Integrating variable renewables: Implications for energy resilience

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Enhancing Energy Sector Climate Resilience in Asia

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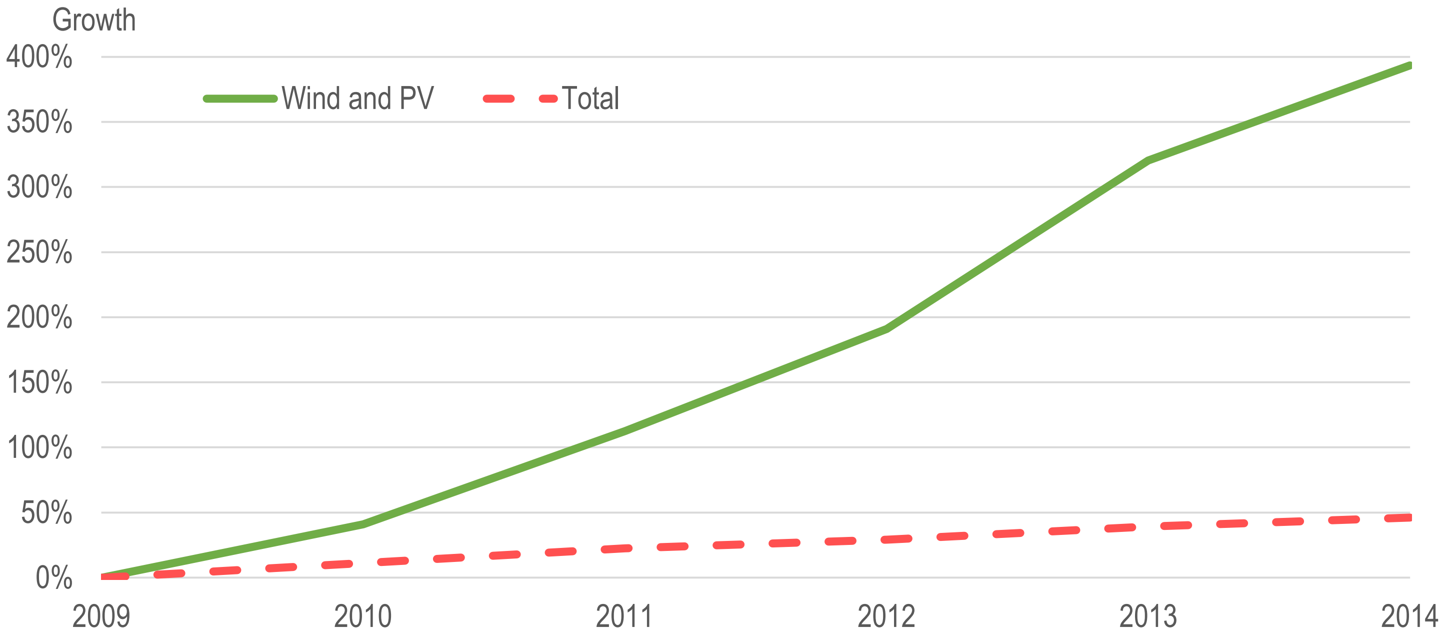
The growth of wind and solar in Asia



Wind and solar power have grown almost 10 times faster than demand. System integration requires attention as the grow continues

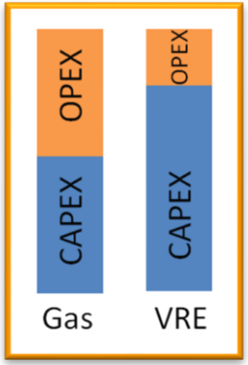
Most relevant properties of variable renewables

