International Energy Agency

Secure energy transition in the power sector with high share of variable renewables

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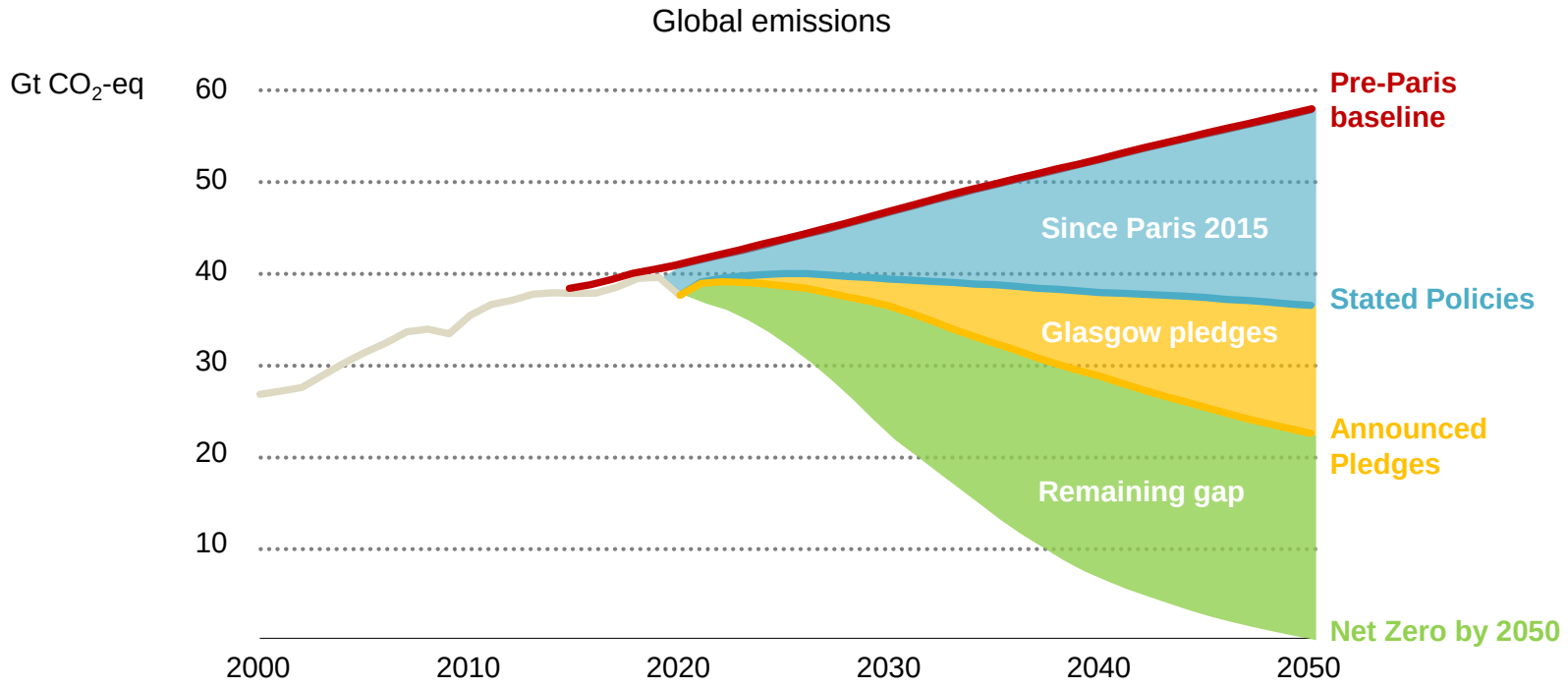
Outline

- Pathways and the gap in achieving Net Zero Emissions
- The transition of the power sector towards a low-carbon future
  - High share of variable renewables (wind and solar)
  - Integrating VRE into the electricity system – challenges and opportunities
- Increasing flexibility needs in the power sector to maintain electricity security
  - Policy and technology options to boost system flexibility

The IEA's participation in this event and the work on electricity security and renewable integration was made possible through the Clean Energy Transitions in Emerging Economies programme has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952363.

Pathways and the gap in achieving Net Zero Emissions

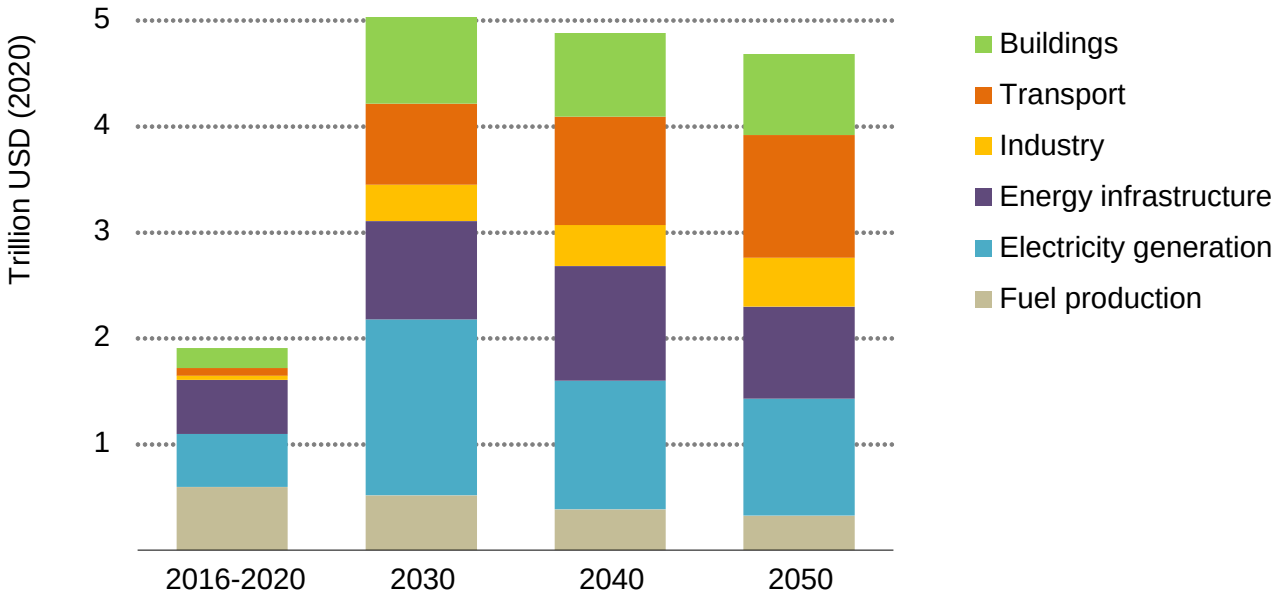
A large ambition gap remains in 2030



Despite some positive signs, today's pledges close less than 20% of the gap to the Net Zero by 2050 scenario: countries with net zero pledges and countries without each account for about half the remaining ambition gap

