **Re-Dispatch Zonal Pricing Market model (RDZP) – realistic!**
  – Both load flow (inter- and intra- regional) and NTC restrictions

ATLANTIS_India: Market model (2)

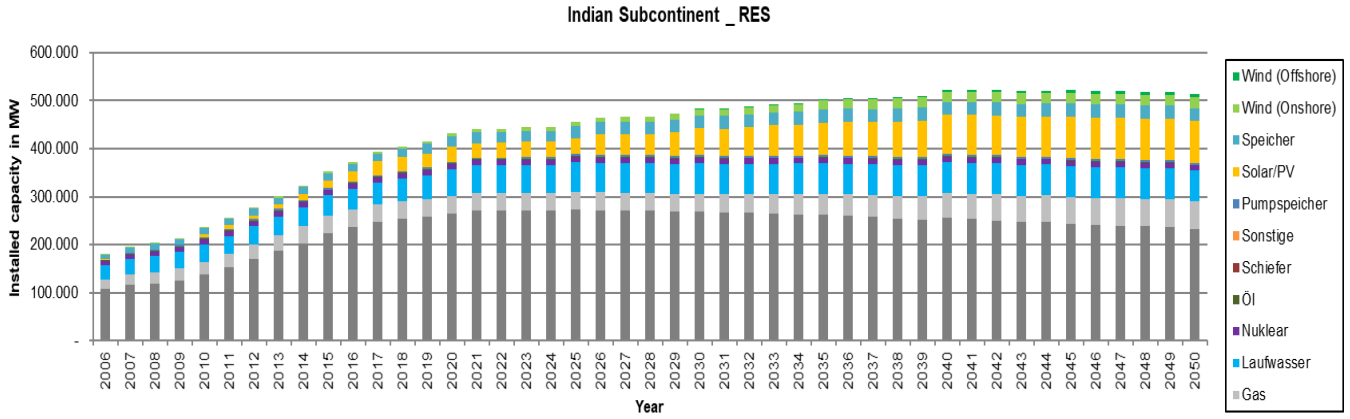
- Simulation mechanism – Electricity economics objective function
- Welfare maximization function – minimization of overall generation costs!
- Load flow calculations: Based on DC-Optimal Power Flow (DC-OPF)
- Other features:
  * Financial balances
  * Profit and loss statements
  * Capital Stock calculations

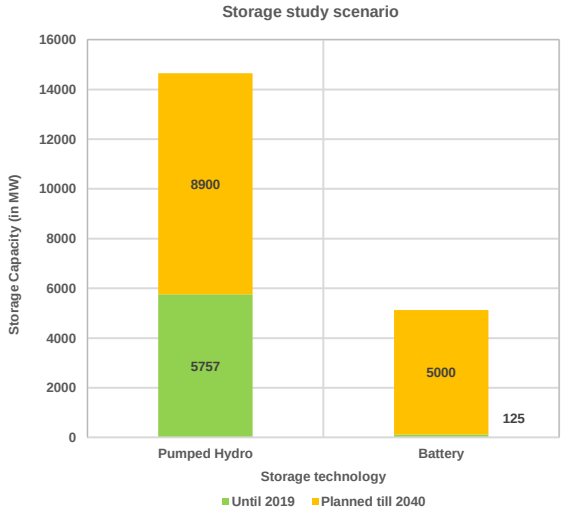
Studies with ATLANTIS_India

- Practicality of base load renewable generation in India (published)
- Large hydro power in Nepal and Bhutan integration studies (presented)
- ‚Clean' carbon technologies and BAU (thesis)
- Aggressive nuclear expansion in India (thesis)
- VRE+DRE strategy for the Indian subcontinent (thesis)
- Integration of 120 GW of Solar PV (85 GW) and Wind (35 GW) by 2050 (published)
- Solar PV integration in Sri Lanka (yet to be published)
- Introducing Nuclear energy in Sri Lanka and Bangladesh (yet to be published)
- LES strategy for the Indian subcontinent (now)

