Integrating solar PV and wind into the grid

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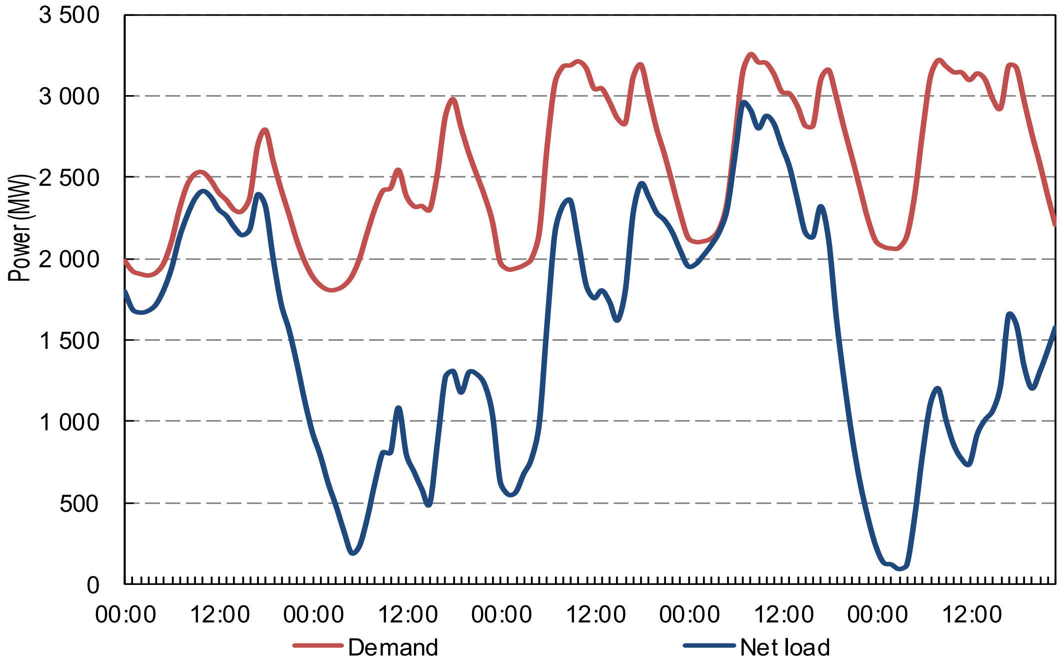
Solar and wind power create new challenges for power systems

New operational requirements

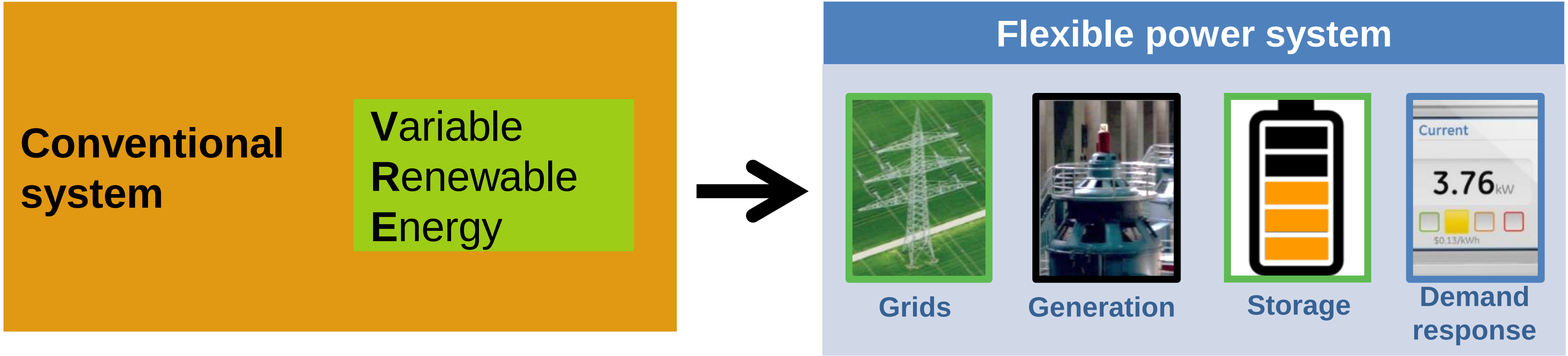
Net load =
power demand
minus
wind and solar output



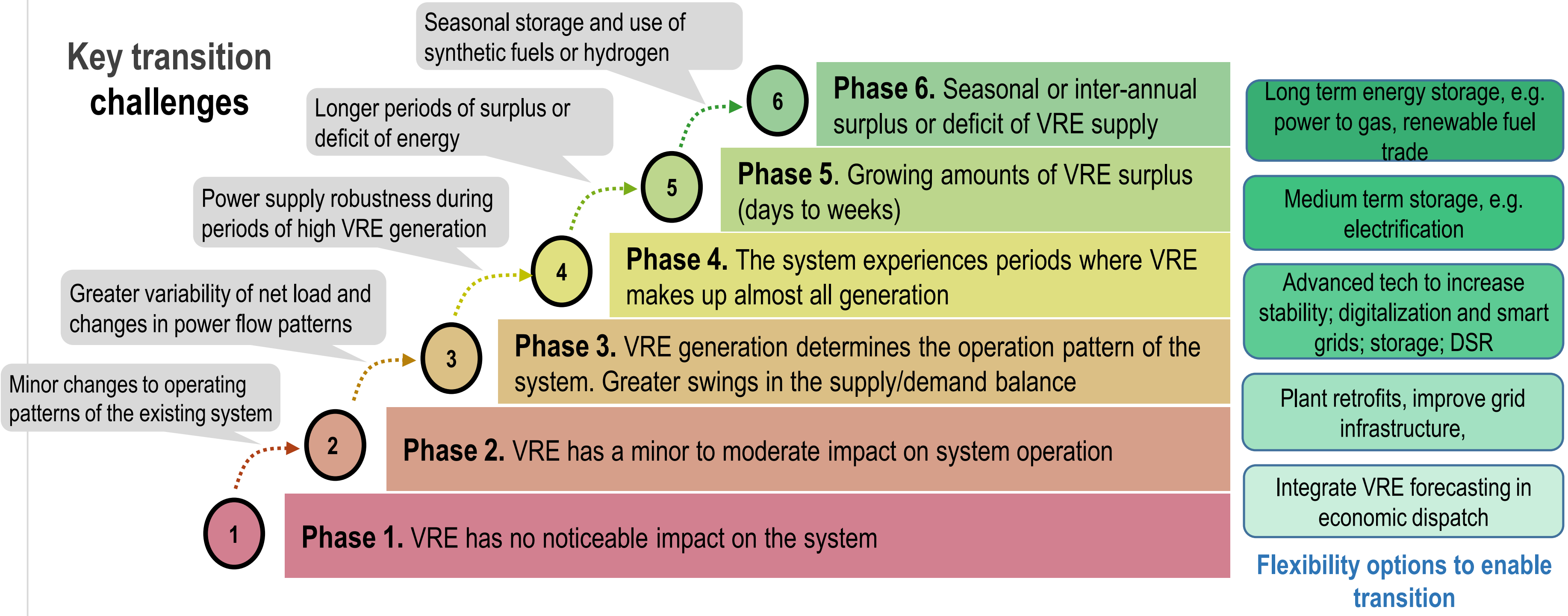
Greater variability and uncertainty with high share of VRE with greater flexibility requirements. But this is manageable. Power systems have already been dealing with demand and supply variability