Investment need for clean energy transitions

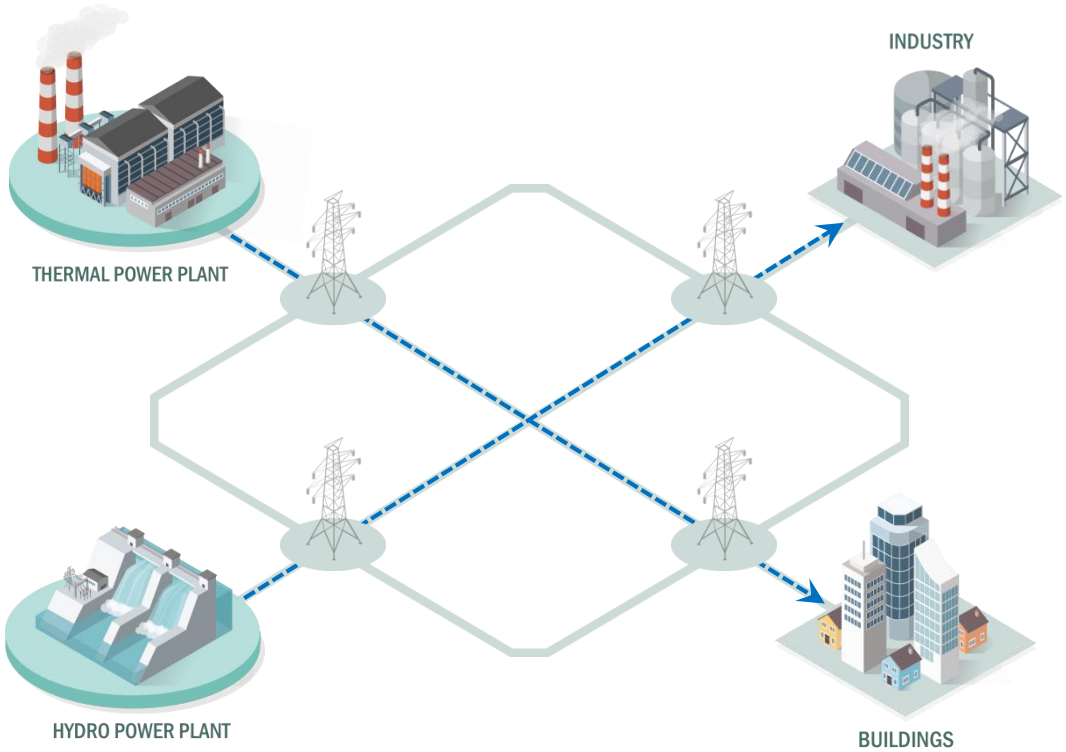
Average annual energy investment 2016-2020, and in the Net Zero Emissions by 2050 Scenario



Meeting the accelerated decarbonisation goals of the NZE requires a surge in global energy investment to USD 5 trillion by 2030, with 85% of spending directed to clean energy

The transition of the power sector towards a low-carbon future

The power sector landscape is changing dramatically



Traditional system

Centralised / dispatchable

High inertia and stability

Central planning

One way flows of energy and communication

Closed networks, few devices

Digital technologies enable a multi-directional and highly integrated energy system. Pre-digital energy systems are defined by unidirectional flows and distinct roles.

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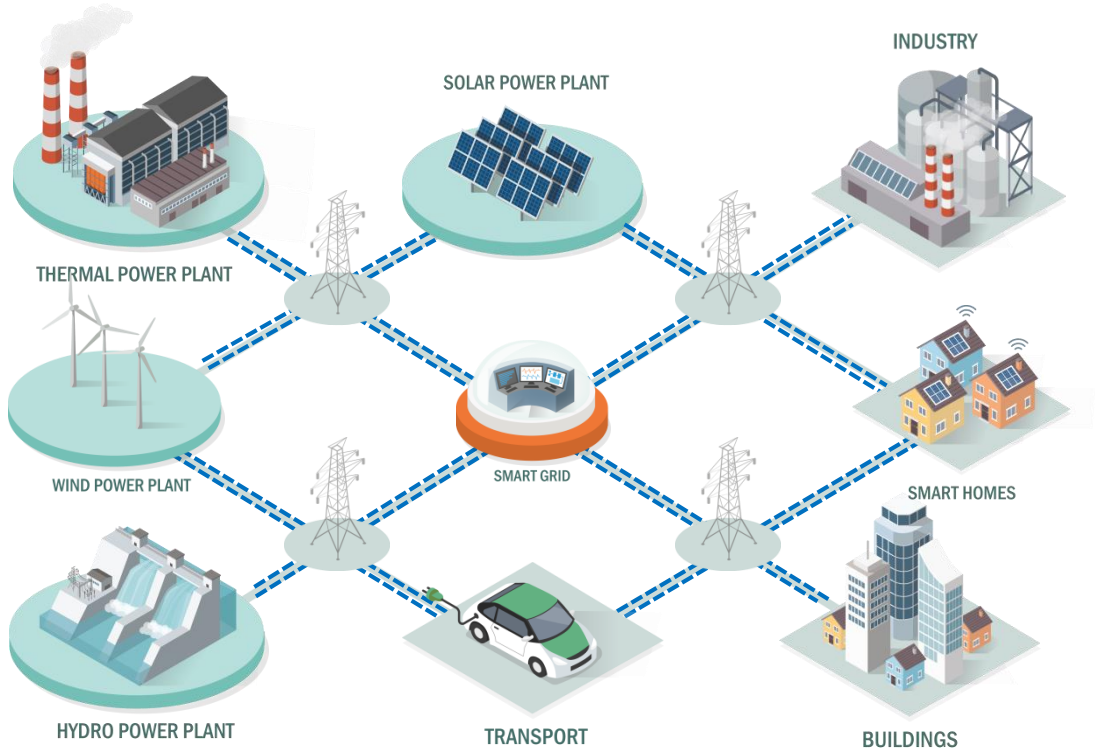


Traditional system

Centralised / dispatchable

High inertia and stability

Central planning

One way flows of energy and communication

Closed networks, few devices

New system

Decentralised / variable generation

Low system inertia from rotating machines

Multiple actors / competitive markets

Two way flows of energy and communication

Open networks and many devices

Changing climate patterns

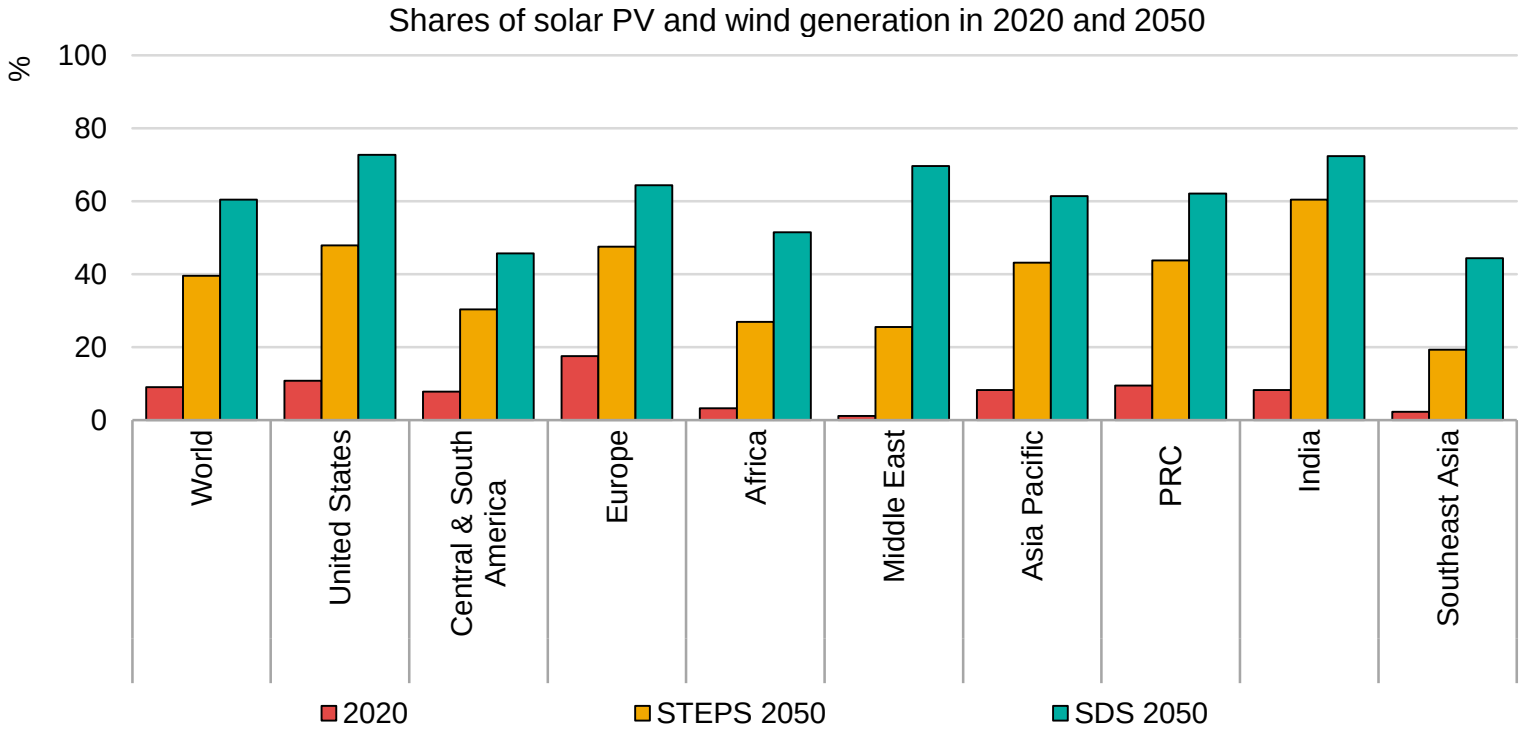
Digital technologies enable a multi-directional and highly integrated energy system. Pre-digital energy systems are defined by unidirectional flows and distinct roles.