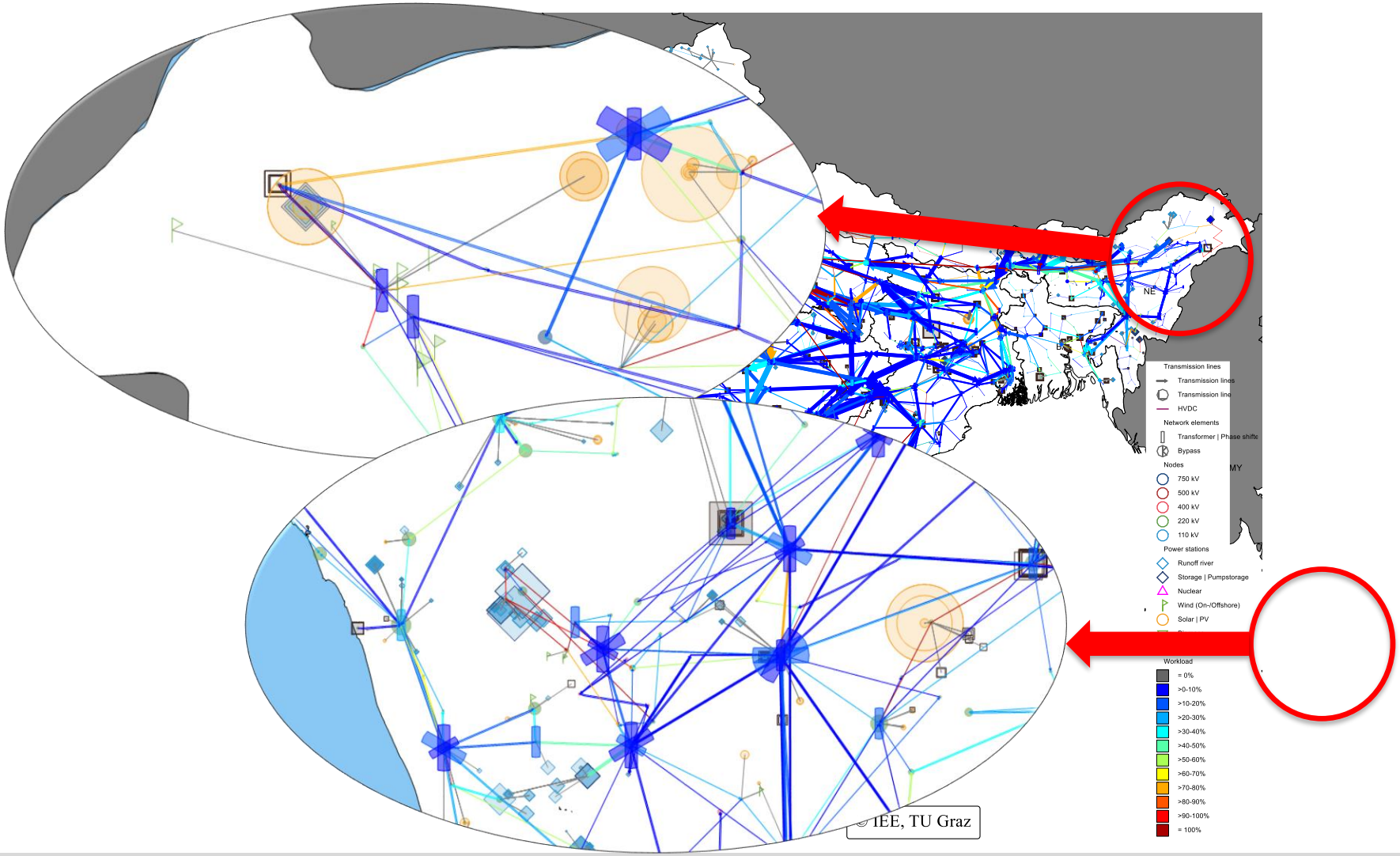
Study: storage scenario

- PHP capacities – published national strategy
- Existing PHP capacities upgraded
- Battery stations: mainly used for peak load coverage
- Battery capacities are assumed to be PHP stations with different generation patterns