Three main messages on system integration

1. No problems at low to moderate shares of VRE, if basic rules are followed
2. Very high shares of VRE are technically possible
3. Reaching high shares cost-effectively calls for a system-wide transformation



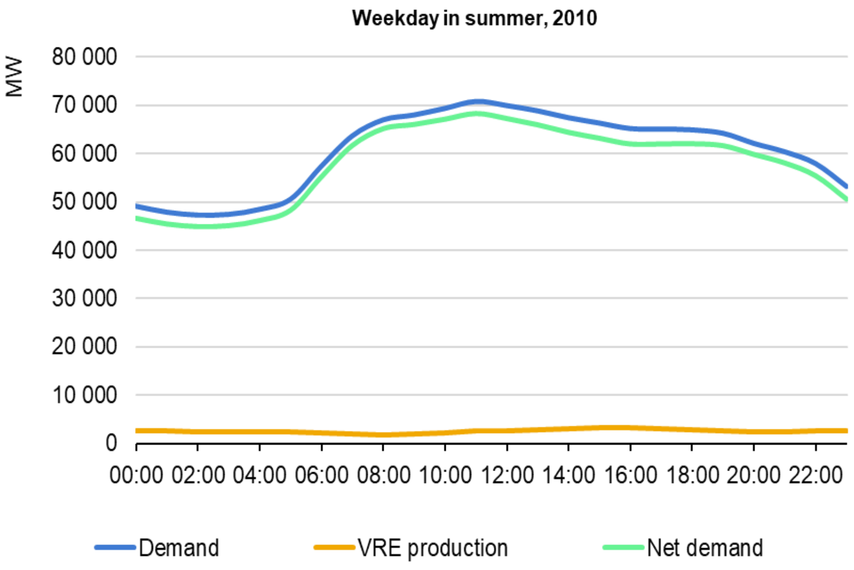
Characteristics in different phases of system integration of VRE



Key challenges in each phase that should be addressed for moving up to higher levels of integrating VRE in the power system

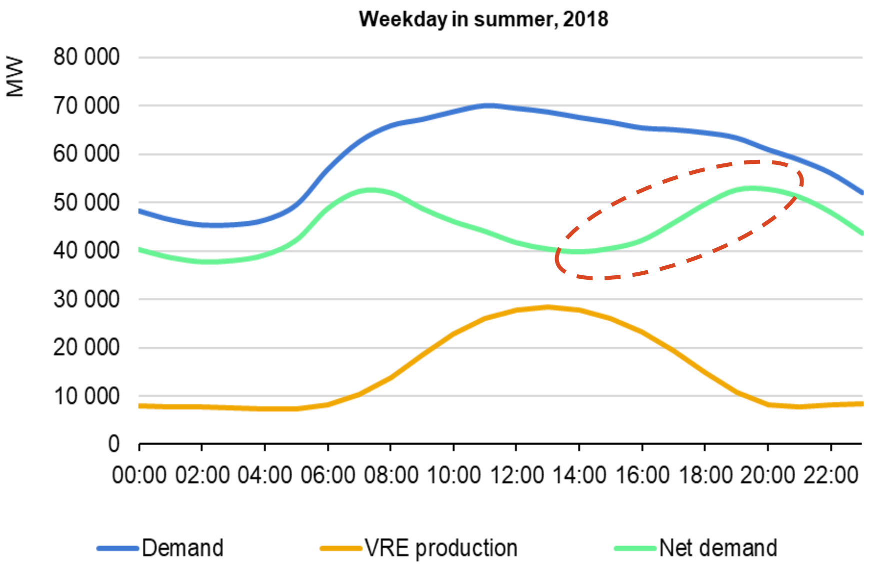
Net load comparison for different phases of VRE integration