The electricity system has to cope with a wide range of threats

Key properties of electricity security

- Electricity security is the capability of the system to ensure **uninterrupted availability** of electricity by withstanding and recovering from **disturbances and contingencies.**
- **Adequacy**
  - Ability to supply demand at all times under normal operating conditions
- **Operational security**
  - Ability to retain a normal state or to return after an unexpected event
- **Resilience**
  - Ability to absorb and accommodate short-term shocks and long-term changes

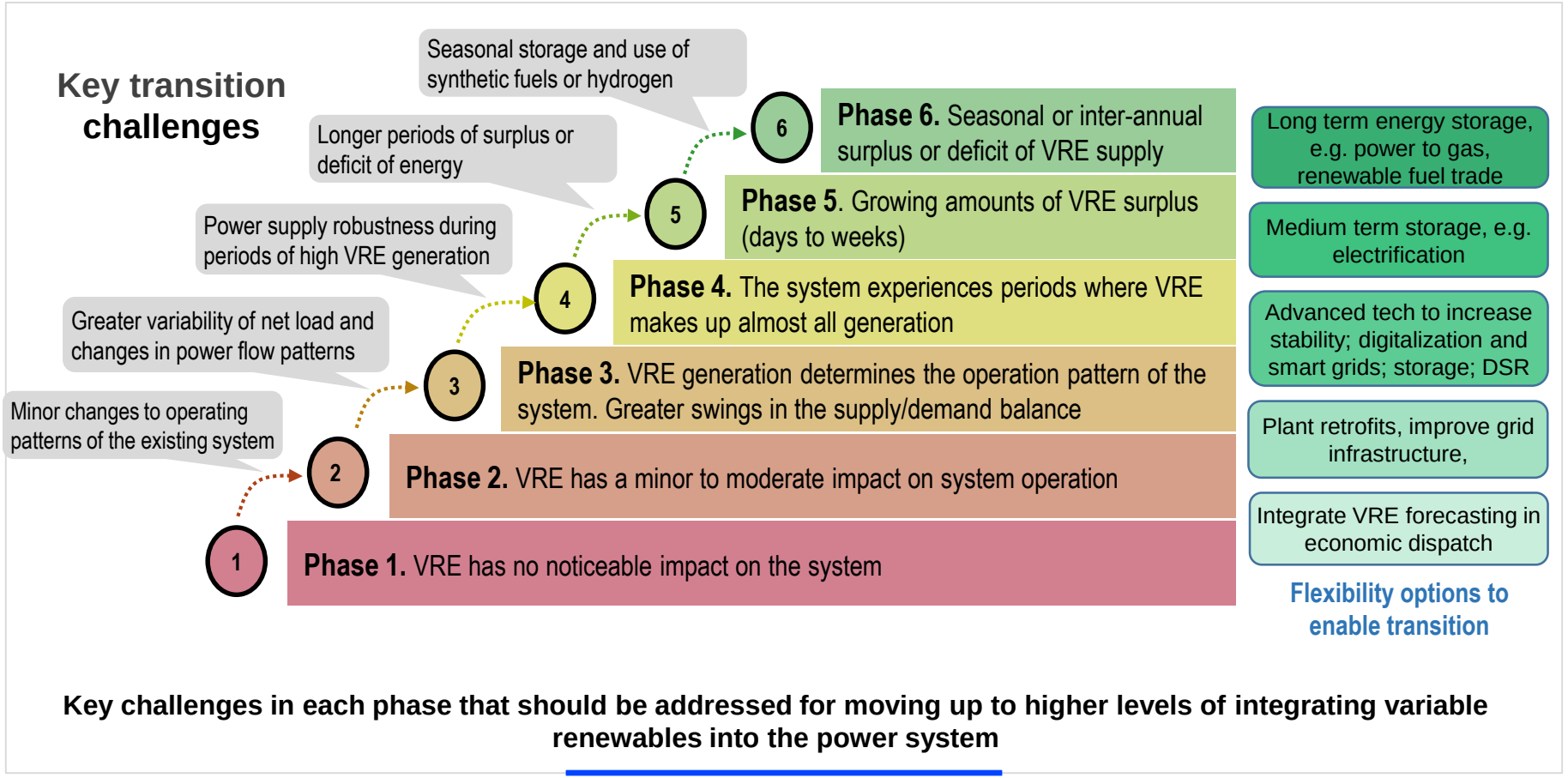
Variable Renewables will be the main building block in power systems



STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario

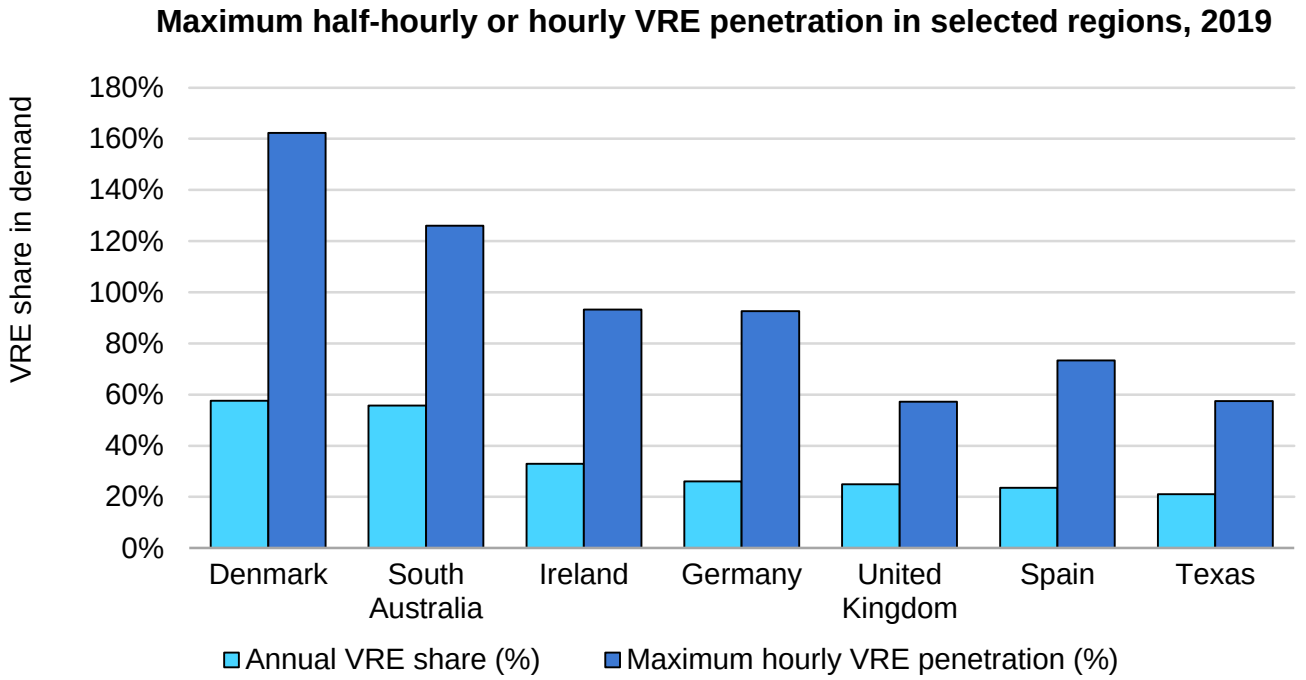
More countries are expected to deploy higher shares of variable renewables – including in emerging economies
Flexibility sources need to keep up with the rapid growth in variable renewables