Variability

Uncertainty

Non-synchronous technologies

Low short-term marginal cost



Modularity

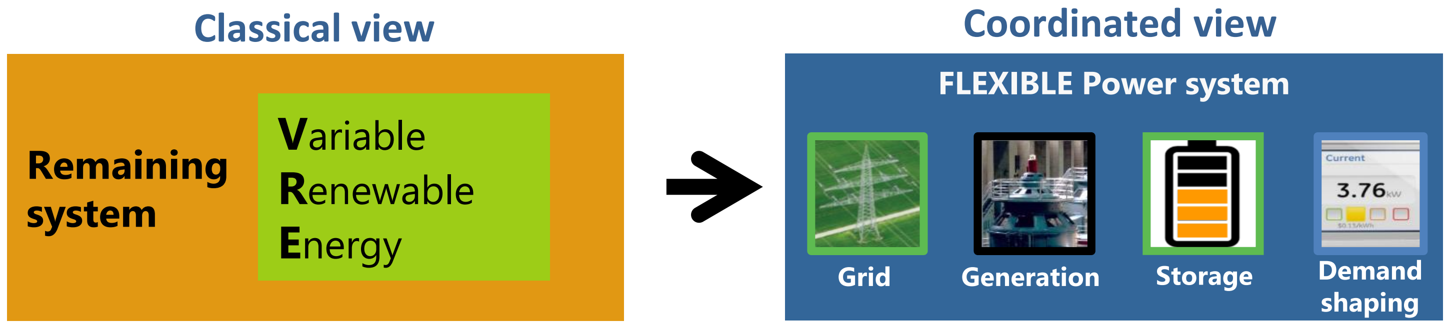
Location constraint

Variable renewables and energy resilience

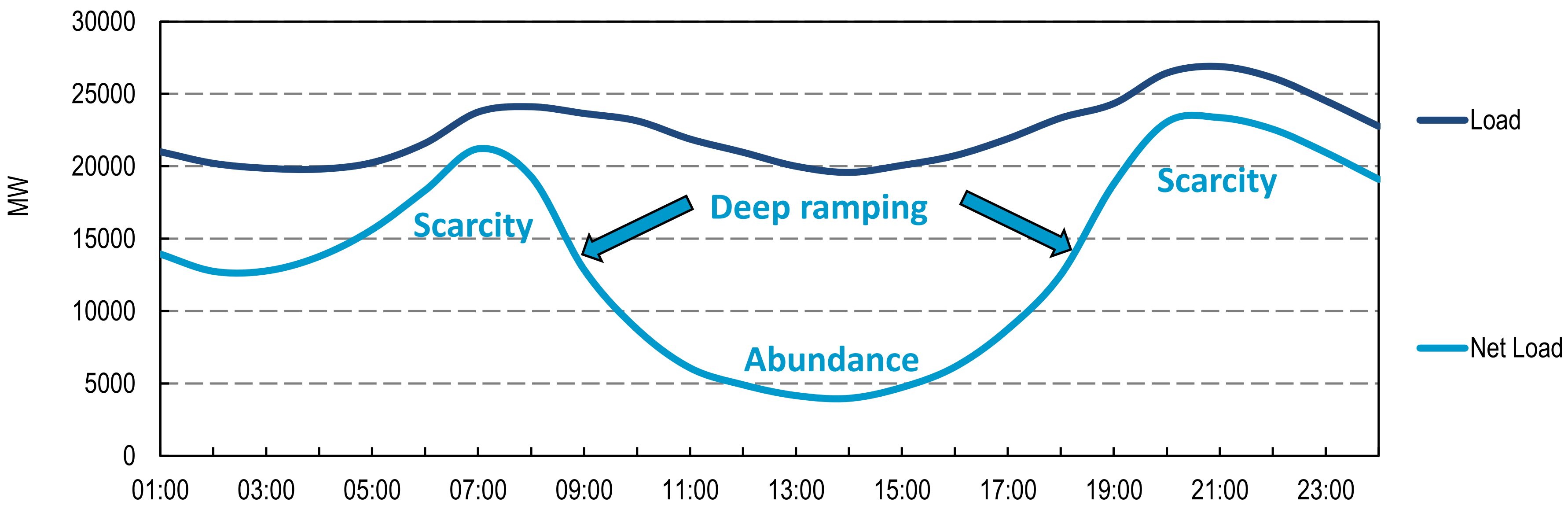
1. **Benefits**
   - Climate change mitigation, fuel diversifications, reducing fossil-fuel import

2. **Challenges**
   - Variability and uncertainty
   - Energy security implications at high shares if system integration challenges are not addressed