Demand and VRE production, Germany, 2010



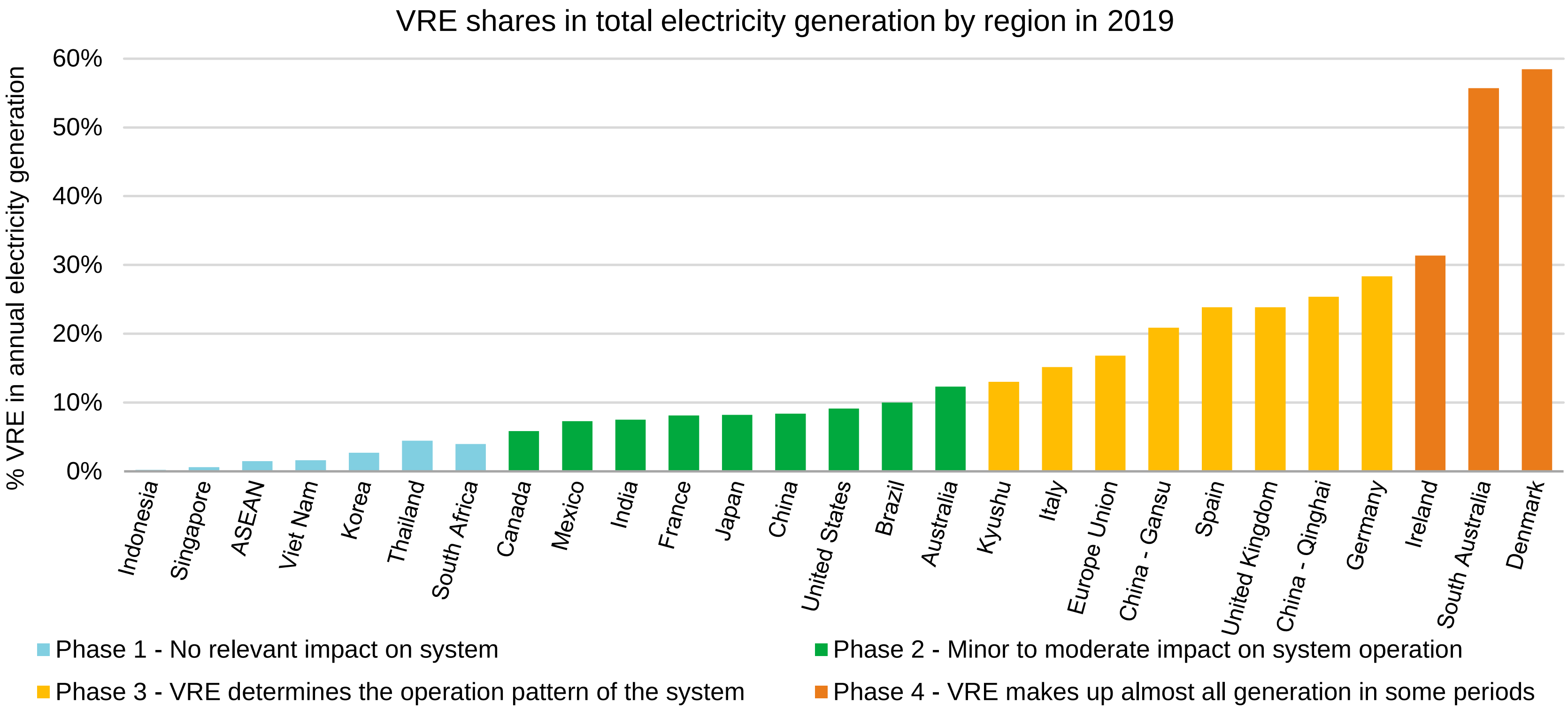
~5% annual share of VRE
Not much difference in net load
(Phase 1-2 of VRE integration)

Demand and VRE production, Germany, 2018



~30% annual share of VRE
Flexibility is key to manage variability in net load
(Phase 3 of VRE integration)

System integration can be classified into different phases



Various regions have demonstrated successful integration of VRE in Phases 3 and 4 with dedicated efforts for system flexibility. Many countries are expected to reach Phase 4 within the next 5 years

Phases 1 & 2: Getting Wind and Solar Onto the Grid

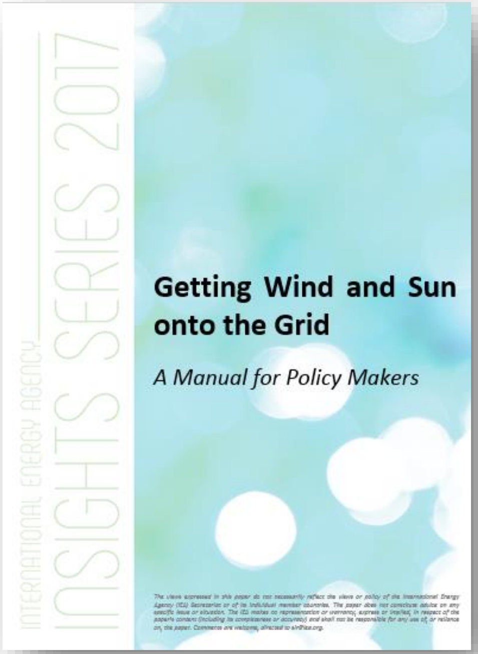
Two main objectives

- Debunk myths and common misconceptions
- Provide a framework and practical guidance on dealing with main technical priorities

Myths related to wind and solar generation

1. Weather driven variability is unmanageable
2. VRE capacity destabilises the power system
3. VRE deployment imposes a high cost on conventional plants
4. VRE capacity requires dedicated “backup”
5. The associated grid cost is too high
6. Storage is a must-have

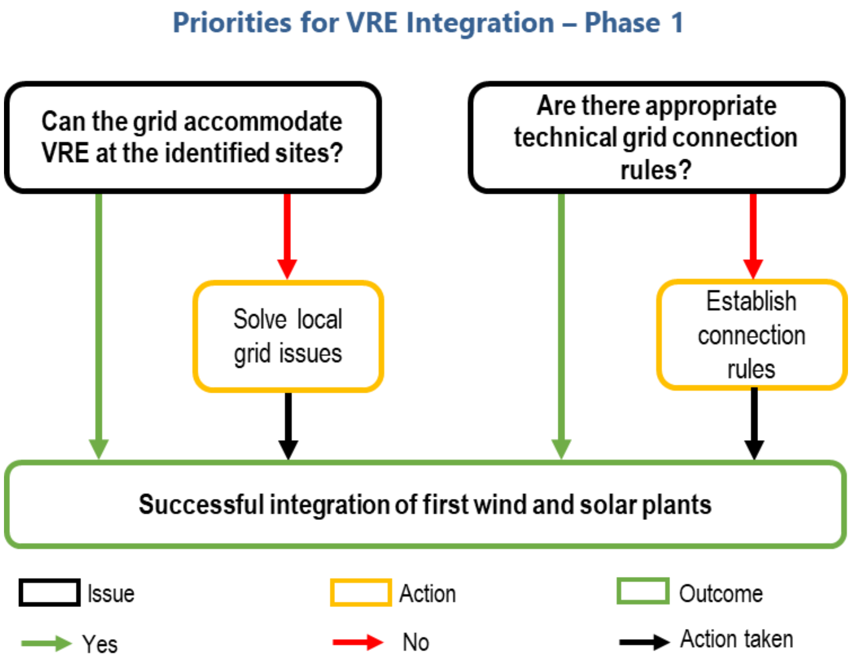
A step by step guide for policy makers and system operators on how to deal with first stages of VRE integration



