International Energy Agency

Maharashtra Power System Transformation

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Mumbai

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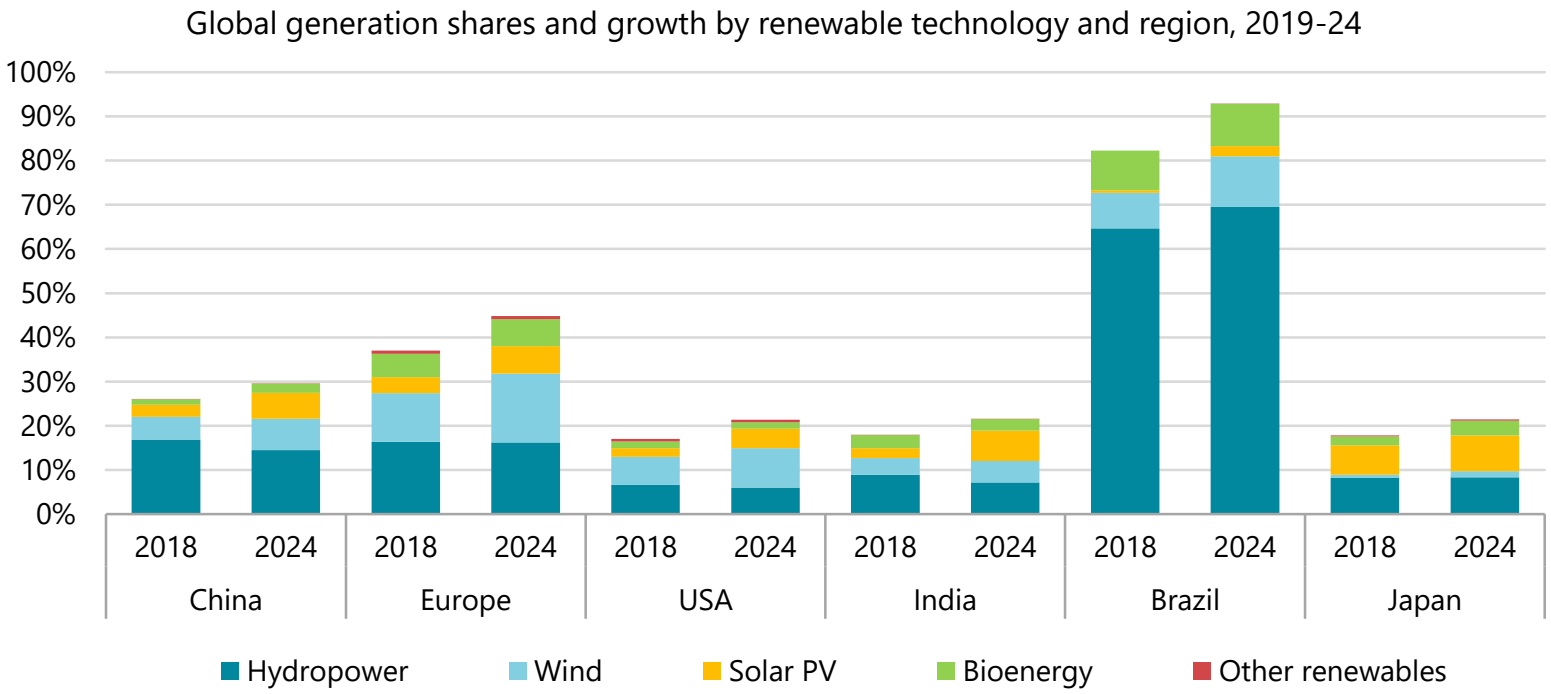
Renewables are forecast to provide 30% of global electricity generation by 2024



By 2024, renewable electricity generation totals more than 9 000 TWh, with 75% of it concentrated in just six markets: China first, then Europe, the United States, Brazil, India and Japan. In India and China additional renewable generation comes mostly from PV and wind.

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India's significant progress in sustainable development

- India is the largest overall source of global energy demand growth by 2040 in SPS in the 2019 *Outlook*
- Renewable sources dominate the increase in global power generation capacity in the Stated Policies Scenario, with solar PV taking the lead
- India is the world's 5th region measured in % of renewables in total power generation capacity additions. This is coupled with significant growth in coal generation to meet demand

Share of renewables in total capacity additions by region and scenario, 2019-2040

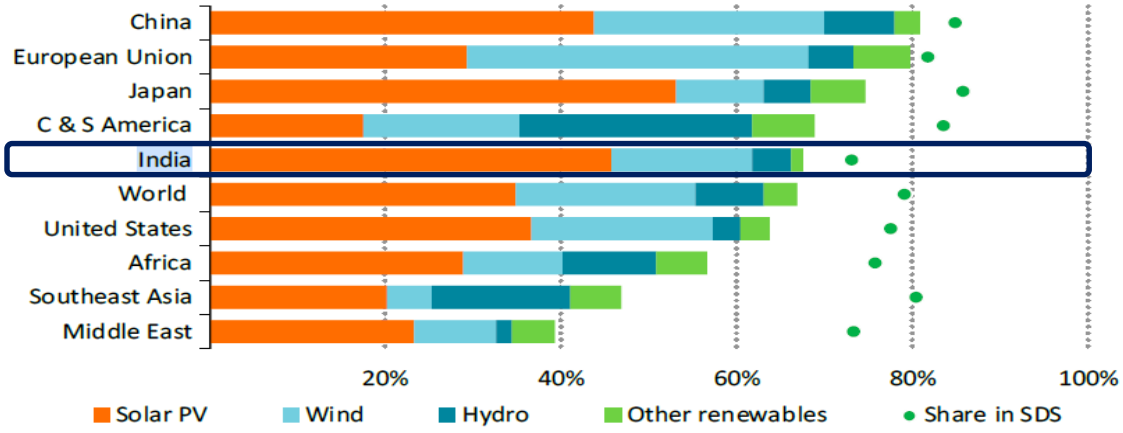

Image source: WEO 2019, page 39

India has emerged as a global leader in renewable energy, notably in solar power.

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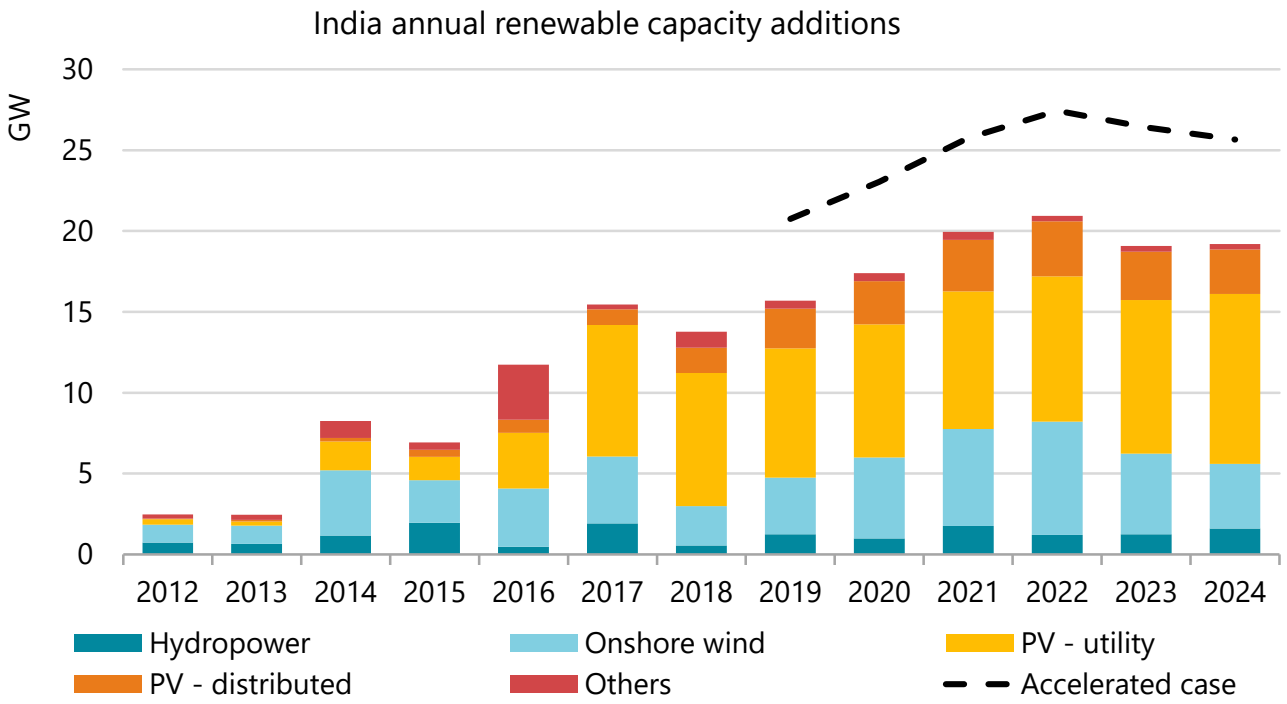
India's annual renewable capacity additions to increase 50%