Phases of system integration and evolving priorities



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

Large shares of VRE will change the way power systems behave

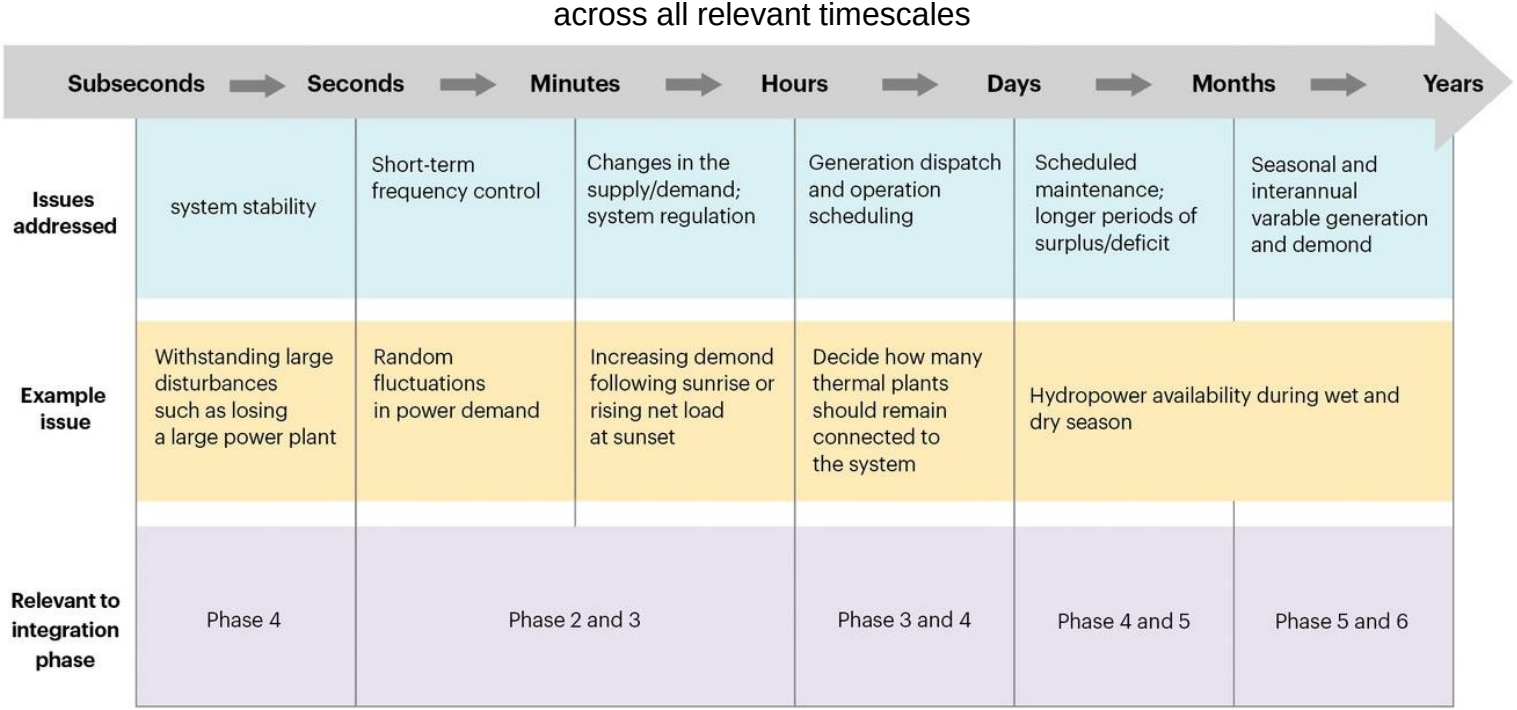


Reduced costs will make variable renewables the fastest growing source of electricity in the coming years. Variability and uncertainty will require updates in market frameworks and new ways to operate the system

Meeting flexibility needs to ensure electricity security

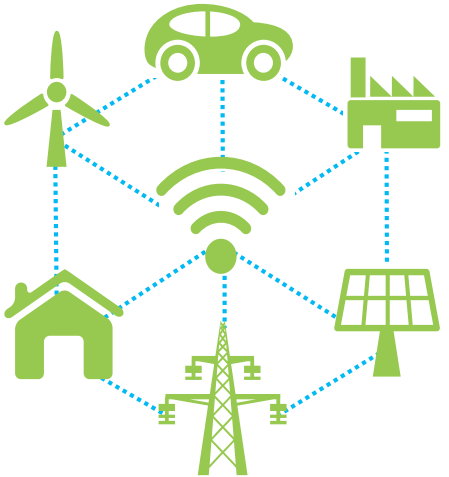
Power system flexibility has become a priority

The ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales



Understanding the system's current and future flexibility needs is key for all power system actors

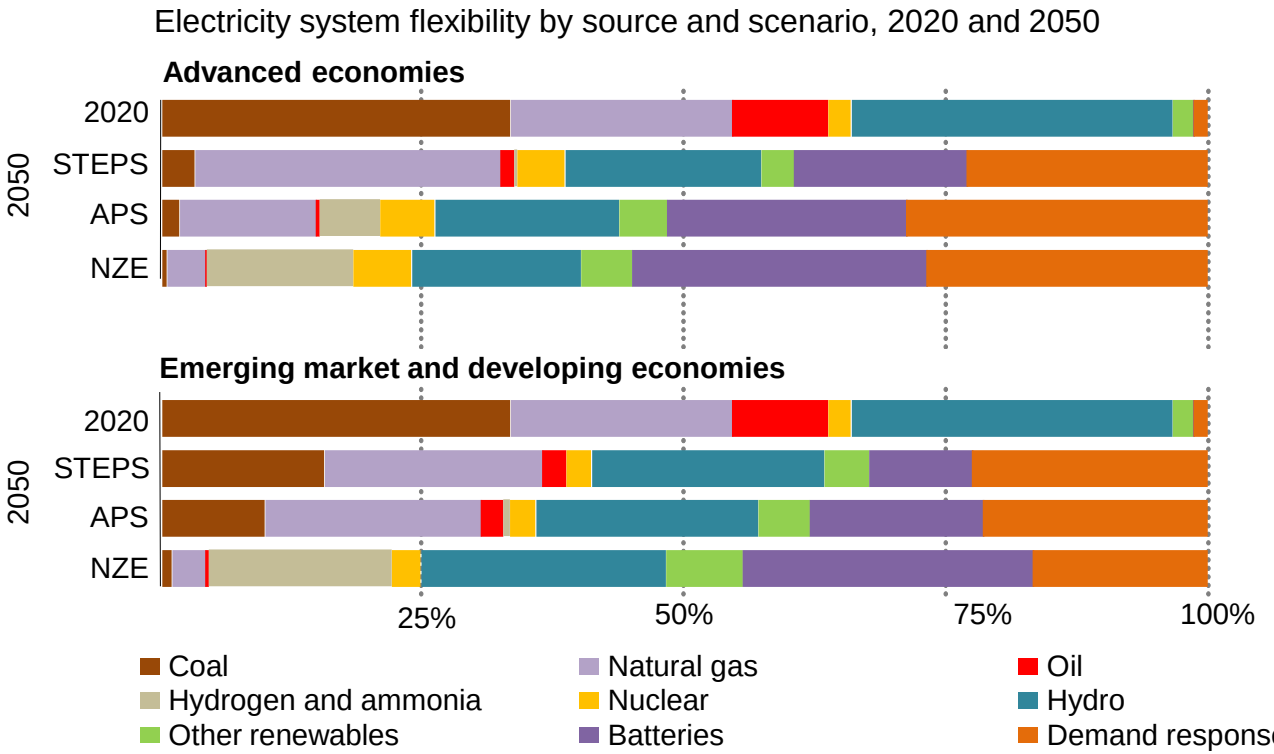
A wealth of strategies to boost system flexibility