https://www.iea.org/reports/getting-wind-and-solar-onto-the-grid

Focus on Phase 1 of VRE integration

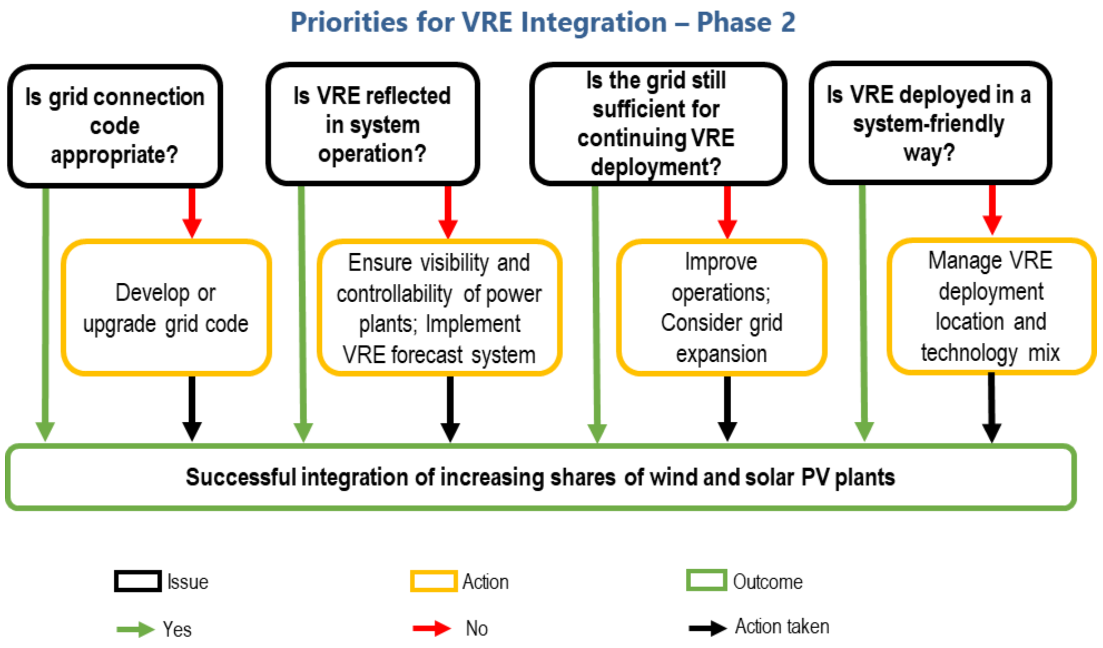
- VRE output is not noticeable for system operator
- VRE variability tends to be negligible compared to fluctuations in demand
- Priority areas are connection requirements and grid codes
- At initial deployment, integration of VRE requires little additional effort



Appropriate technical grid connection rules are critical to ensure that VRE plants do not have a negative impact on the local quality and reliability of electricity supply.

Focus on Phase 2 of VRE integration

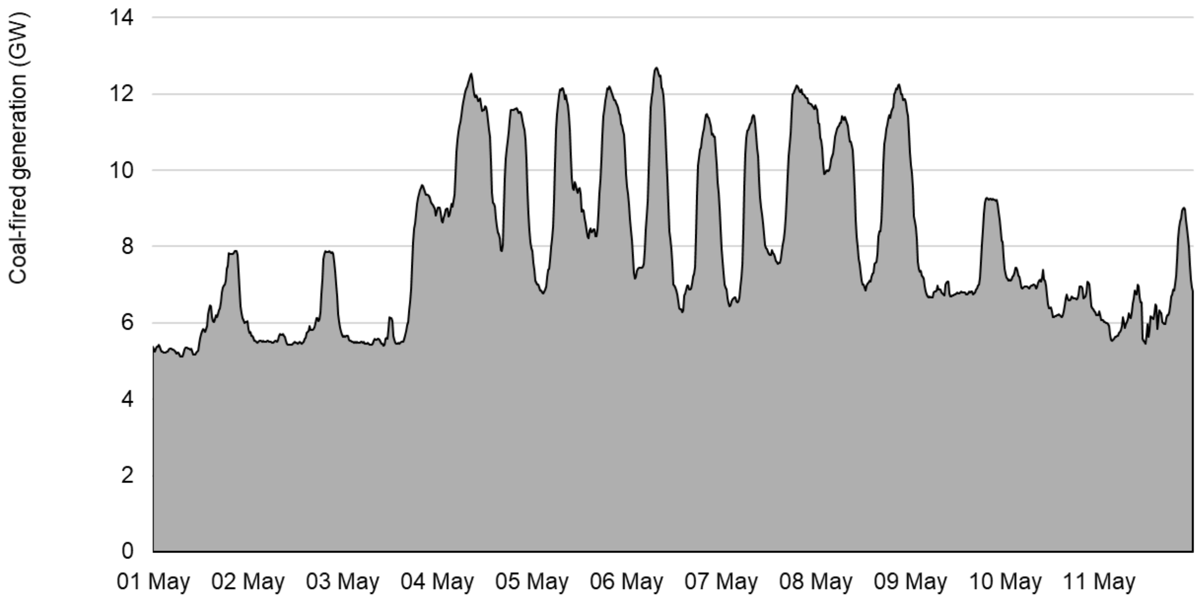
- First instances of grid congestion
- Appropriate grid connection codes are in place
- Incorporate VRE forecast in scheduling & dispatch of other generators
- Focus also on system-friendly VRE deployment



Updated system operations, sufficient visibility & control of VRE output becomes critical in Phase 2

Flexible thermal generation – business as usual already today

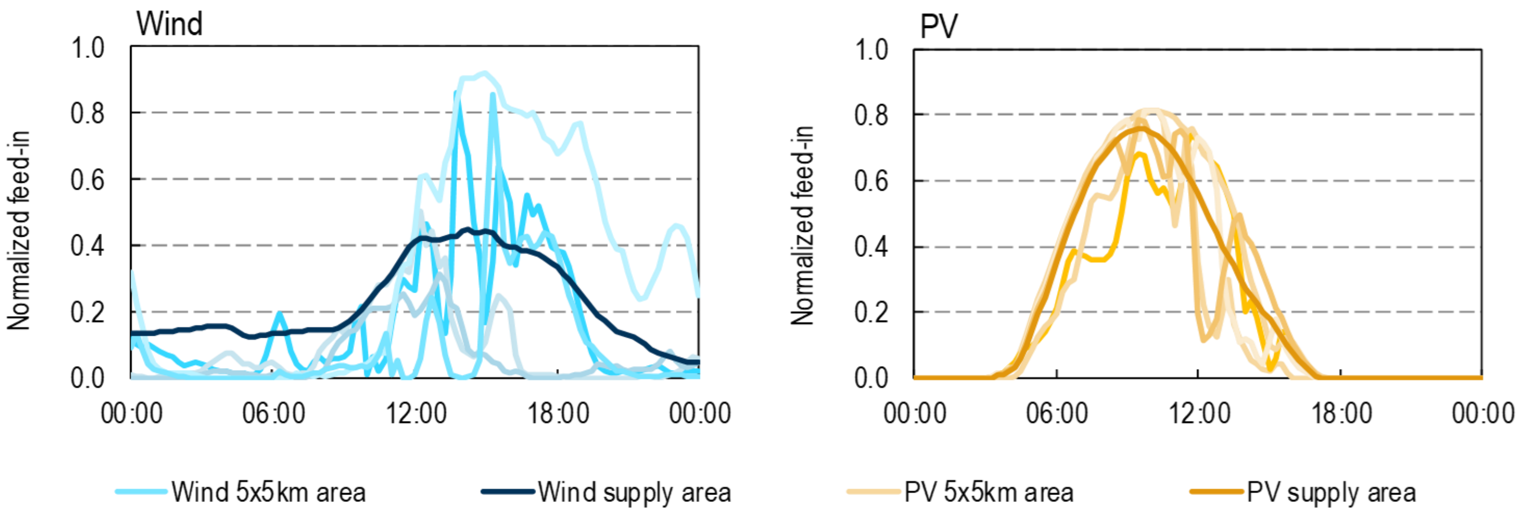
Hourly coal-fired generation pattern in Germany, 2020