Forecast is driven by utility-scale auctions for wind and solar PV but DISCOMs financial health, grid connection, financing remain key challenges hampering faster growth

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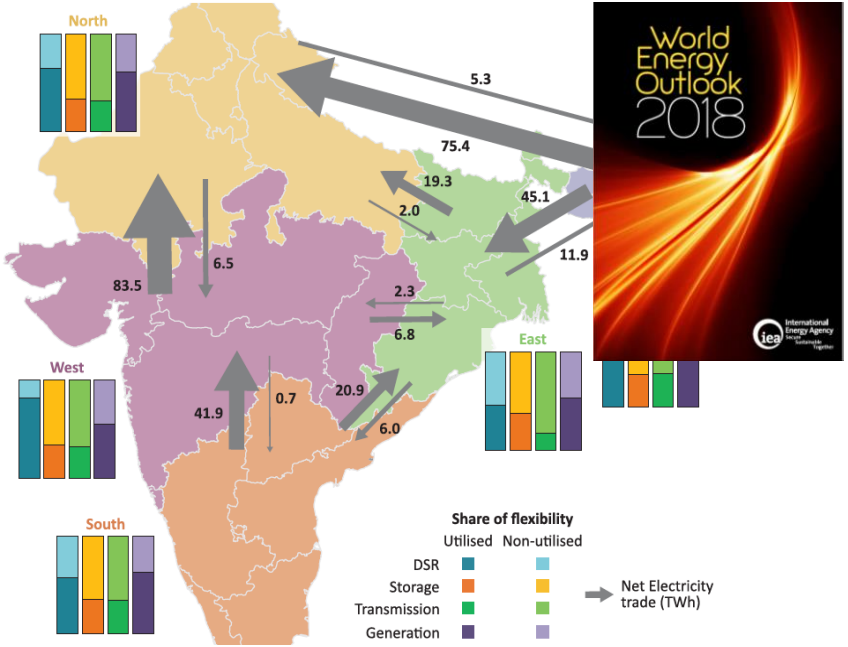
India – Production cost modelling to assess flexibility requirements

- **Adequate system flexibility is essential** for the **security and reliability** of electricity supply in India in 2040.
- Given the seasonality of India's wind generation and the step down in generation from solar at sundown in all the modelled regions, **storage is deemed to play an important role in the electricity markets.**
- Generation remains the **largest source of short-term flexibility**
- **The average use of demand side response resources is higher** in the **western, northern and southern region**, driven by strong presence of wind and solar.



Power systems around the world are undergoing significant changes driven particularly by the increasing availability of low-cost variable renewable energy (VRE), renewable integration needs right tools to assess flexibility requirements

Source: World Energy Outlook 2018, https://www.iea.org/weo2018/

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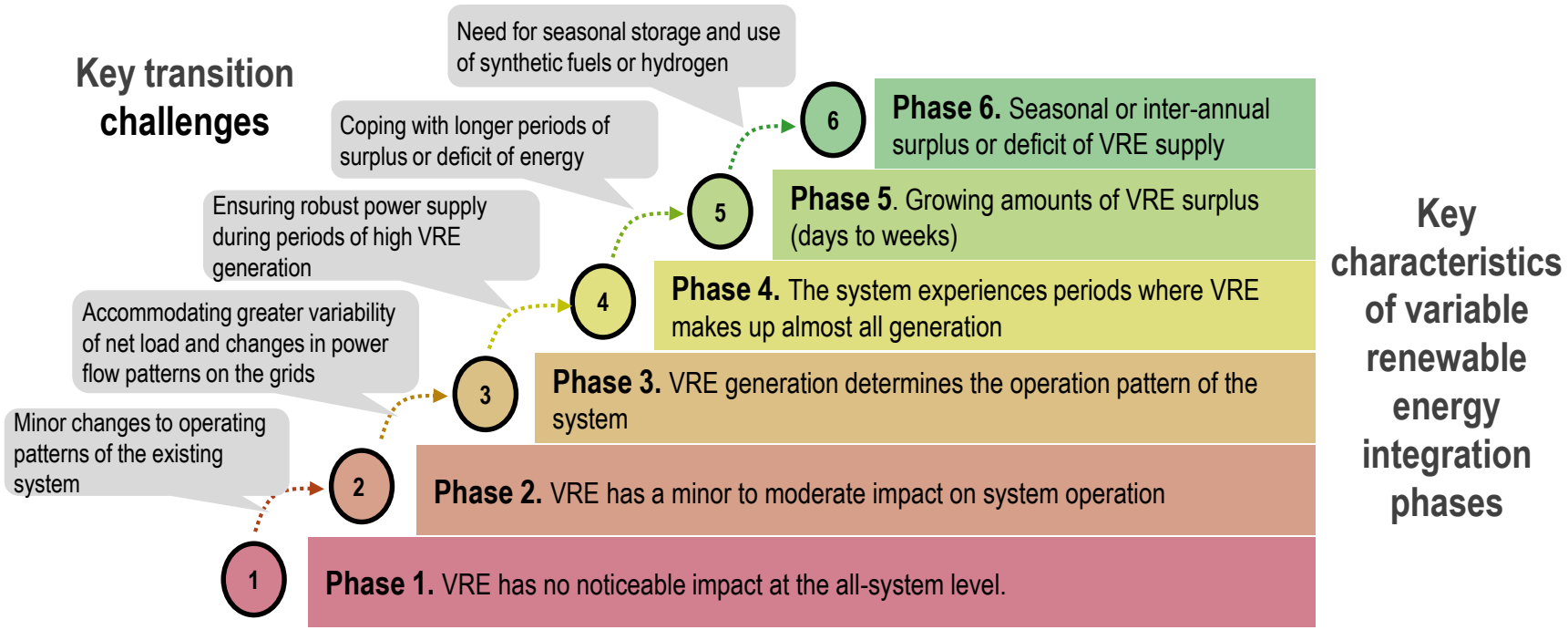
Introducing the six phases of system Integration



Key challenges in each phase that should be addressed for moving up to higher phases of variable renewable energy (wind and solar) integration