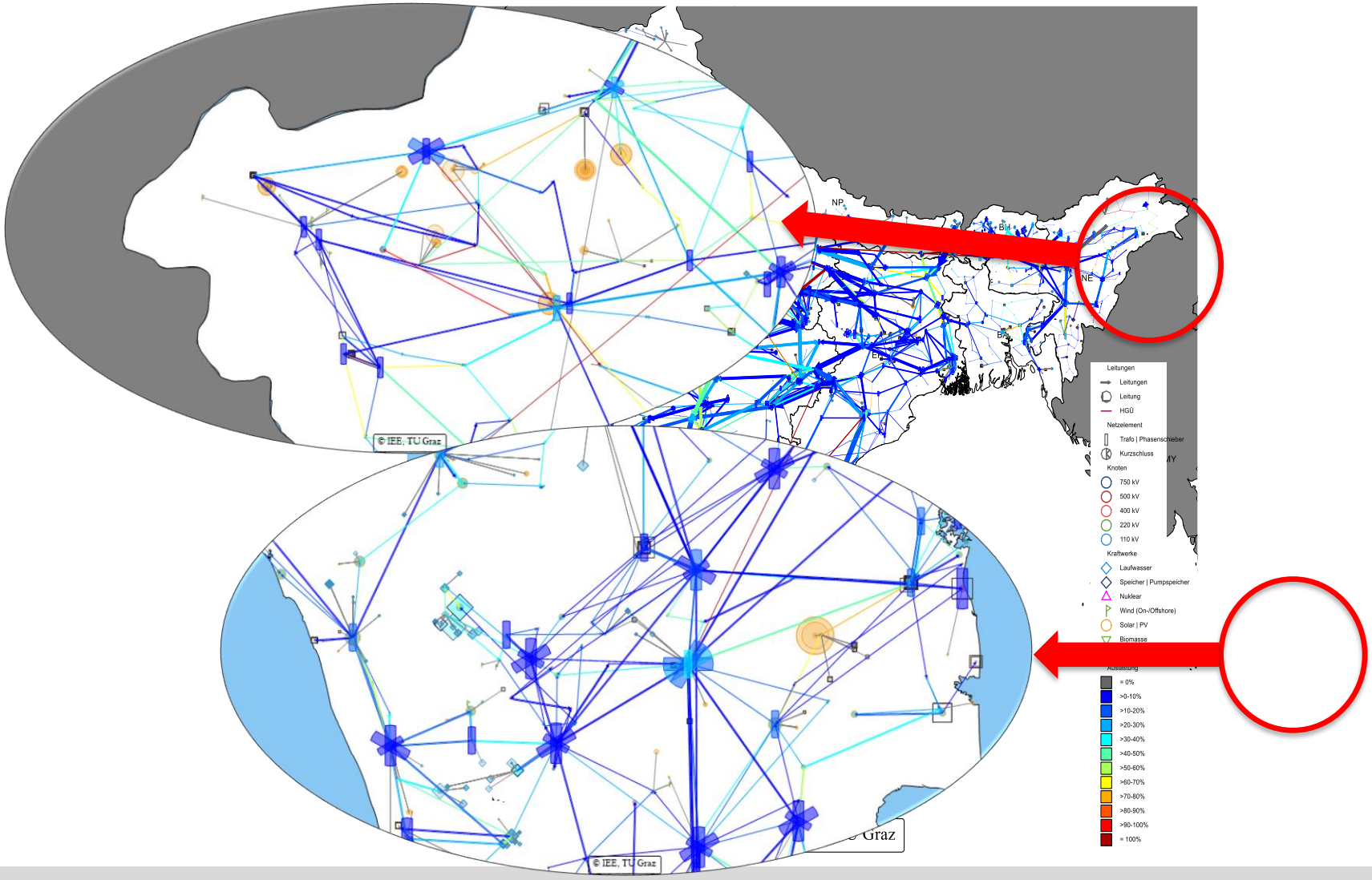




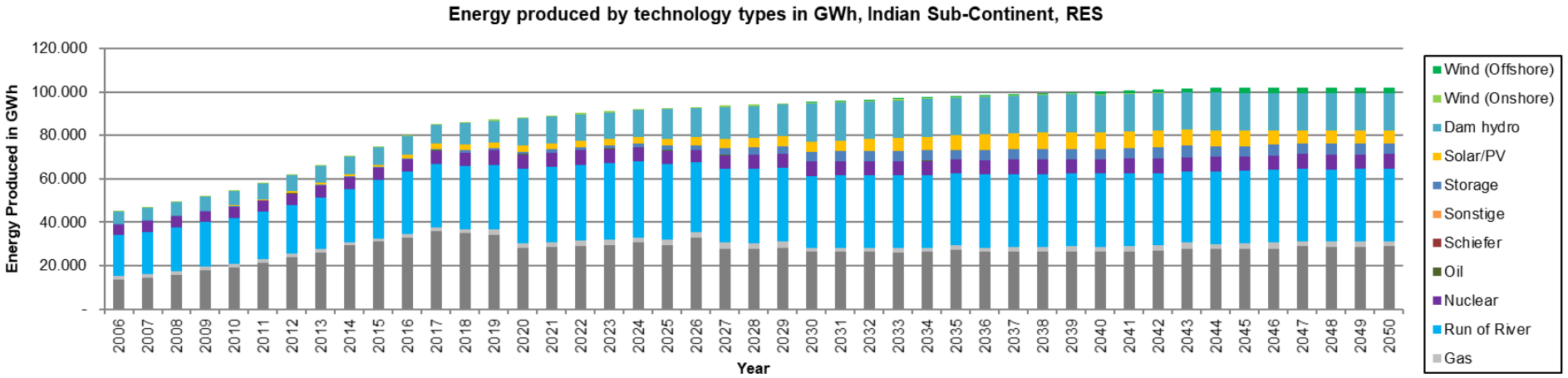
Results: ‚Peak_a' Period, August 2040, Loadflow