3. **System Transformation**
   - To achieve secure and resilient energy

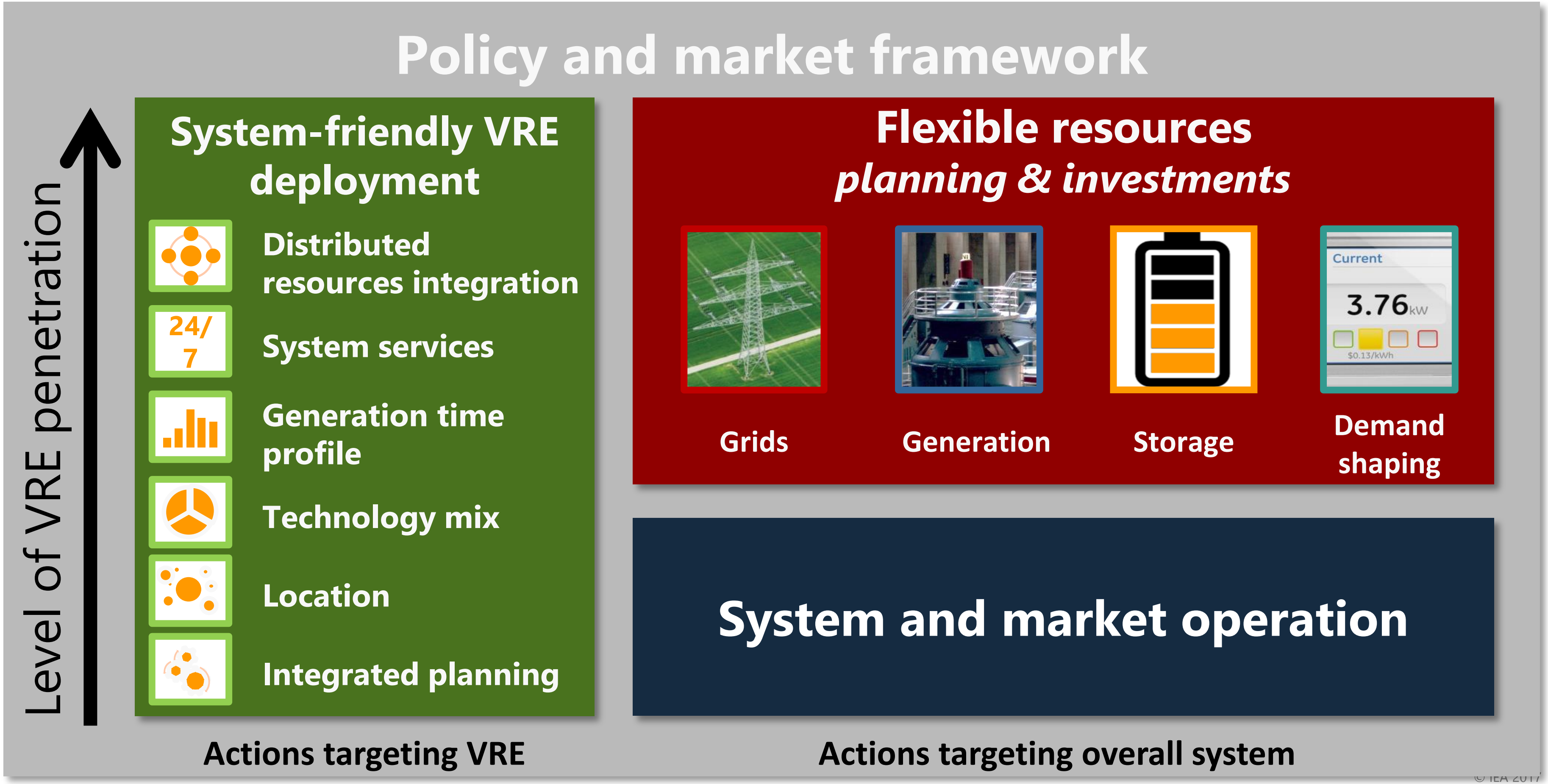


Impact of wind and solar on net demand



- The rise of VRE amplifies certain operational challenges
  - **Abundance**: high VRE output decreases the net load and may reduce output of conventional power plants
  - **Scarcity**: potentially low contribution during hours of peak demand
  - **Deep ramping**: enhanced need for reliable flexibility options during peak periods

System transformation



Transformation depends on context

Stable Power Systems

- Little general investment need short term

Dynamic Power Systems

- Large general investment need short term

➔ Maximise the contribution from existing flexible assets

➔ Decommission or mothball inflexible polluting surplus capacity to foster system transformation