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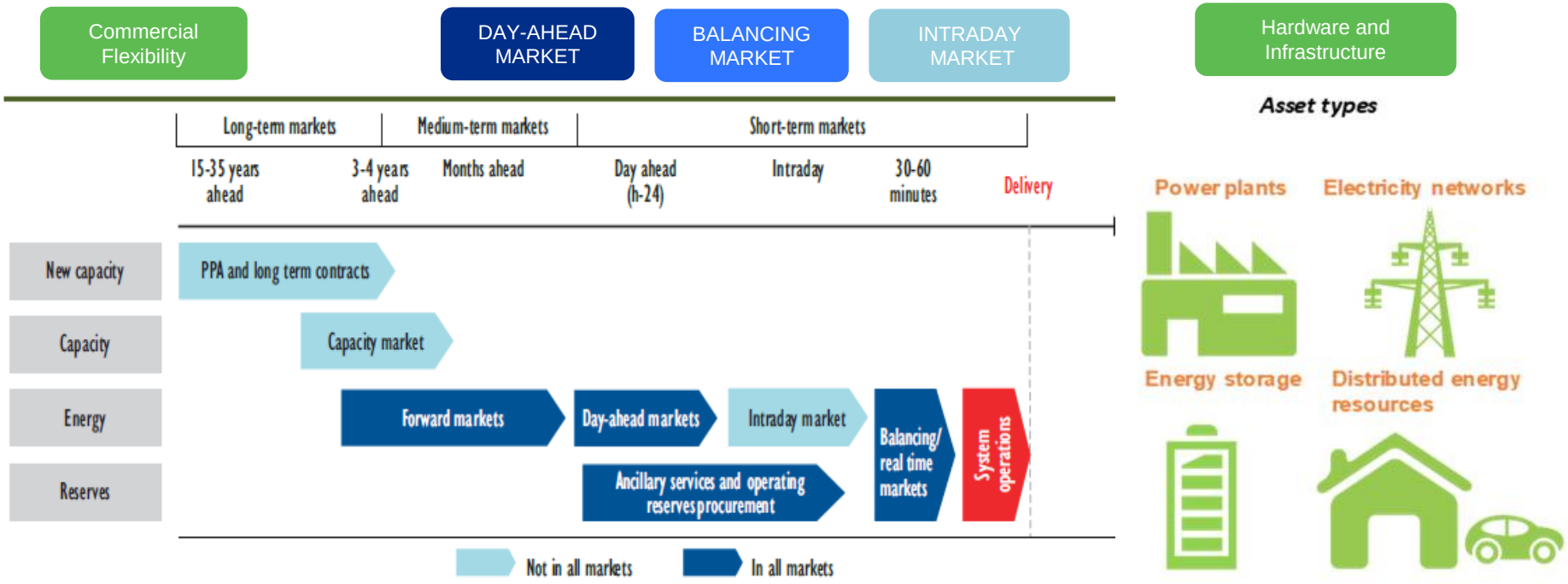
Drivers of system flexibility around the Globe



Enabling greater power system flexibility may require designing, rethinking and reforming of market mechanisms. Sector players often highlight that hardware flexibility is ahead of policy, market, regulatory and institutional reforms

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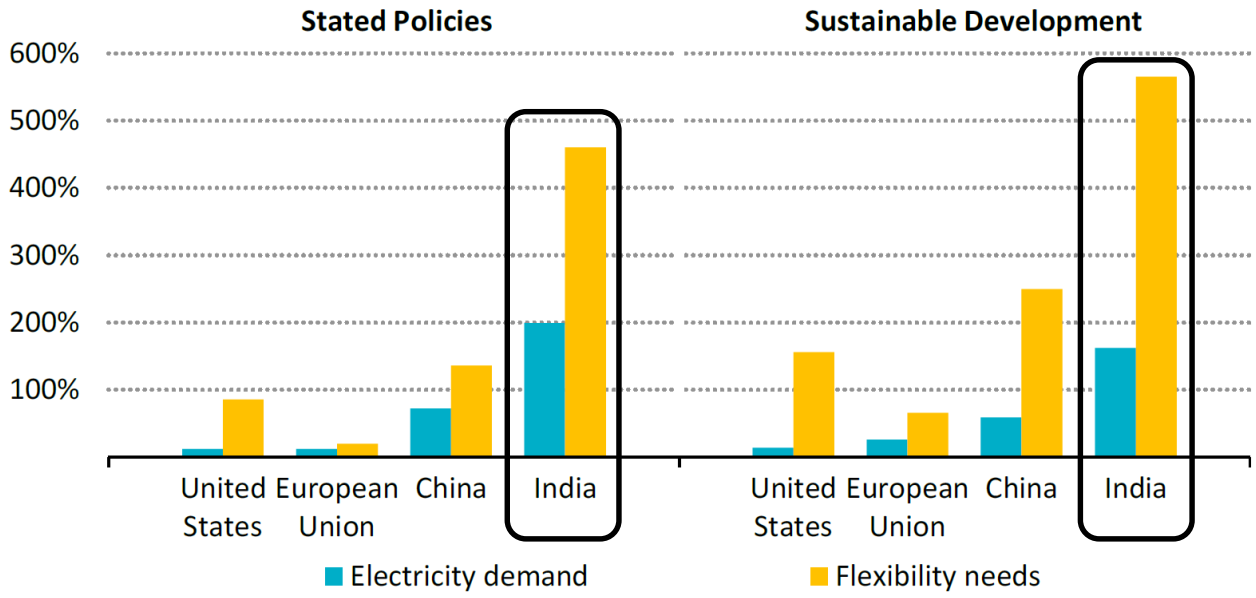
Need for exploring new frontiers of Flexibility

- Hour-to-hour adjustments required in power systems due to variability in demand, wind and solar

Growth in electricity demand and flexibility needs by selected region and scenario, 2018-2040



Flexibility needs increase much faster than electricity demand, driven by rising shares of variable renewables, more electric vehicles and higher demand cooling

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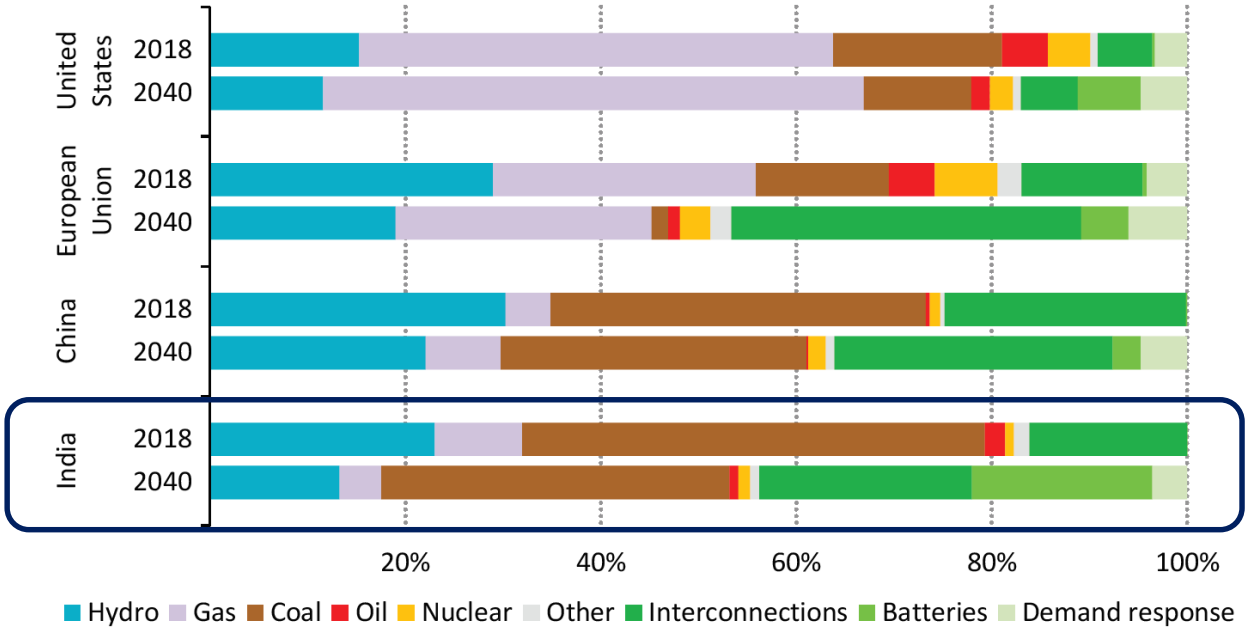
Diverse portfolio of Flexibility options will be required

Sources of flexibility by region in the Stated Policies Scenario



Thermal power plants continue to provide the bulk of flexibility needs, along with interconnections, but batteries and demand-side response are rising fast