Institutions and actors ("Who")	Policy, market and regulatory frameworks ("How")	Hardware and infrastructure ("What")
Typical decision makers	*Categories of interventions*	*Flexibility Asset types*
Energy ministry	*Energy strategies* *Legal frameworks* *Policies and programmes*	
Regulatory agency	*Regulatory frameworks and decisions* *Power sector planning exercises* *Retail electricity pricing*	
System operator, electric utility, standards body	*Power market rules and codes* *System operation protocols* *Connection codes*	

Source: Status of Power System Transformation 2019

A range of approaches to enhance power system flexibility are available at different levels of decision making. The institutional context defines the set of instruments available to boost system flexibility.

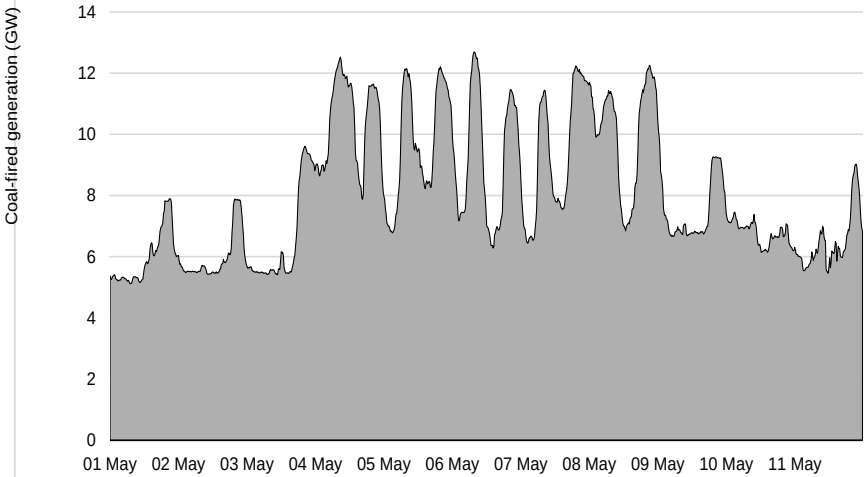
Flexibility is at the heart of electricity security



Coal and natural gas remain cornerstones of electricity flexibility in the STEPS, but the mix of flexibility sources shifts dramatically on the path to net zero emissions by 2050

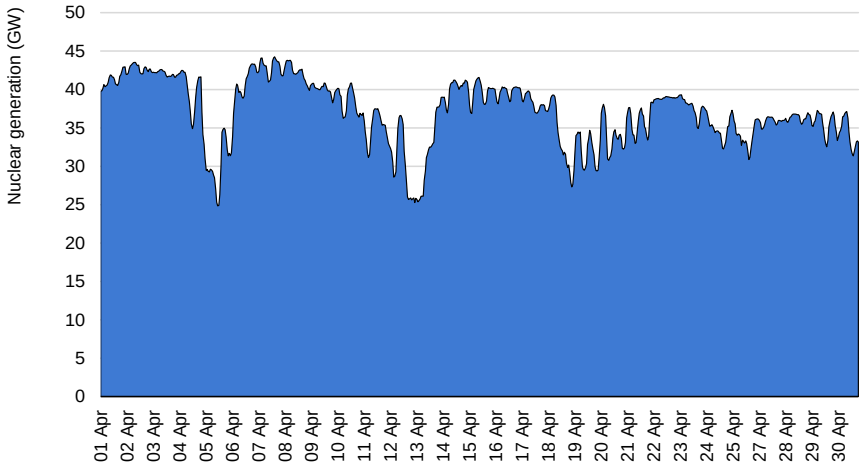
Flexible thermal generation – business as usual today

Flexible operation of coal plants in Germany, May 2020



At initial stages, shifts in the operation of power plants, from baseload to flexible operations can improve the integration of VRE

Flexible operation of nuclear plans in France, April 2020

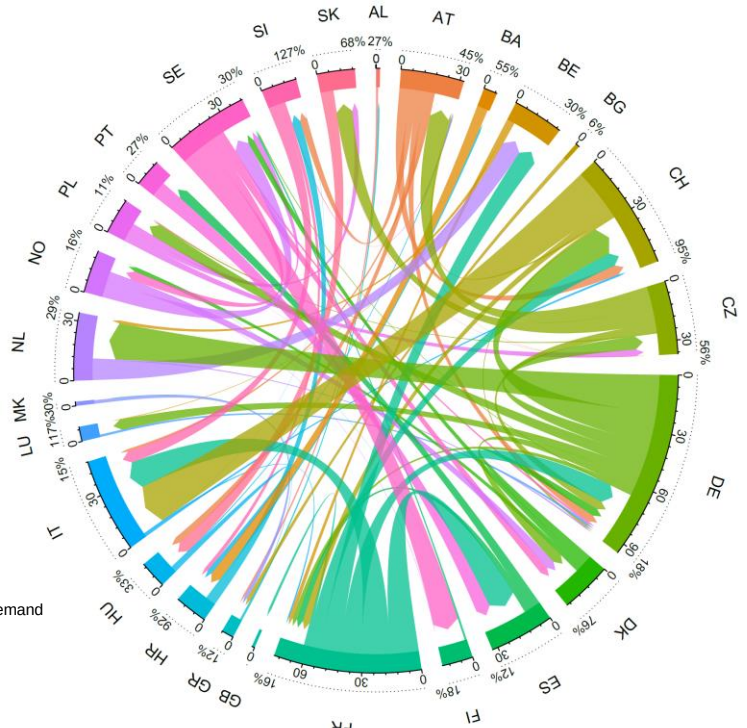


In France operational changes allow the nuclear fleet to be dispatched flexibly.
Such operational changes usually require regulatory validation.