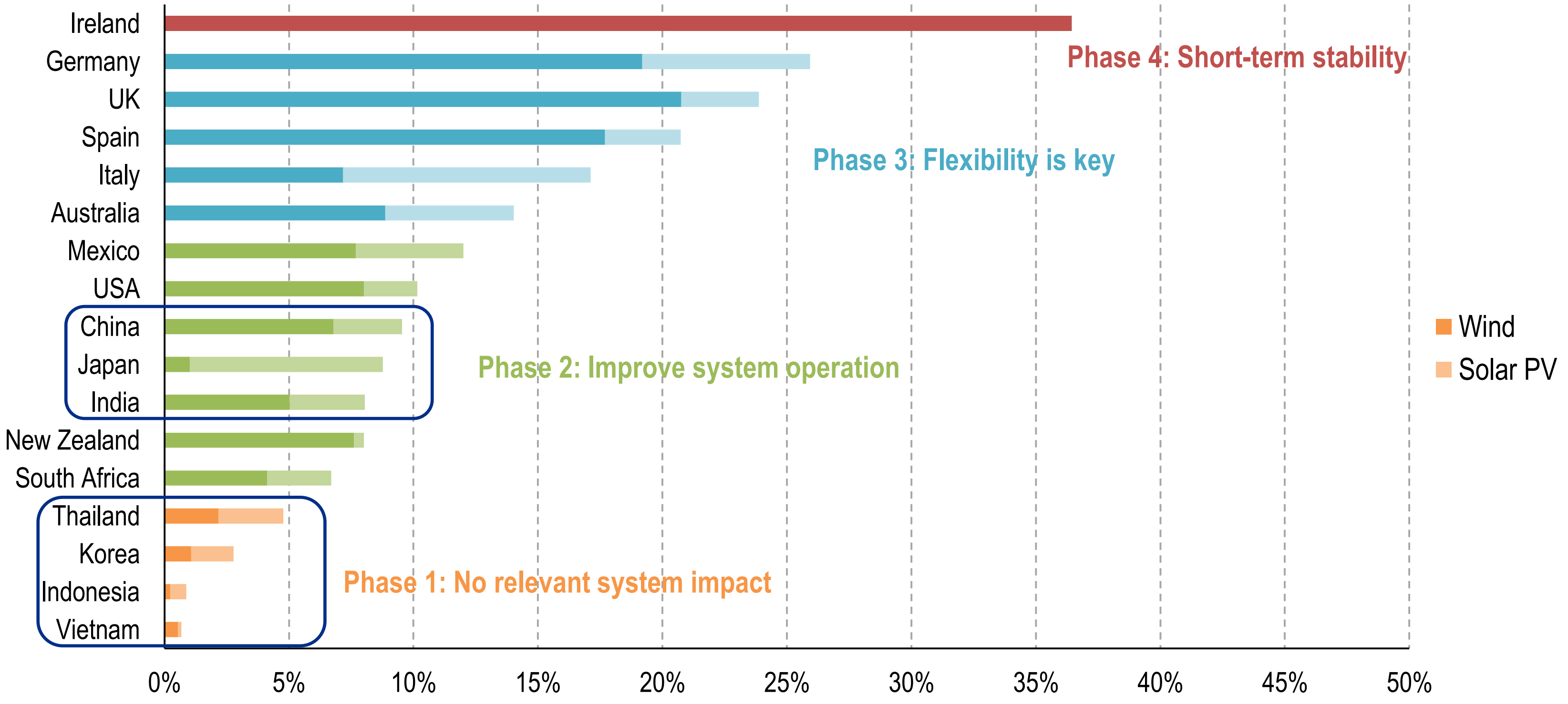
➔ Implement holistic, long-term transformation from onset

➔ Use proper long-term planning instruments to capture VRE's contribution at system level

* Compound annual average growth rate 2012-20 , slow <2%, dynamic ≥2%; region average used where country data unavailable

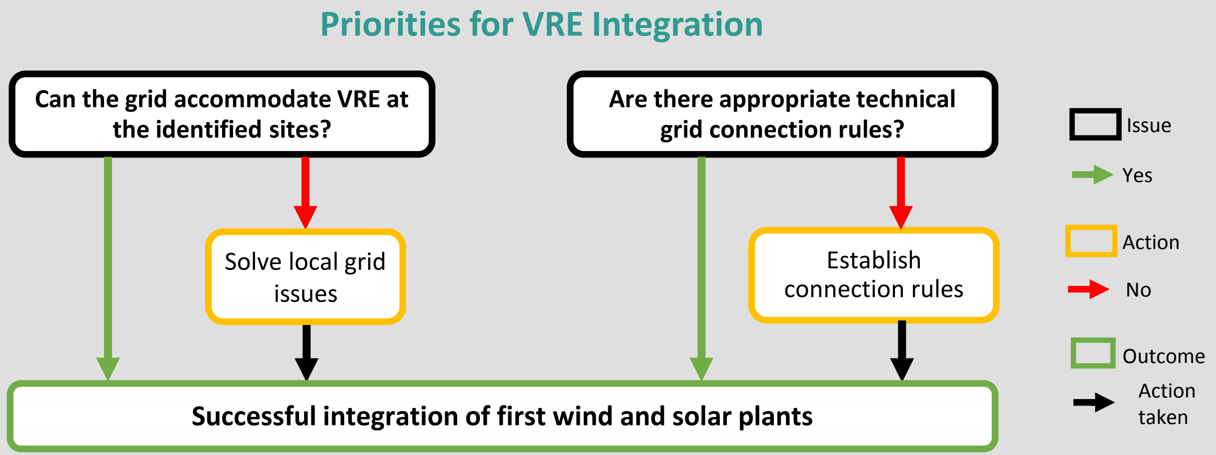
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Policy guidance for different phases of system integration