Power plants are an important source of flexibility, evident in countries such as Germany. Coal plants can carry ramping duty.

System friendly deployment of VRE and the grid

VRE output and the benefit of geographical spread, South Africa



- 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.)

Better system operation to accommodate VRE

Ensure visibility of power plants to system operators

- **Real time data** of power plant output, including VRE plants
- For assessing the current and future state of the system

Real-time control of power plants

- **Automatic generation control (AGC),** particularly large plants
- Controlling VRE active power output

Load and VRE Forecasting

- System-wide forecasting of VRE output in different timescale (closer to real time, the more accurate)

Power plant schedule and operating reserves

- frequent schedule updates close to real-time.
- Sophisticated approaches in determining reserves

Make use of grid infrastructure

Utilising existing grid infrastructure

- Instead of grid reinforcement, consider utilising the existing grid first
- Options to enhance capacity of transmission line includes DLR, FACTS, special protection scheme (SPS)
- *Examples in Spain, Ireland, UK, ERCOT, Australia, Thailand*

Integrated planning

- Integrate generation and grid planning with VRE deployment
- To achieve technology and geographical spread of VRE plants
- *Examples in Texas, South Africa, Germany, Australia*

Contractual implications of flexibility

Utilising existing and future assets

- Minimum take obligations need to fit with more flexible operations – long term physical PPAs can be a barrier
- If curtailment is needed PPAs need to include very clear rules on terms and compensation
- *Examples in Thailand and India*

Fuel supply contracts

- Fuel supply contracts can change the merit order which limits flexibility
- Portfolio approaches to fuel purchases should be used in order to maximise flexibility of the generation fleet
- *Examples in Thailand*

Summary

- Challenges for integrating wind and solar are often smaller than expected at the beginning
  - Power systems already have flexibility available for integrating wind and solar
- Challenges and solutions can be group according to different phases
  - Measures should be proportionate with the phase of system integration
  - Making better use of available flexibility is most often cheaper than ‘fancy’ new options
  - Barriers can be technical, economic and institutional, all three areas are relevant
- VRE targets should be considered in concert with wider energy system developments to ensure reliable and cost-effective integration in the grid.
- Challenges can be minimised via system friendly deployment
  - Integrated planning is the foundation for long term success
- Integrated power system studies are essential to assess the impact and options for integrating VRE

Experiences and lessons learned

Thailand's experiences and lessons in integrating VRE

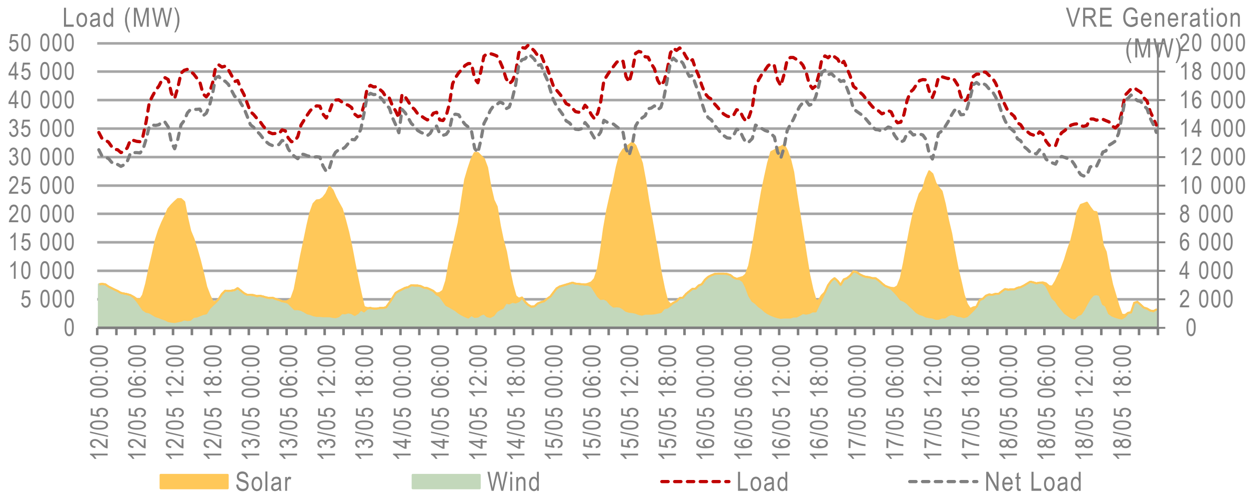
- Thailand's power sector has been experiencing the growing share of VRE
  - ~4% annual share of VRE in 2020
- In 2018, MoEN and EGAT requested the IEA to conduct a RE grid integration study and capacity building workshop to assess RE integration challenges and options
  - It aims to assist energy regulators, energy policy and planning, system operators
- The study considered up to 15% share of VRE (17 GW solar PV and 6 GW wind)
- Findings and recommendations were considered for the latest PDP
  - Higher share of VRE is possible
  - System flexibility requirements were considered in the formulation of the PDP
  - EGAT is conducting studies on 'Grid Modernization'
- VRE targets have increased from the previous PDP, from **9 GW** to **15 GW (12 GW solar, 3 GW wind)** by 2037

https://webstore.iea.org/partner-country-series-thailand-renewable-grid-integration-assessment