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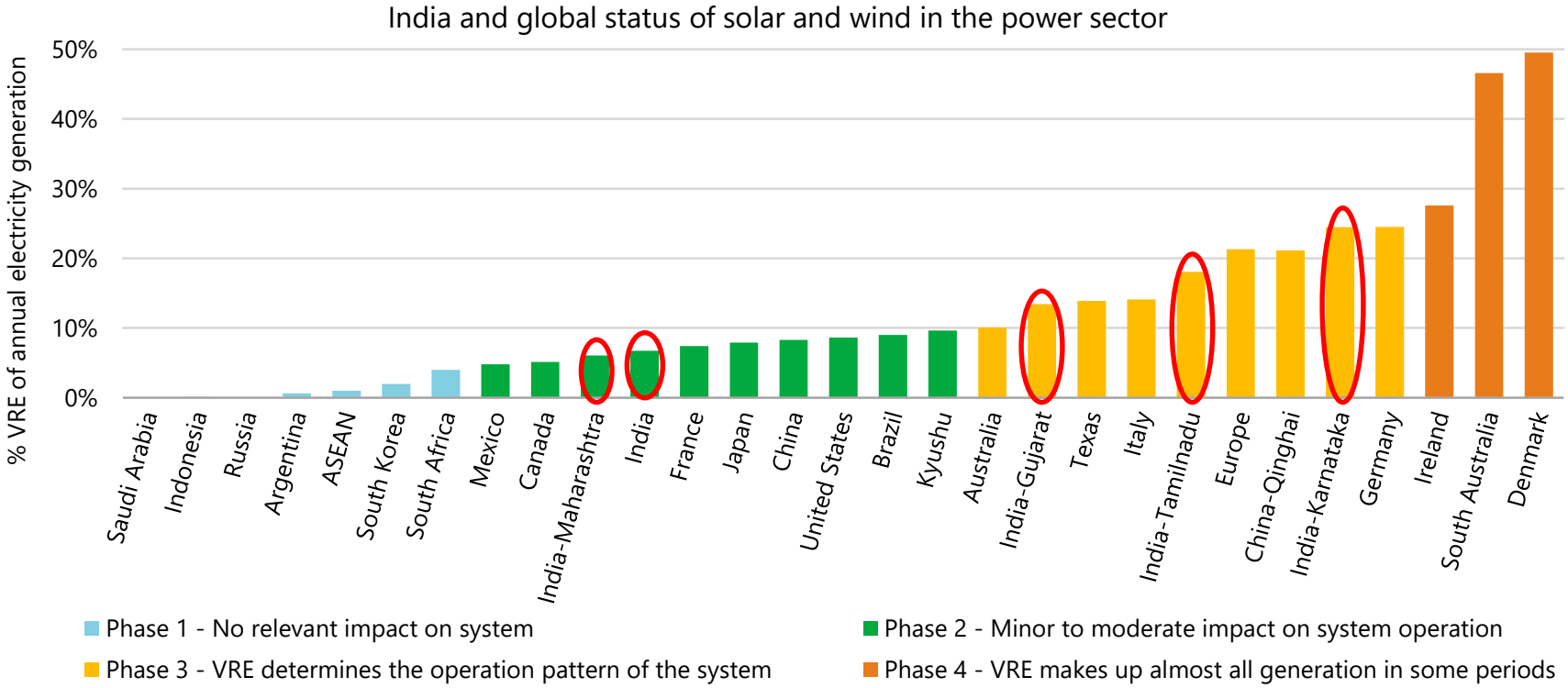
Status of solar and wind in the power systems globally vs India (some VRE rich States)



Globally most regions remain in phases 1 or 2. India's rapid energy transition already places some states in phases 2 or 3, while global examples of regions in phases 3 and 4 demonstrate a diversity of measures that can accelerate VRE integration.

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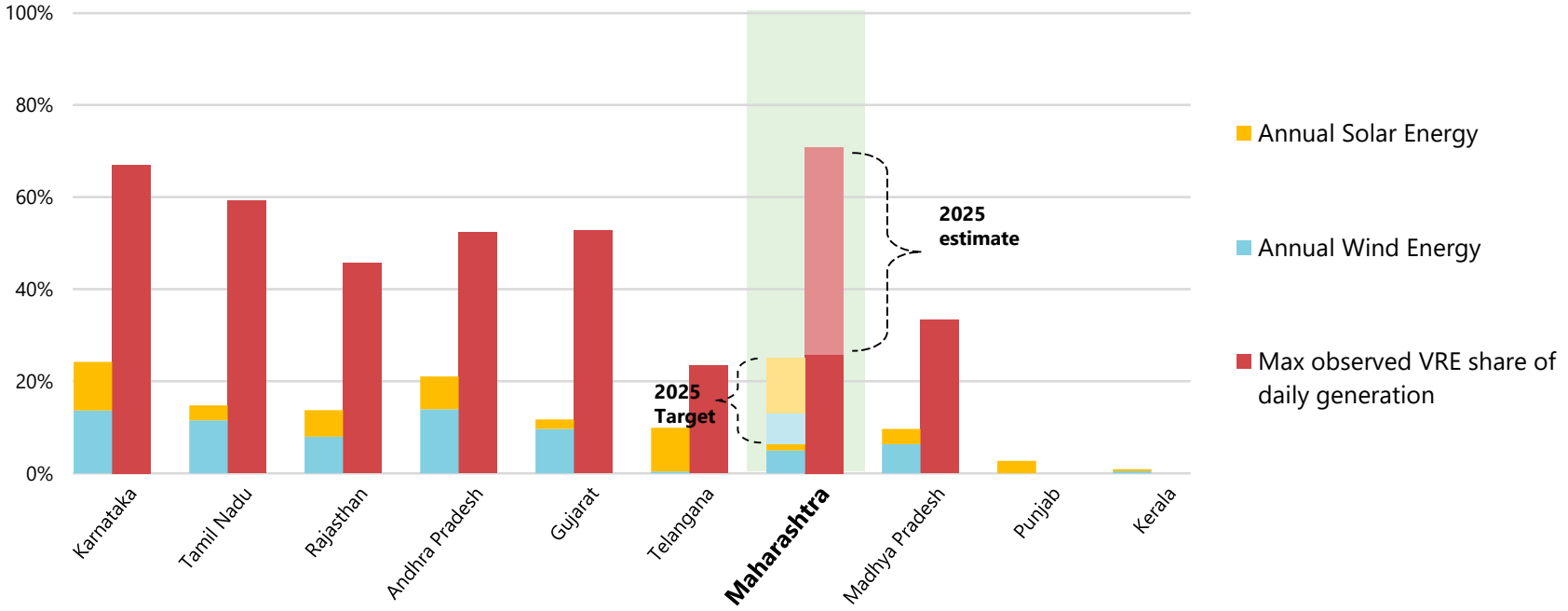
Power systems with high share of Solar and Wind generation, VRE rich states comparison

Electricity generation from VRE as a percentage of all generation in VRE-rich Indian states, 2018/19



Achieving the 2025 VRE targets of Maharashtra results into a significant increase of the daily VRE share of peak demand, requiring more flexibility services which will put the state in phase 3 similar to Karnataka.