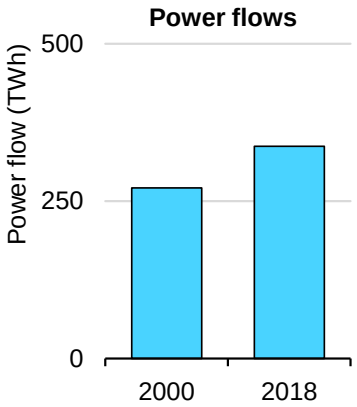
Operational guidelines could be updated to enable the secure operation of flexible thermal power plants, enabling greater VRE penetration

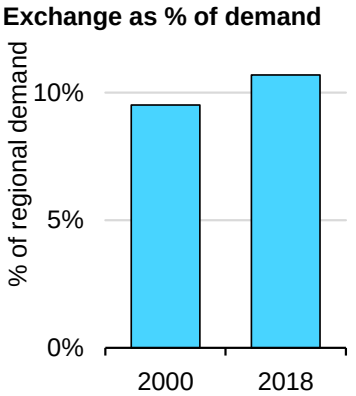
Cross-border interconnection is a critical enabler of system flexibility which enhances system security

Cross-border exchanges in Europe (2018)



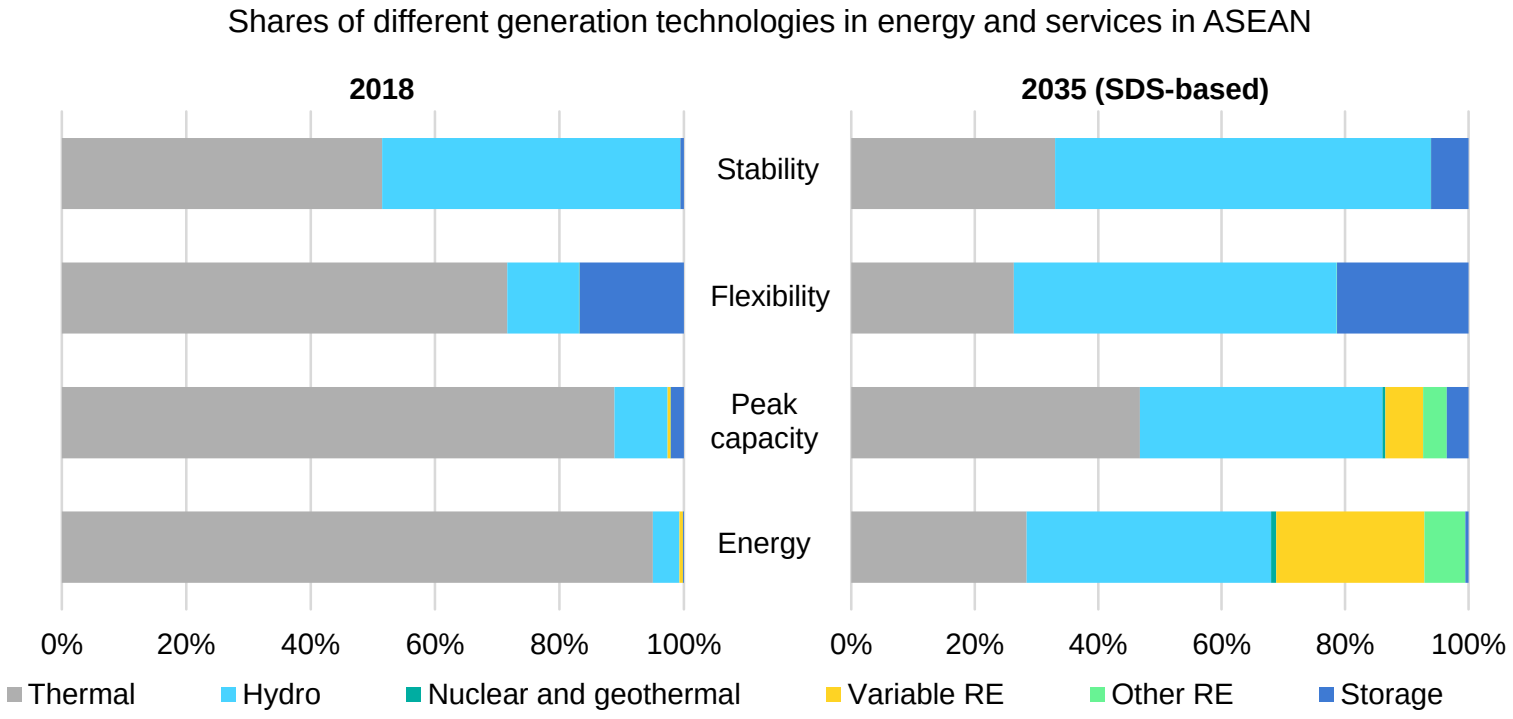
XX – Region code
… - % of regional demand
Energy flow (TWh)





Wind and solar PV generation and demand profile vary by region. Interconnection with neighbouring systems allows systems to take advantage of complementarity, increase security and bring down overall system costs

Markets need reforms to remunerate all system services to ensure electricity security



Power systems need to reward and incentivise flexibility and capacity contributions of assets and technologies. Australia, Ireland and Chile are examples of countries adapting their markets to achieve this.

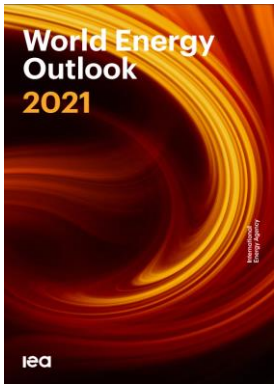
Broader context: achieving power system resilience with high share of variable renewables

Efficient operation of the power system	**Ensuring least-cost dispatch with trading closer to real time** • Market integrations over large regional areas
Unlocking flexibility from all resources	**Upgrade planning and system service markets to realise flexibility potential** • Generation, grid, storage and demand-side integration
Security of electricity supply	• **Improve pricing during scarcity/capacity shortage** • **Possibly capacity mechanisms mechanism as safety-net**
Sufficient investment in clean generation capacity	**Sufficient investment certainty with clear policies** • Competitive procurement (with long-term contracts)
Pricing of externalities	**Reflecting the full cost (i.e. environmental impacts)** • Carbon pricing, Emission Trading Scheme (ETS)

Summary and key takeaways

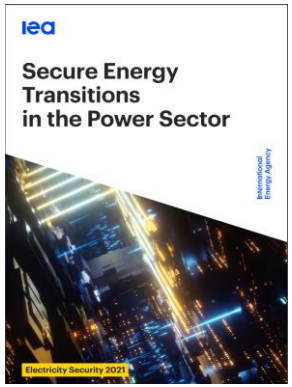
- A large gap in terms of reaching the Net Zero emissions target but **there are cost-effective solutions available** – wind and solar; improving efficiency and methane abatement
- The power sector is undergoing significant transition. **Variable renewables are the main building blocks** in low-carbon power systems
- The electricity system will also have to **handle the challenges from rising VRE**, **distributed energy resources and electrification.**
- **Electricity security matters more than ever** if we are to have successful clean energy transitions.
- Flexibility is the key for electricity security. The secure power systems require timely **investment in flexible resources (dispatchable power plants, grids, demand side and storage)**
- As flexibility needs increase and evolve, **it is possible to make use of existing and new flexibility resources but their system value should be acknowledged** in their remuneration

Further readings on related to electricity security and RE integration



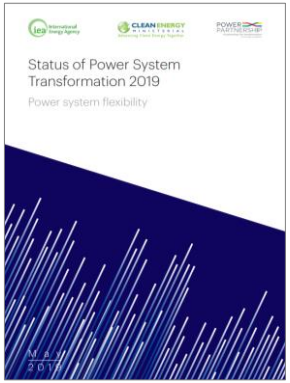
2021 Global

https://www.iea.org/reports/world-energy-outlook-2021



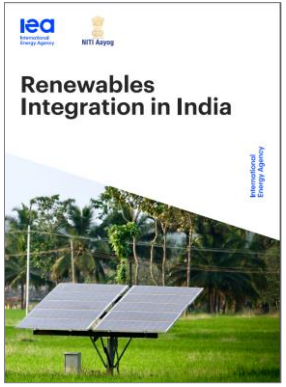
2021 Global

https://www.iea.org/reports/secure-energy-transitions-in-the-power-sector



2019 Global

https://www.iea.org/reports/status-of-power-system-transformation-2019

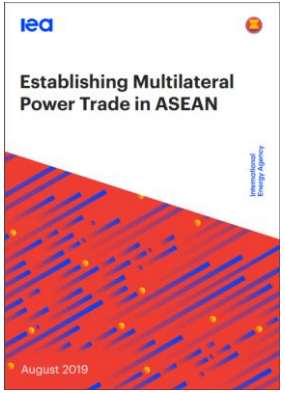


2021 India

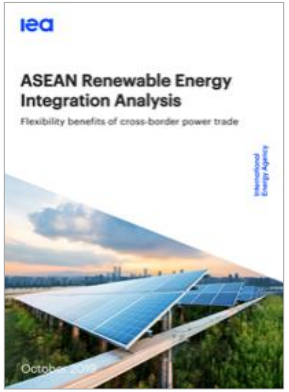
https://www.iea.org/reports/renewables-integration-in-india