Thailand Grid Integration Study 2018

Key findings

- Higher shares of VRE reduce system operating costs
- Thai power system can technically integrate up to **15% VRE**
- **Complimentary profiles** between solar, wind generation and demand
- **Contract flexibility** (i.e. PPA and fuel contract) allows for the most notable cost savings via optimal dispatch
- **Power plants, DSM, EV and storage** can provide system flexibility



Main recommendations

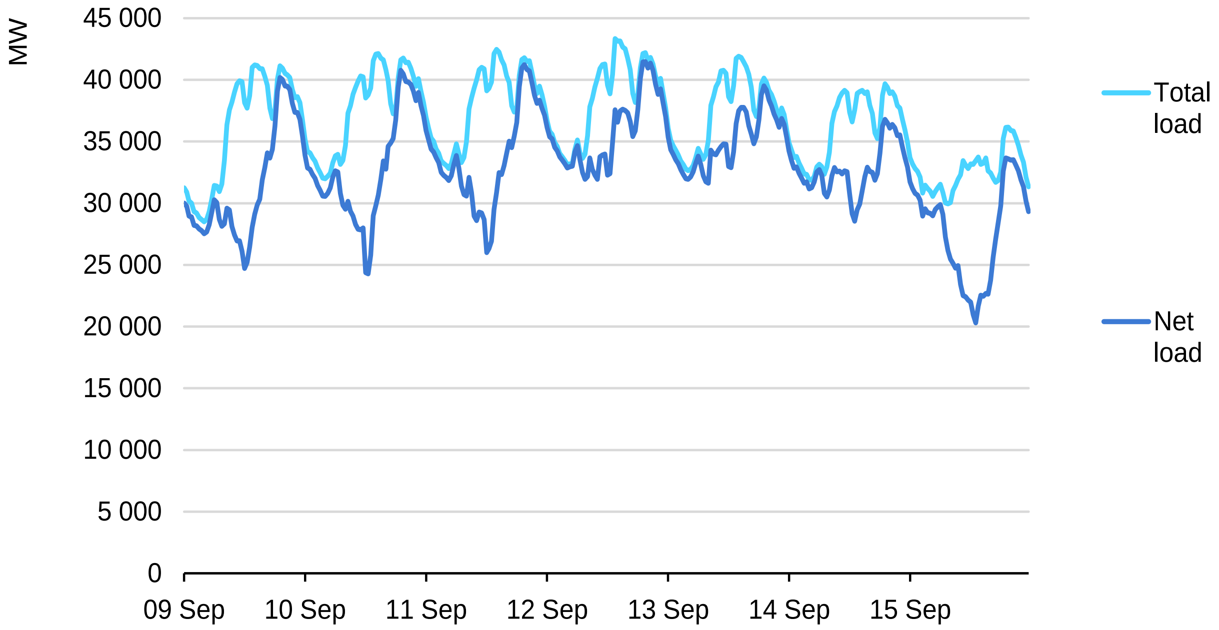
- Consider higher VRE target in PDP
- **Unlock** latent flexibility from existing power plants:
  - through **enhanced procurement contracts** between Fuel Supplier and Electric Utility and
  - **Reviewing options for greater flexibility** in contractual arrangements between Utility and IPPs more flexible
- **Improve** the flexibility of conventional power plants

Thailand power system flexibility

- Findings and recommendations led to an in-depth flexibility study (to be published April 2021)
  - With the growing share of VRE, Thai power system needs to adapt to greater flexibility requirement
- Two key components: **Contractual and Technical flexibility**
  - Appropriate technical flexibility options (power plant flexibility, storage) in short- and medium term based on the techno-economic aspect
  - Appropriate options for improving the existing and future contract structures both for fuel supply and offtake of electricity
- **Key findings**
  - The system has sufficient latent technical flexibility to integrate up to 15% VRE by 2030 (19 GW solar, 6 GW wind)
  - Investing in technical options (plant retrofits, storage) is not priority in the short- to medium term
  - There is a need to increase contractual flexibility in order to integrate higher shares of RE. The value of technical flexibility resources are highly dependent on the structure of fuel supply contract

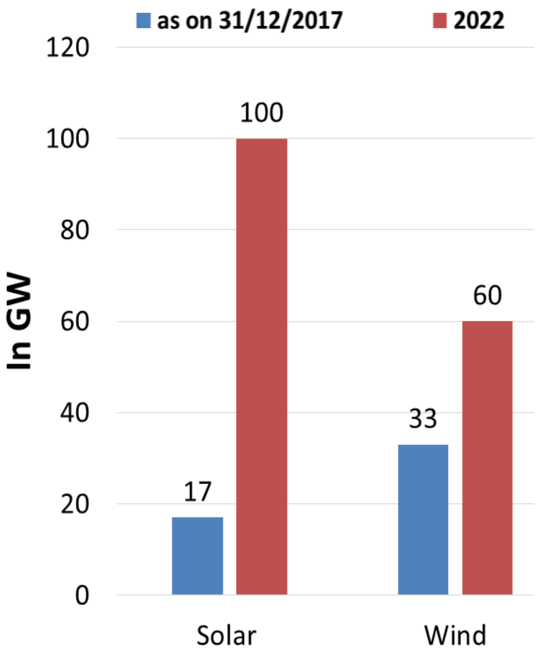
Flexibility requirements with more solar and wind power in Thailand