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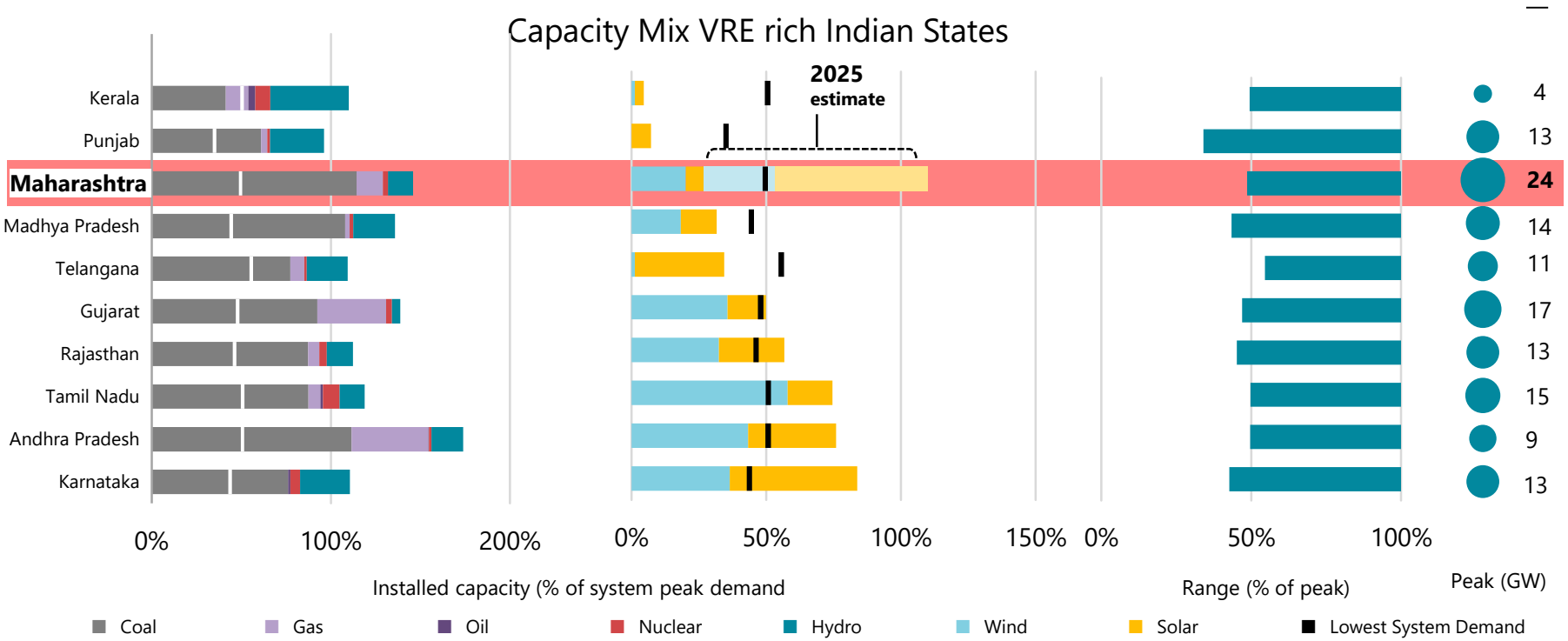
Installed components of power systems relative to peak demand



In 2025 the generation mix of Maharashtra will look similar to the current mix of Karnataka, with the installed VRE capacity doubles to the lowest system demand.

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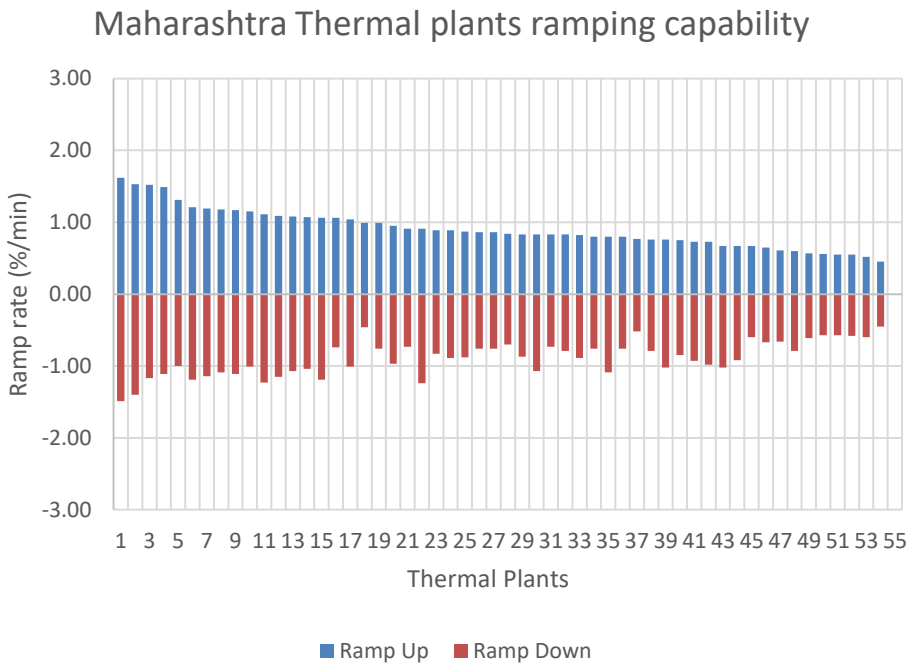
Unlocking flexibility through Thermal Plants

- In Q1 (April-June) wind generation is supporting its demand
- In Q2 (July-September), wind generation is following the ramping up in demand and ramping down when demand is low.
- In Q3 (Oct-Dec) wind generation is opposing its demand
- In Q4 (Jan-Mar) wind generation is opposing its demand
- **Solar generation remains low during July to September** because of rainy season **and high during January to March**.



Ramping support from thermal generation would be an important attribute considering the large scale renewable integration and changing load shape

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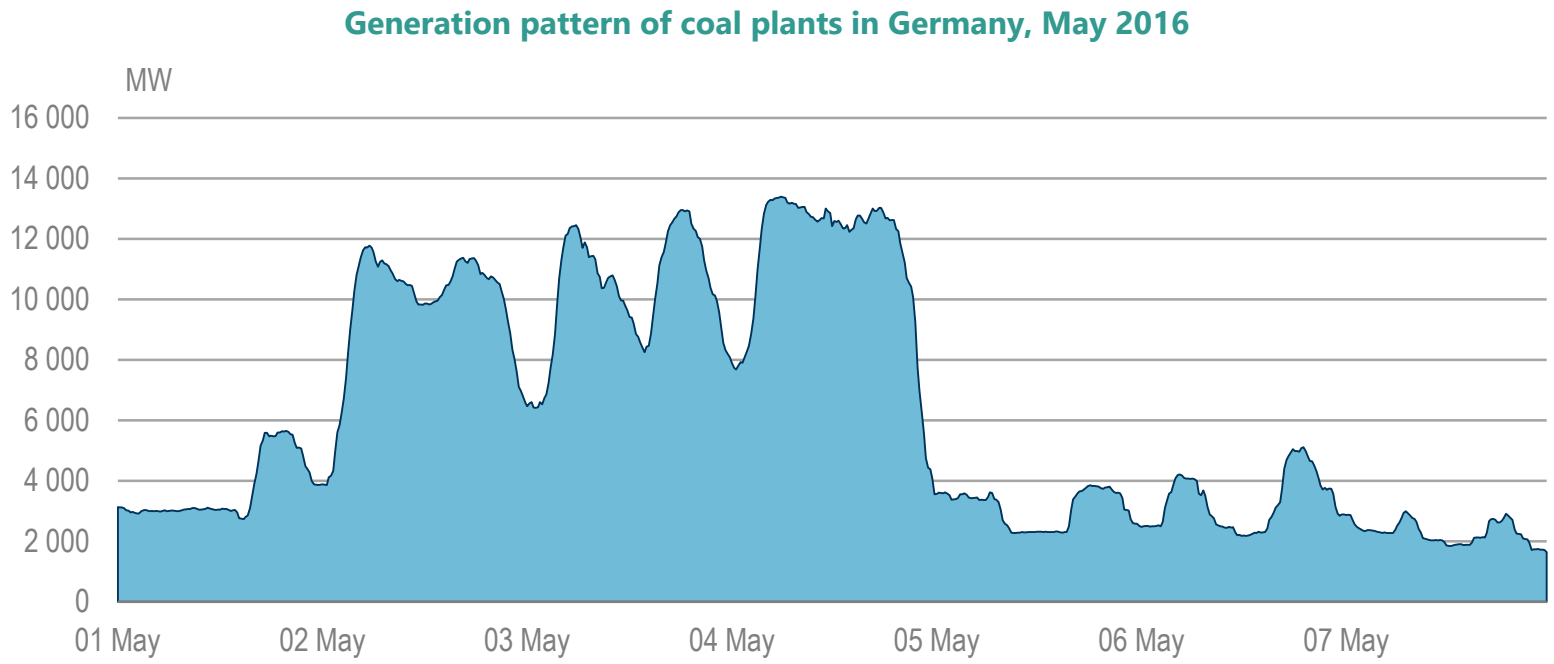
Power plant flexibility can be enhanced



Power plants are an important source of flexibility, evident in countries such as Germany, Denmark, Spain, the United States