2021 Thailand

https://www.iea.org/reports/thailand-power-system-flexibility-study



https://www.iea.org/reports/establishing-multilateral-power-trade-in-asean



2019 ASEAN

https://www.iea.org/reports/asean-renewable-energy-integration-analysis

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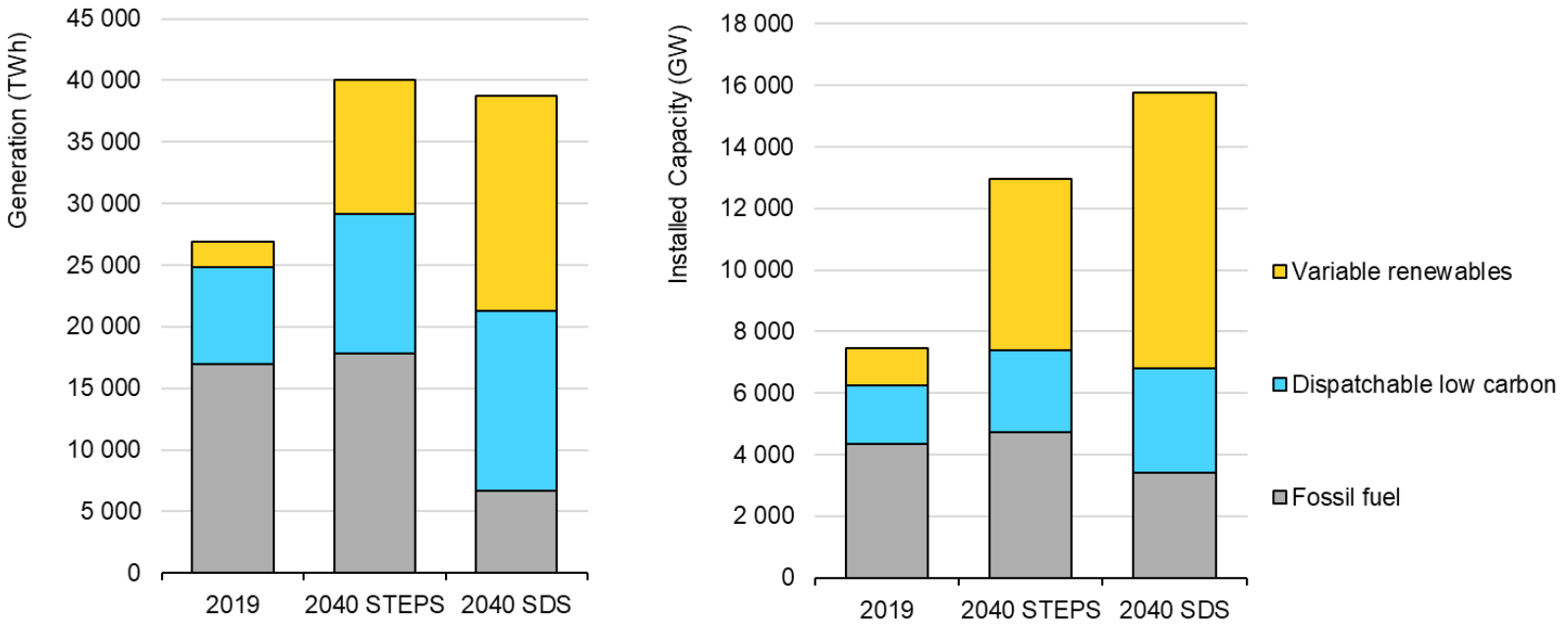
Backup slides

Increase in VRE calls for more flexibility when dispatchability declines

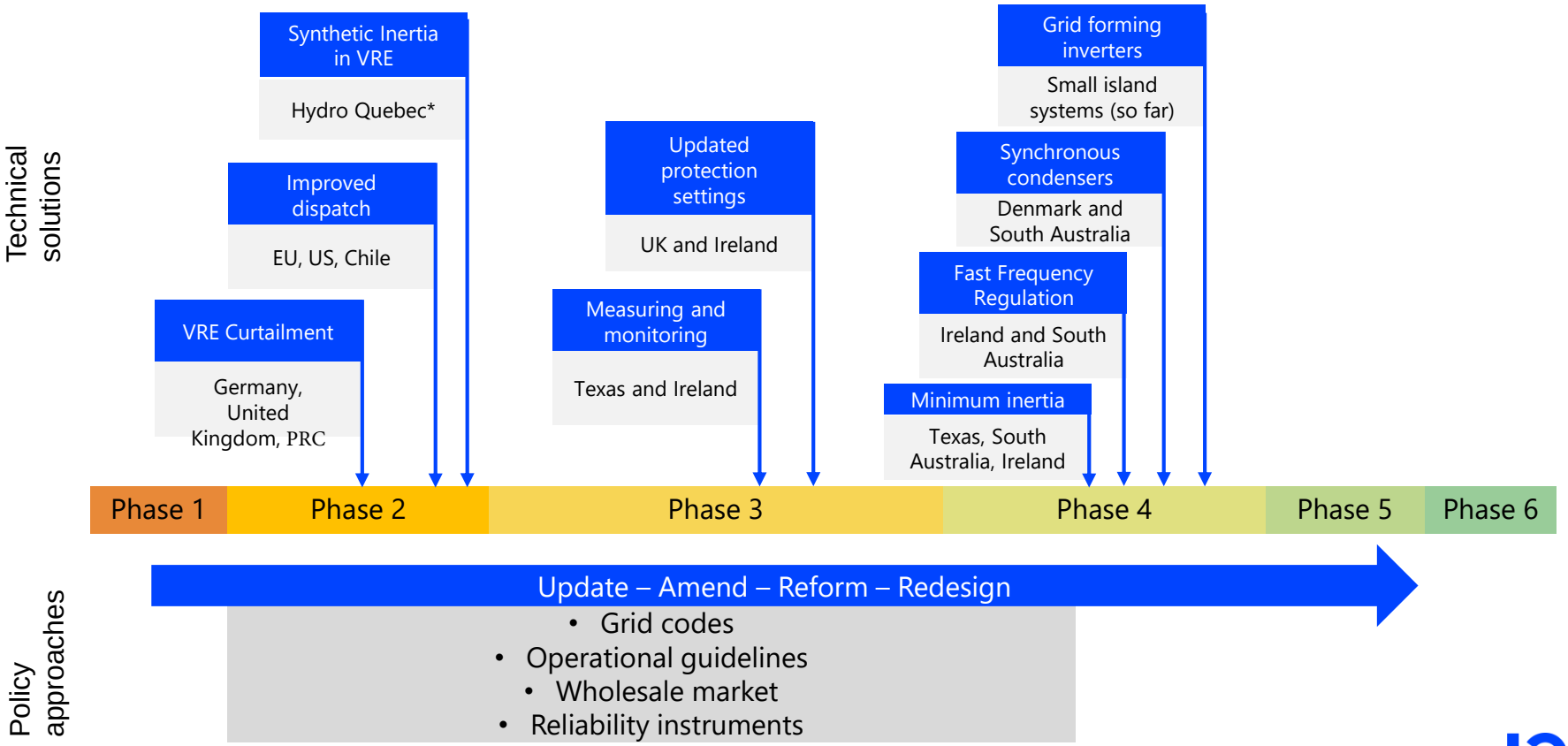
Global electricity production and capacity in 2019 and 2040



STEPS = Stated Policies Scenario
SDS = Sustainable Development Scenario

Flexibility sources, low carbon ones in particular, need to keep up with the rapid growth in variable renewables