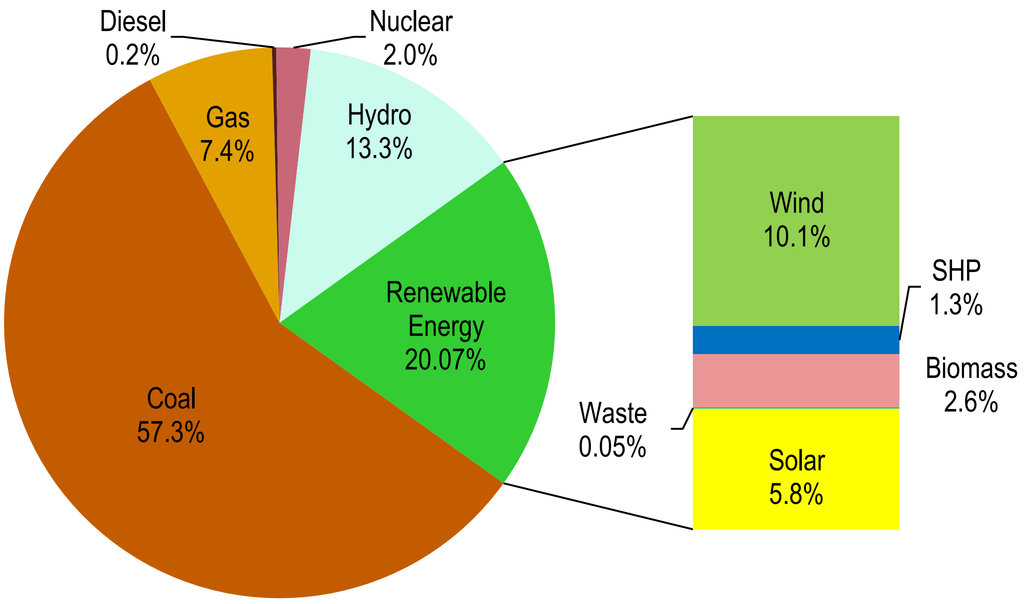
Load and net load during the peak demand period with 15% share of VRE in 2030



Thailand's power system is technically capable to handle up to 15% annual share of solar and wind in 2030.

Flexibility requirements in India's power system

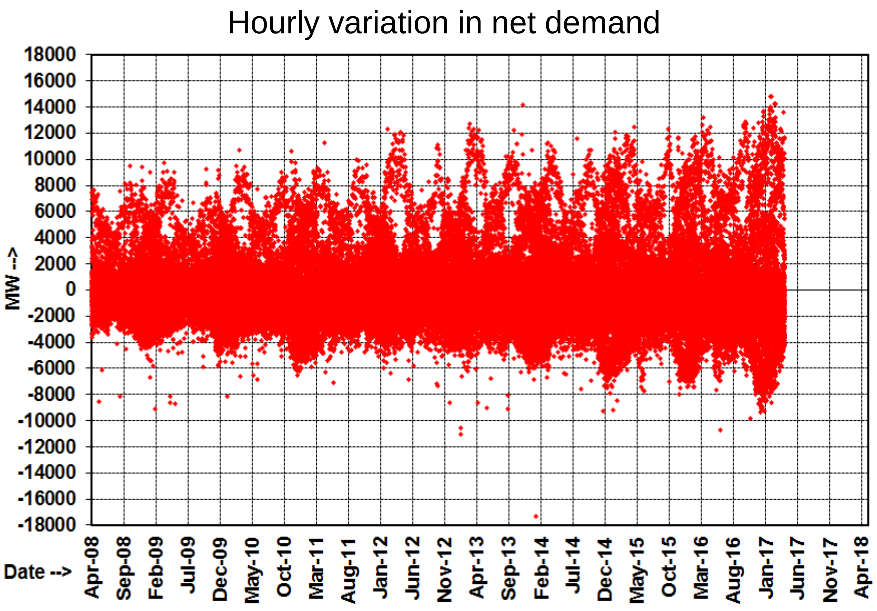


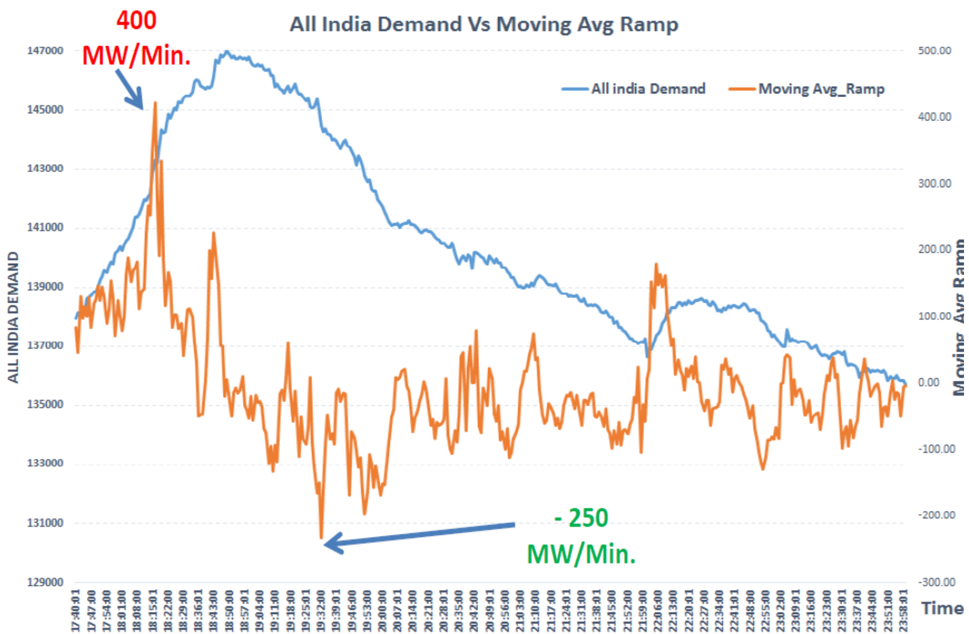


Installed generation capacity by technologies as of March 2018

- Rapid growth of wind and solar with high targets in 2022
- The system is still dominated by coal-fired generation