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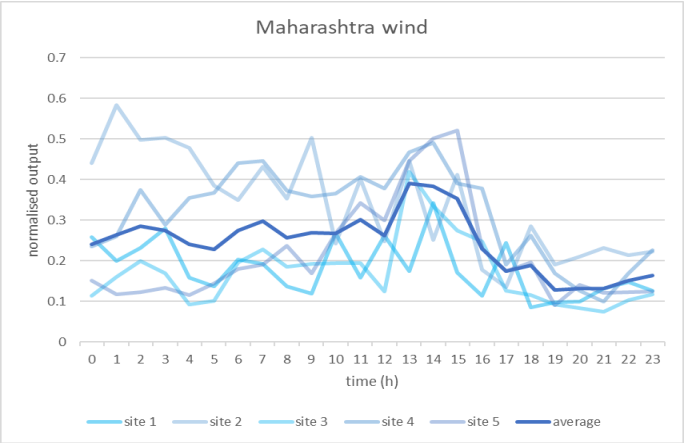
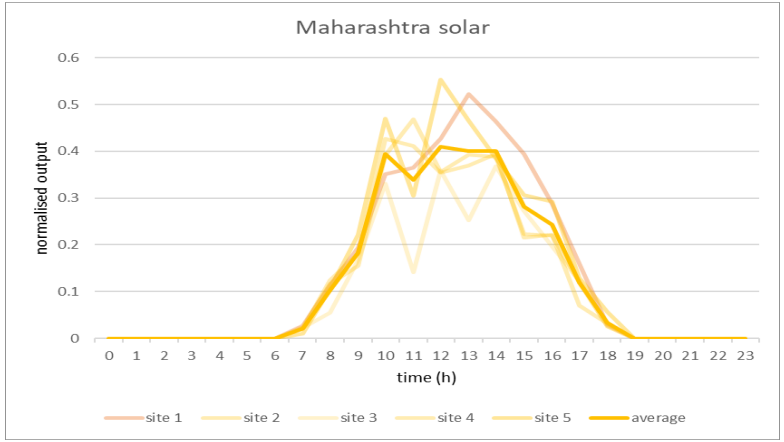
System friendly deployment of VRE and the grid

Measures that make the deployment of VRE more accommodating to the system

- **Technology mix** – outputs from different technologies can compliment one another
- **Geographical spread** – dispersal of VRE plants can smooth the variability
- **System services** – VRE plants that can provide system services (frequency, voltage, etc.)





VRE output and the benefit of geographical spread in Maharashtra, India.

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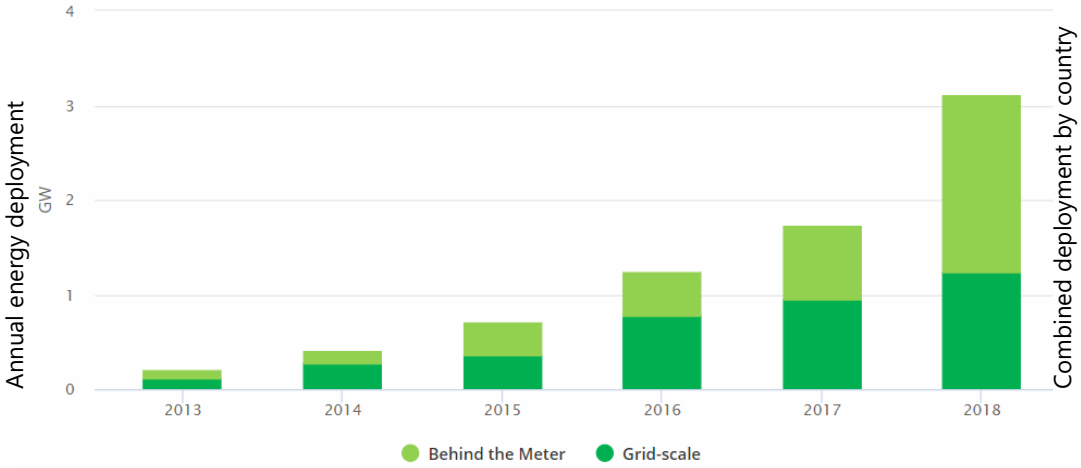
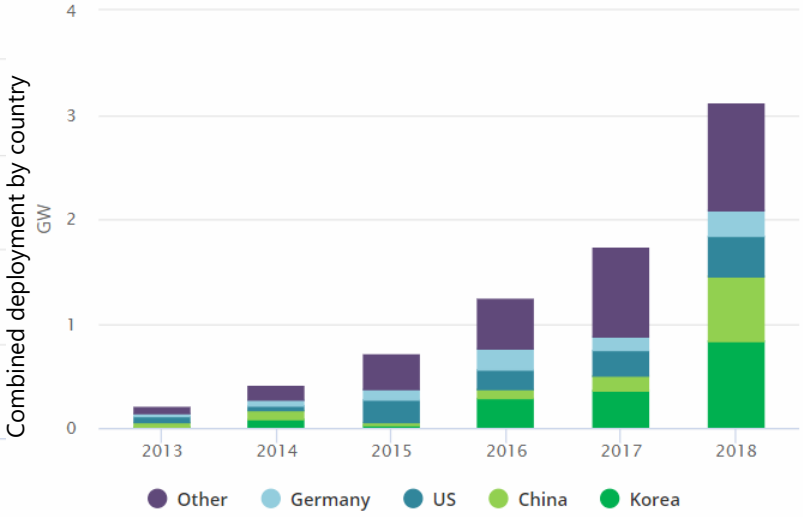
Energy storage capacity is growing fast

Energy storage deployment reached a record level in 2018, nearly doubling from 2017. The leading country was Korea (accounting for over one-third of all global capacity installed in 2018), followed by China, the United States and Germany.





Source: IEA: https://www.iea.org/tcep/energyintegration/energystorage/

Korea's strong deployment is a result of favourable policy measures. China's significant increase in 2018 was from a range of backed projects supporting network operations and markets for frequency regulation services. Germany got the support of subsidy programme and US had favourable state-level policy developments.

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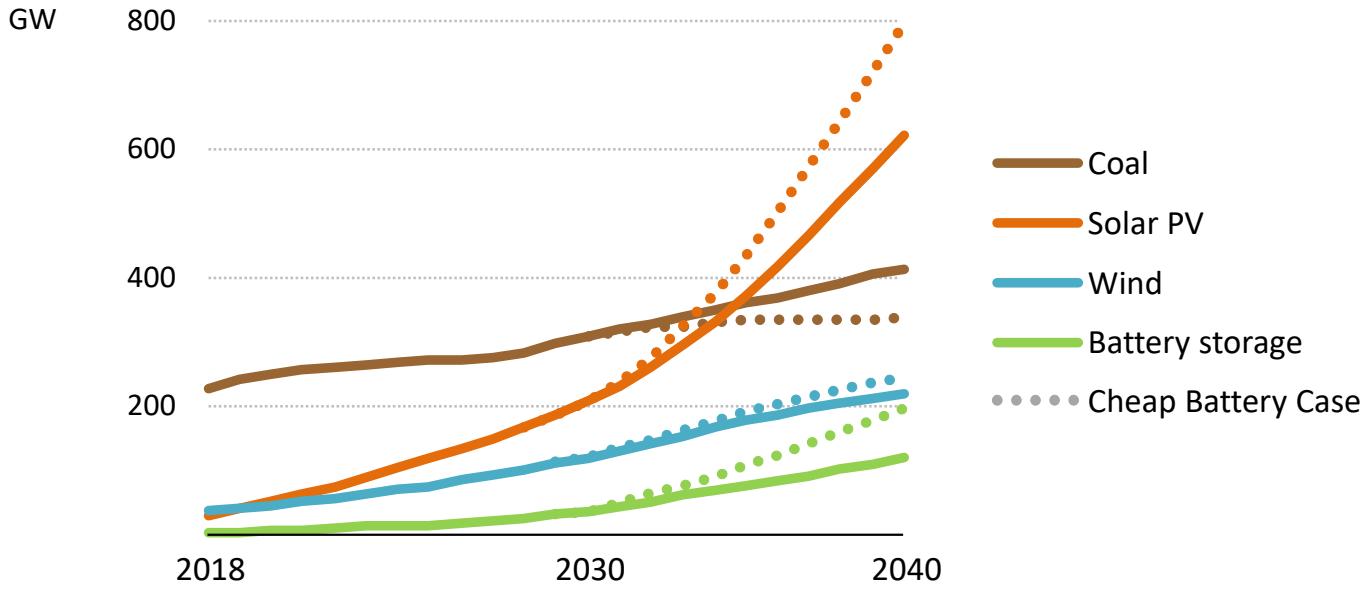
India could be the launch pad for battery storage