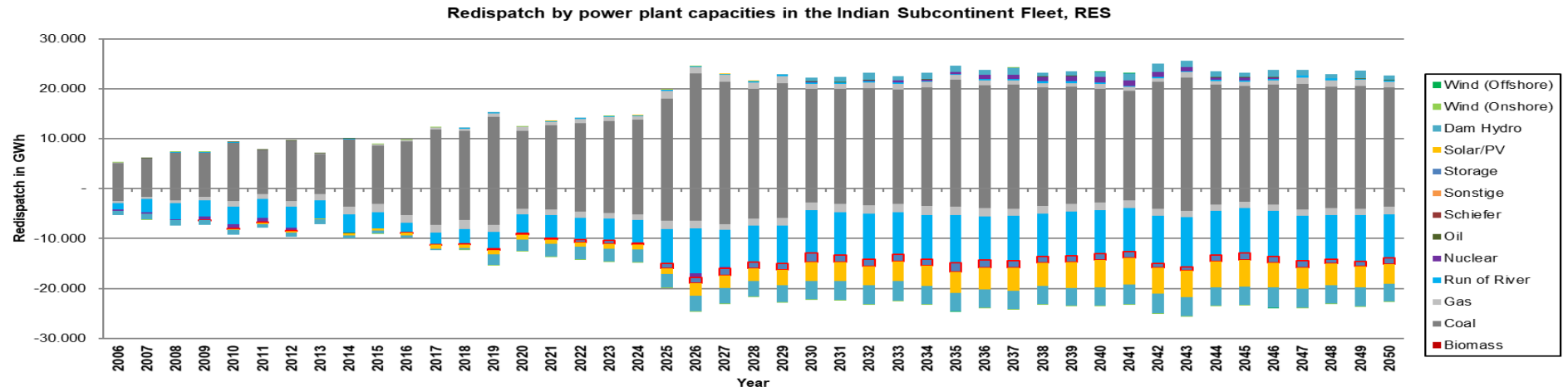


Results: ‚Off-Peak_a' Period, August 2040, Loadflow



Results: Electrical energy generated and Re-dispatch





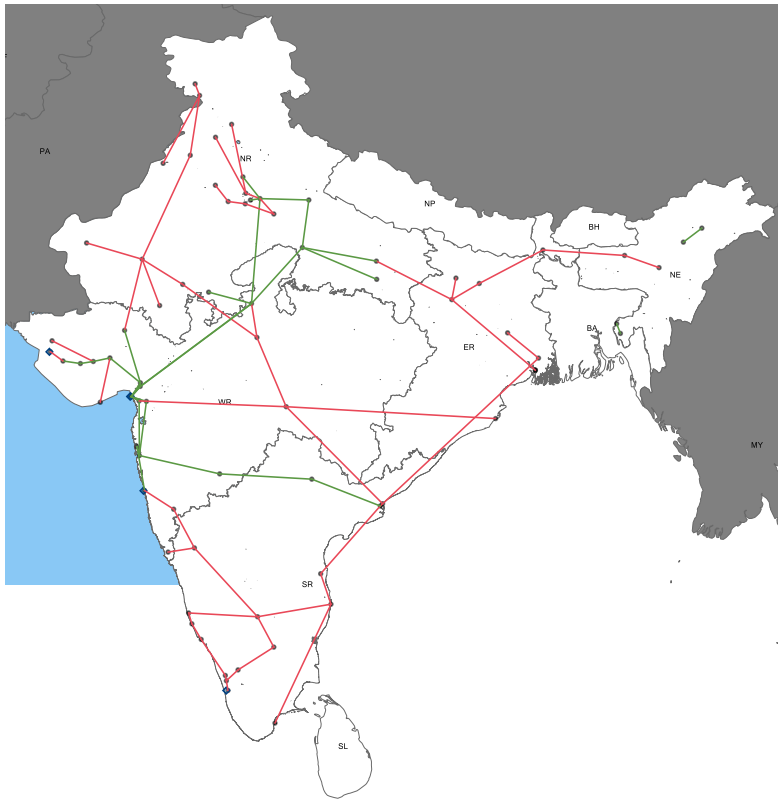
Conclusions

- More emphasis on LES in national strategy : Major priority
- Planned LES: barely sufficient, for peak load coverage and RES integration
- Planned RES create major bottlenecks in the 220 kV transmission level
- PHPs should be more encouraged: Large capital stock assets
- Transmission infrastructure around planned LES:

  - strategic planning, preferably at 400 kV level
- Redispatch: due to transmission bottlenecks, LES units are under-utilized

For the future..

- Charging and discharging patterns for Battery storage units
- Alternative LES options: CAES, Gas networks, P2X
- E-mobility integration for the Indian subcontinent
- Sustainability and footprint analysis for LES in India



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