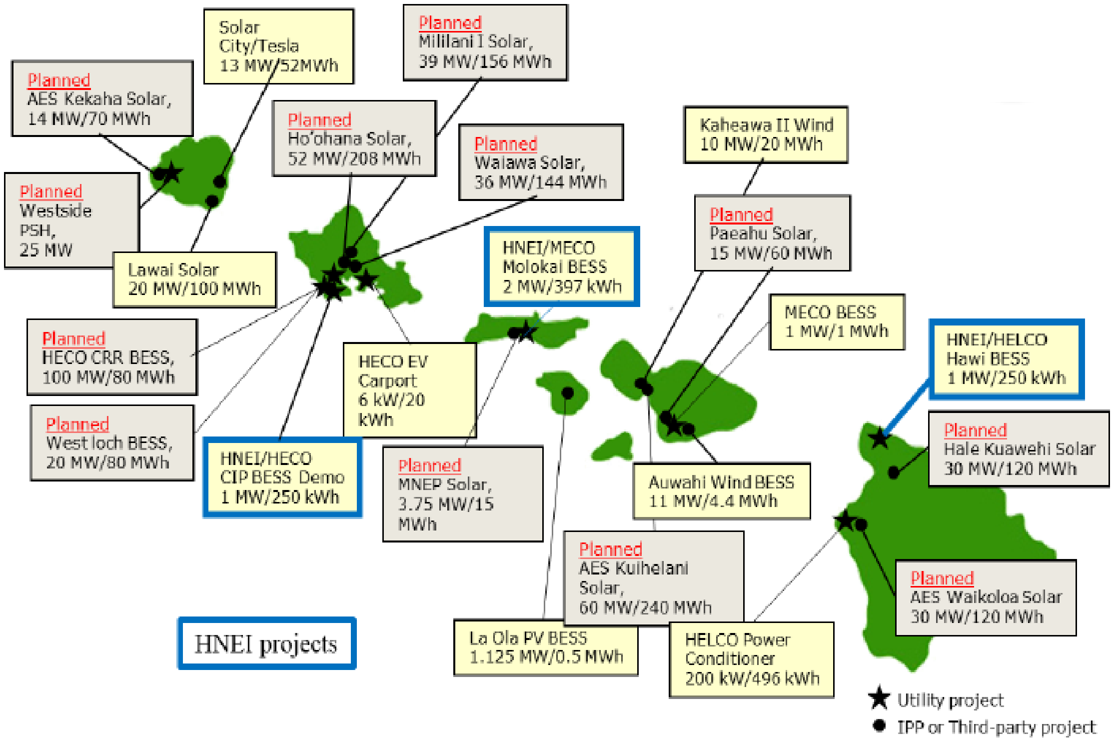
Flexibility requirements in India's power system





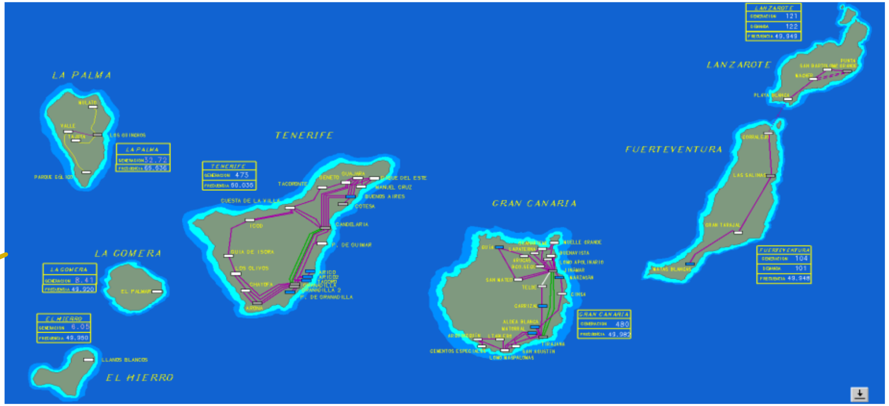
- **Typical ramp rate:** 250 MW/min; **Peak requirement:** 500 MW/min
- Increasing flexibility requirement – *power plants, grid, storage, demand response*
- Actions taken: *load and RE forecasting; power plant flexibility; flexible transmission; established RE management centres; reserves and ancillary services*

Islanded power systems using distributed solar PV and battery



- 6 separate grids with 4 electric utilities
- 28% RE state wide
  - Solar PV, wind, biofuel, hydro and geothermal
- Distributed PV and shifting to battery
  - Total battery capacity of 457 MW/1491 MWh
  - Increasing grid support by providing frequency response

Network development in the Canary Islands Power Systems



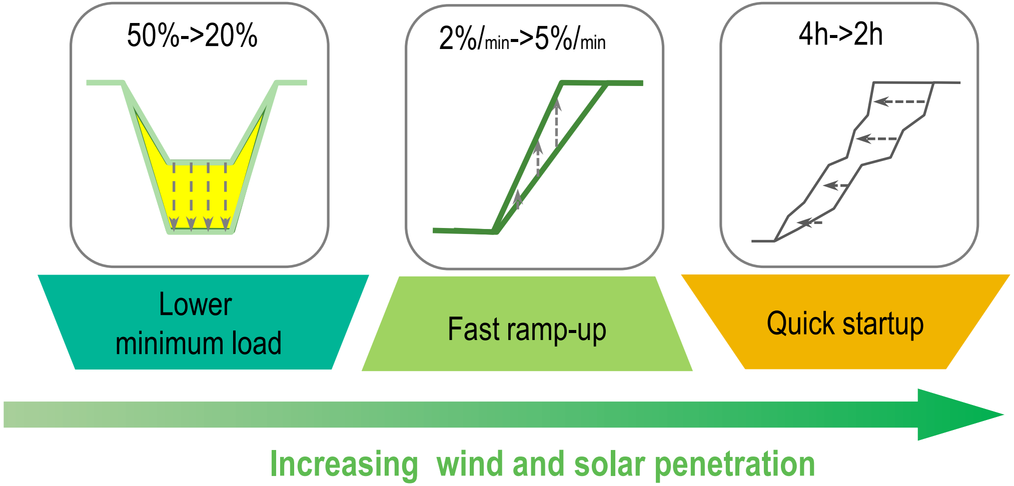
Source: GIVAR Workshop, 2017

- Main characteristics
  - 6 isolated systems on 7 islands
  - Mainly fossil fuel generation
  - Weak infrastructure
  - Great wind and solar potential

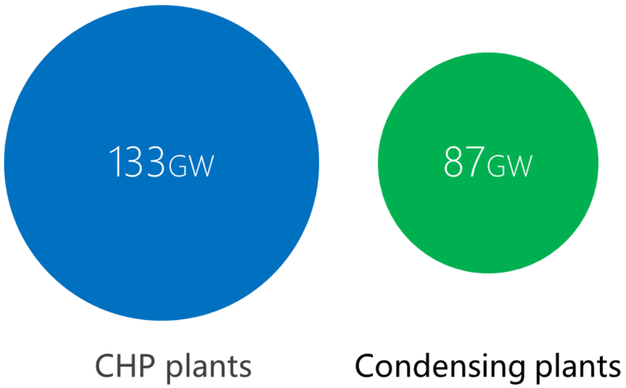
- Developing the network and interconnector between islands is one of the main features
  - 66 kV and 132 kV interconnectors with distances ranging from 14-42 km

Power system flexibility enhancement roadmap in China

- Around 200 GW of conventional power plants will be retrofitted (~20% of the total coal capacity China).
- Lowering the minimum stable operation load is the first priority in the near future.
- 22 demonstration power plants with 17 GW total capacity



Retrofitting scale of coal power



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