Installed capacity by source in India in the Stated Policies Scenario and Cheap Battery Case



Cheap batteries could enable more solar PV and wind installations in India and reduce coal use in the power sector

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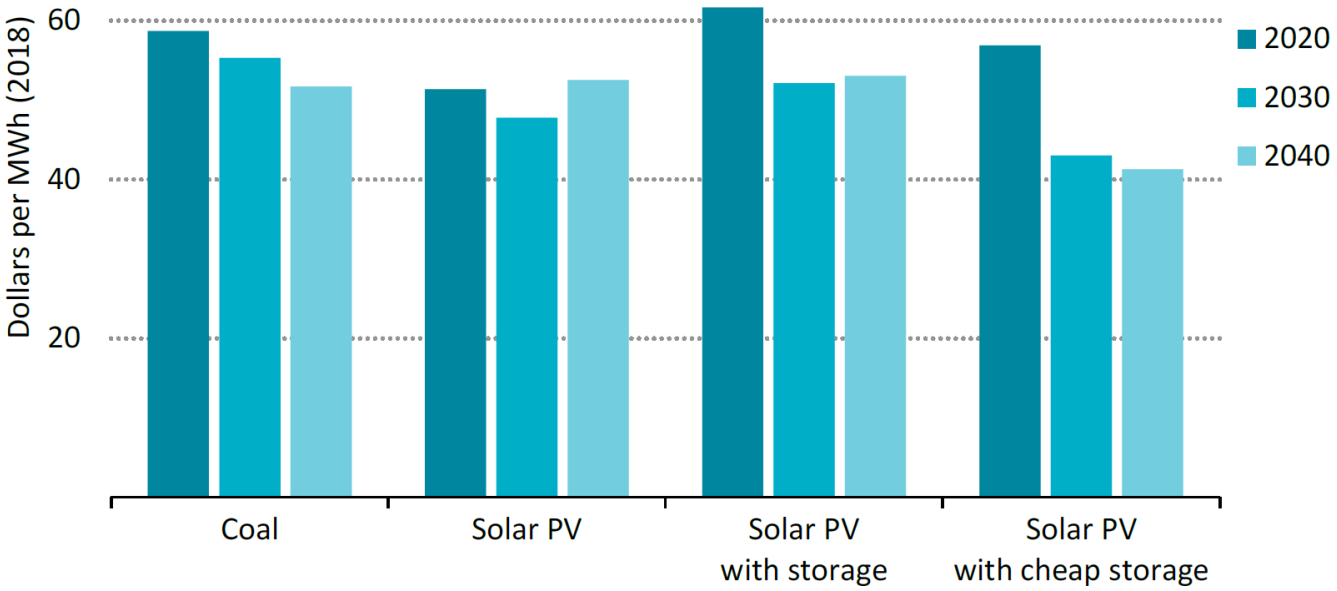
Batteries are becoming a cost-competitive flexibility provider

Value-adjusted LCOE for select power technologies in India in the Stated Policies Scenario



Compared with new coal-fired power plants, solar PV alone is already more competitive and solar PV with storage is rapidly closing the gap, especially if batteries are cheap

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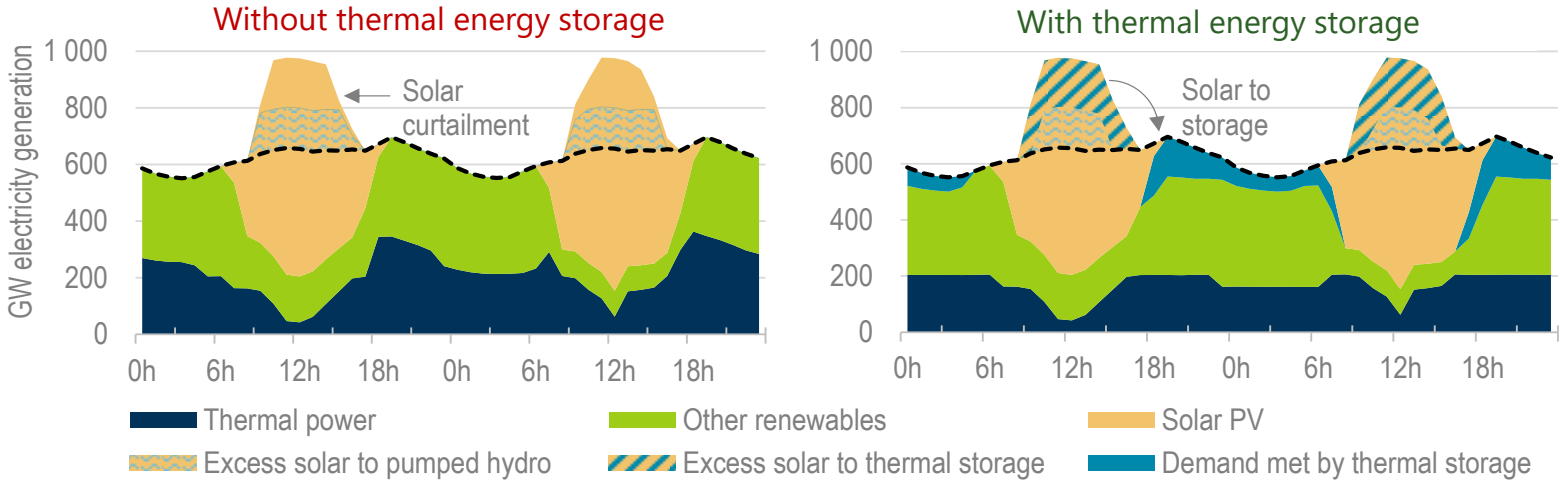
Modelling example – Potential role of thermal storage in India

- Potential solar PV curtailment due to expected high capacity in 2050, Cooling demand is also expected to grow substantially
  - Peaking in the evening when solar PV is no longer available
  - Thermal storage could take advantage of surplus solar output to alleviate the strain of peak cooling demand on the electricity system in the evenings
- 2400 $GW_{thermal}$ cold storage in 2050 allows around a fifth of total PV output to be stored during the day and used to meet around 15% of cooling demand after sunset, translates into savings of around 9.7 billion USD per year, compared with 7.5 billion for battery storage due to the lower thermal storage cost



Source: The Future of Cooling, https://www.iea.org/futureofcooling/

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Flexibility sources: grids

For the EU grid

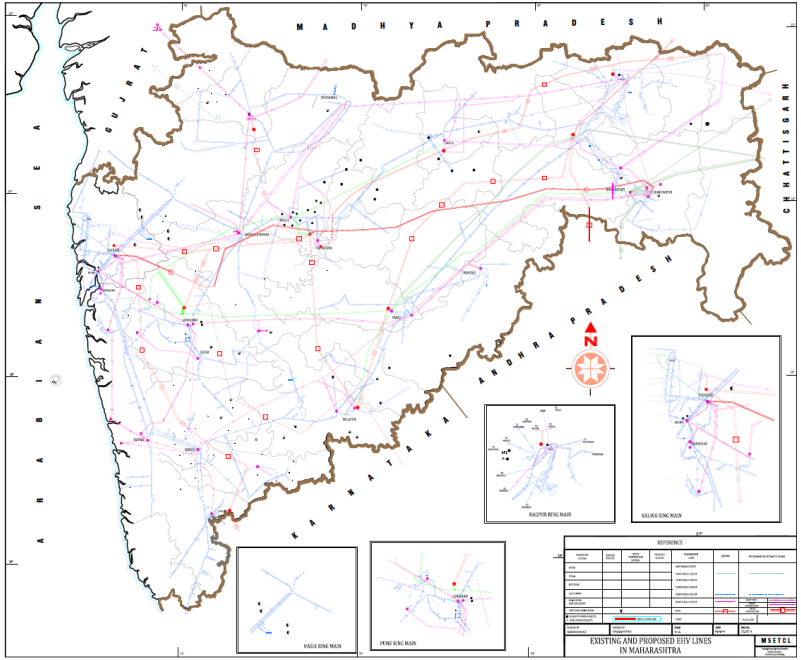
- Total capacity between zones is planned to increase 60% to 75% depending in the scenario compared to today
- In these scenarios for 2040, about 65 to 81% comes from RE
- Grid itself reduces marginal cost by 3 to 14Euro/MWh in 2040 (compared to a scenario without grid expansion)

For China

- Total capacity between zones is planned to increase by 500% by 2030.