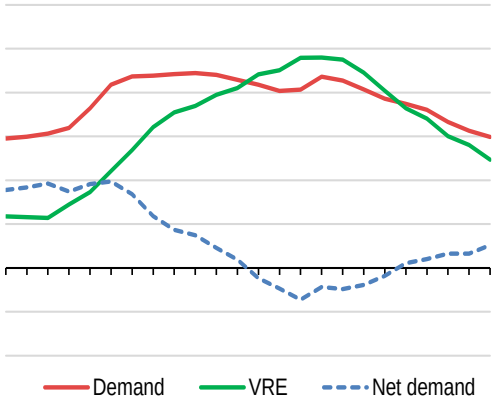
A step-wise approach to advanced VRE integration solutions



A snapshot of high VRE power systems and their experiences

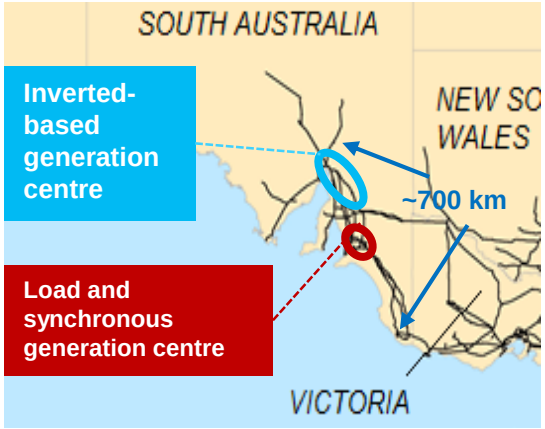
Denmark 162%

- Strong interconnections
- Yet system strength issues at very high shares (>60%)



South Australia 126%

- Not well interconnected
- Long power system and isolated VRE resources



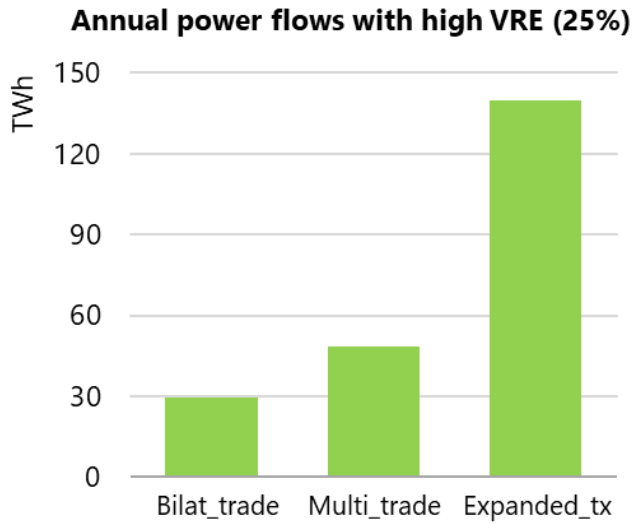
Ireland 91%

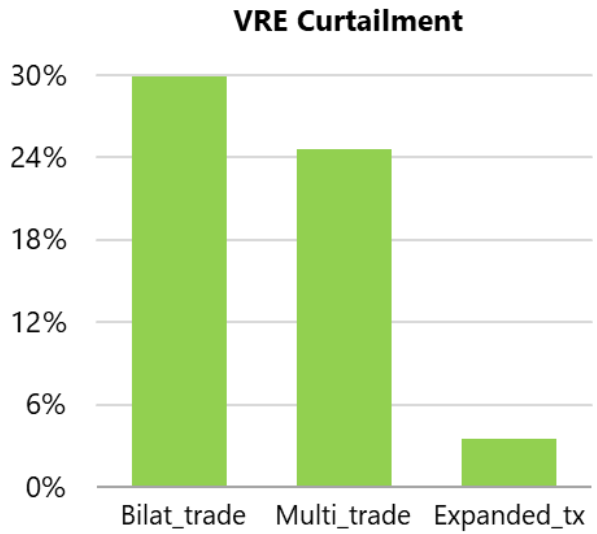
- Island system
- Large amount of HVDC interconnection

Each country's ability to integrate more VRE will depend on their inherent network characteristics, geography and local resources

Cross-border interconnection is a critical enabler of system flexibility

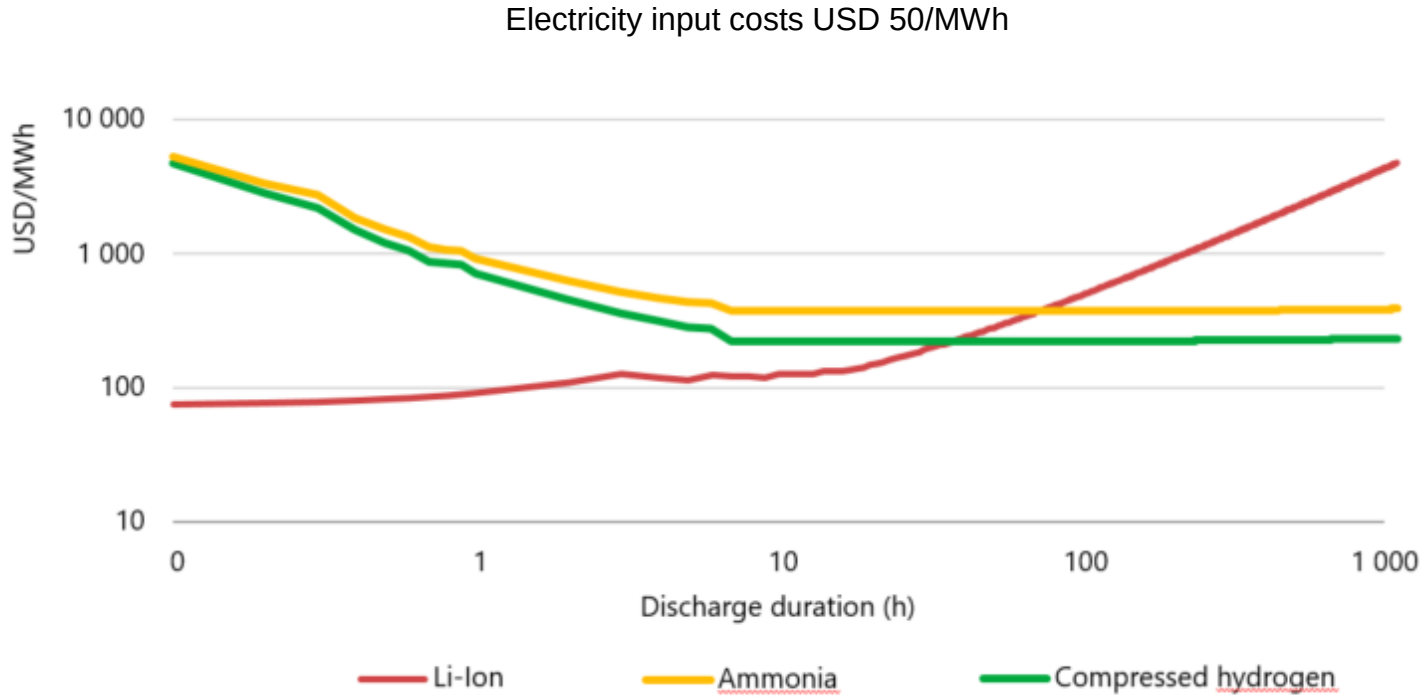
Annual power flows from east to central region in ASEAN and curtailment of VRE output in 2035 (25% share of VRE)





Expanded transmission enables greater trade between regions. With high shares of wind and solar PV, expanded cross-border trade is essential to avoid excessive curtailment of their generation

Long-term storage will become increasingly relevant with high RE



Depending on the costs of stored electricity, PtX represent a more cost-effective opportunity for long-term storage than other storage technologies