For Australia

- Total capacity between zones is planned to increase 50% to 70% by 2040.



Multilateral trade based on the existing cross-border interconnectors can reduce the overall operational costs, expanding interconnectors can further reduce operational costs. It enables the integration of higher share of VRE (Less curtailment) while providing economic and environmental benefits

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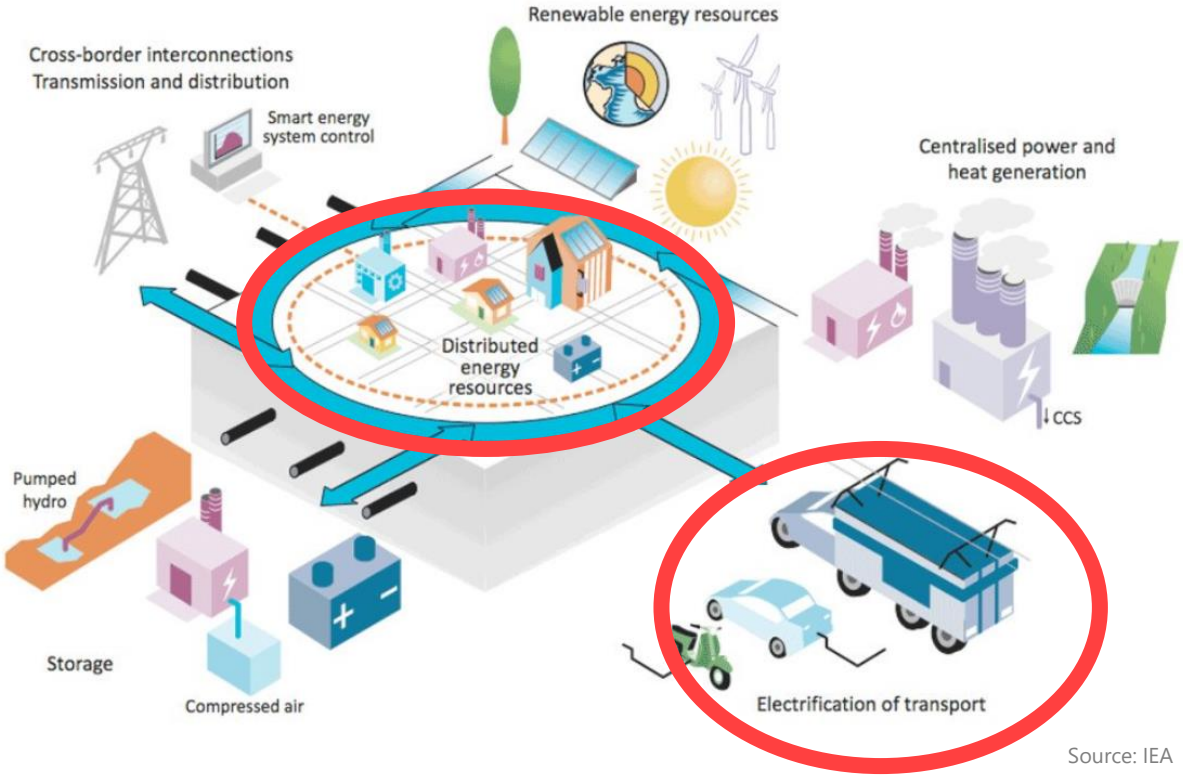
Flexibility sources: Distributed Resources, Demand Side Flexibility?



Source: IEA

All resources on the customer-side of the meter, including:

- Distributed generation
- Distributed storage, thermal and electric (including EV charging)
- Demand response
- Energy efficiency

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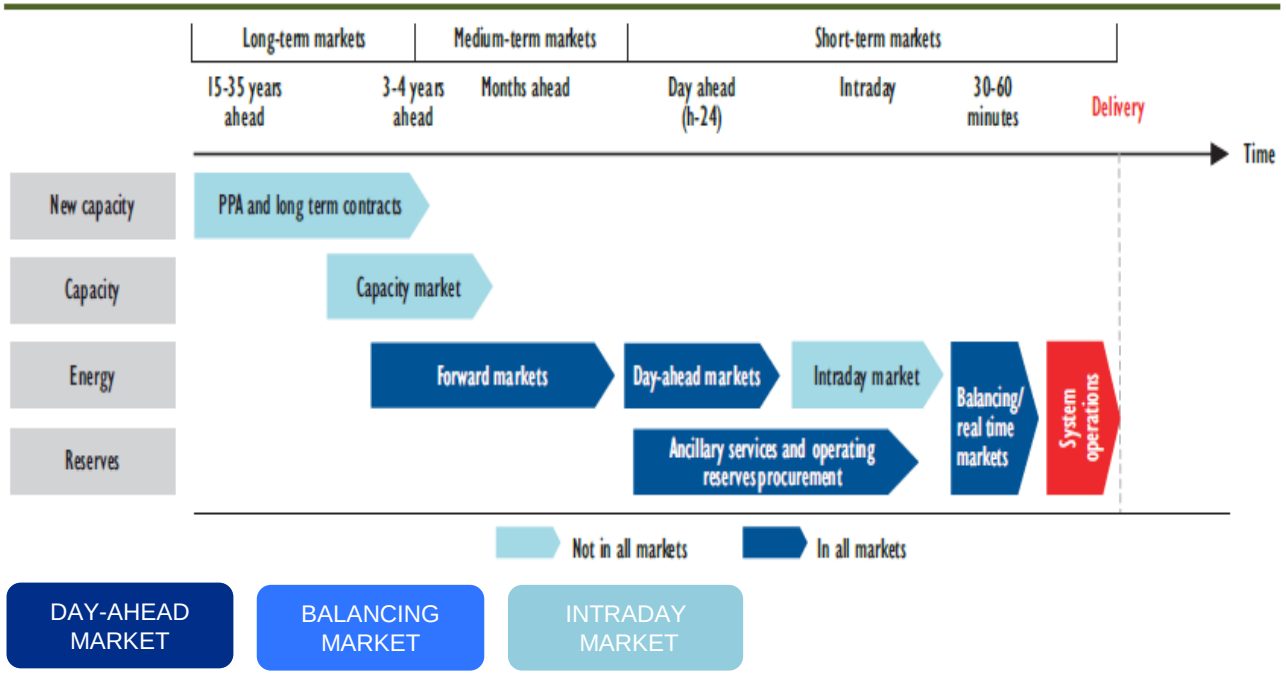
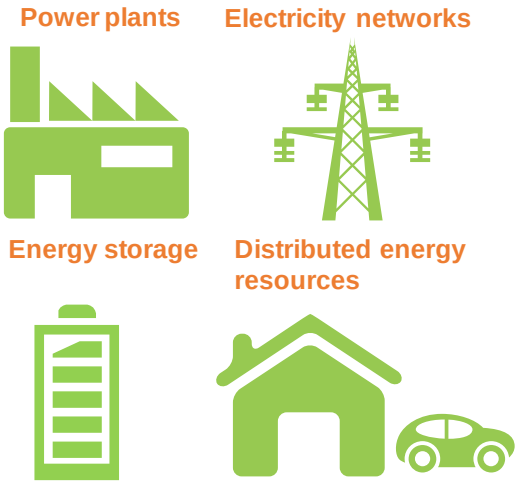
Drivers of system flexibility around the Globe



Hardware and infrastructure ("What")

Asset types



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