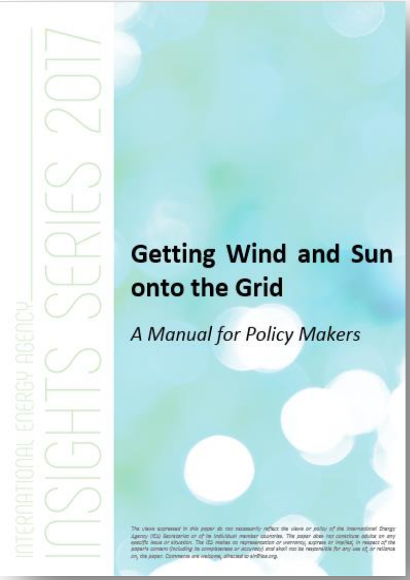


Integration strategies differ by phase of VRE deployment.
Phases one and two currently most relevant for majority of countries.

Priority during the early phase of VRE deployment



Source: IEA 2017, *Getting wind and sun onto the grid*



- VRE output is not noticeable for system operator
- VRE variability is negligible compared to fluctuations in demand
- Priority areas are connection requirements and grid codes

At initial deployment, integration of VRE technologies requires very little effort

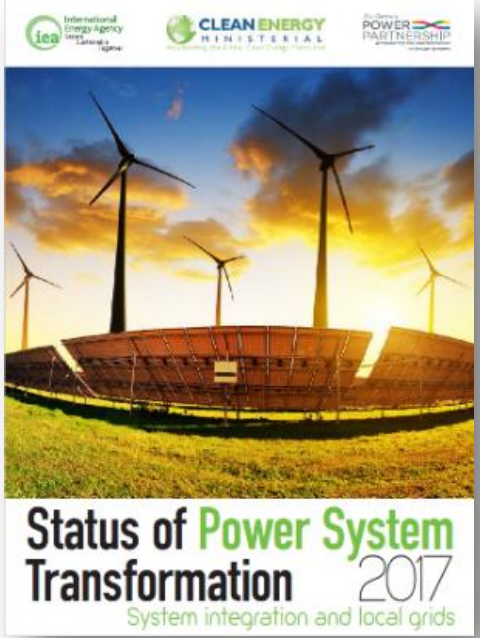
Addressing operation challenges

Technical measures

- **Address system reliability** issues arising from VRE
- Some measures can also improve the cost-effectiveness of power system operation
- E.g. real-time monitoring and control, power plant flexibility, enhancing line capacity

Economic measures

- **Improve the cost-effectiveness** of power system operation
- Without economic measures, the grid can still operate in a reliable manner (but more costly)
- E.g. better forecasting, reduce dispatch interval, include VRE in the dispatch



- A range of measures to maintain reliability and cost-effectiveness
- Different measures are needed for different phases of VRE deployment
- Grid code is important for successful integration

Key action areas and policy examples

Action area	Policy example
Integrated planning: wind and solar embedded in energy strategy	**Denmark:** integrated energy strategy
Location: siting VRE closer to existing network capacity and/or load centers	**Location:** new auction design for wind and PV
Technology mix: balanced mix of VRE resources can foster lasting synergies	**Technology mix:** Integrated Resource Plan
Optimising generation time profile: design of wind and solar PV plants	**California:** incentive to produce at peak times
System services: wind and sun contribute to balance system	**System services:** wind active on balancing market
Local integration with other resources such as demand-side response, storage	**Australia:** incentives for self-consumption

Conclusion

- Variable renewables can enhance energy system resilience
  - Fuel diversity, environment benefits, long-term security

- It is technically possible and economically feasible to integrate high shares of wind and solar despite their variability and uncertainty

- Integration of high shares in a cost-effective and reliable manner requires changes to the power system
  - Operation practices
  - Planning practices
  - Policy, market and regulatory frameworks

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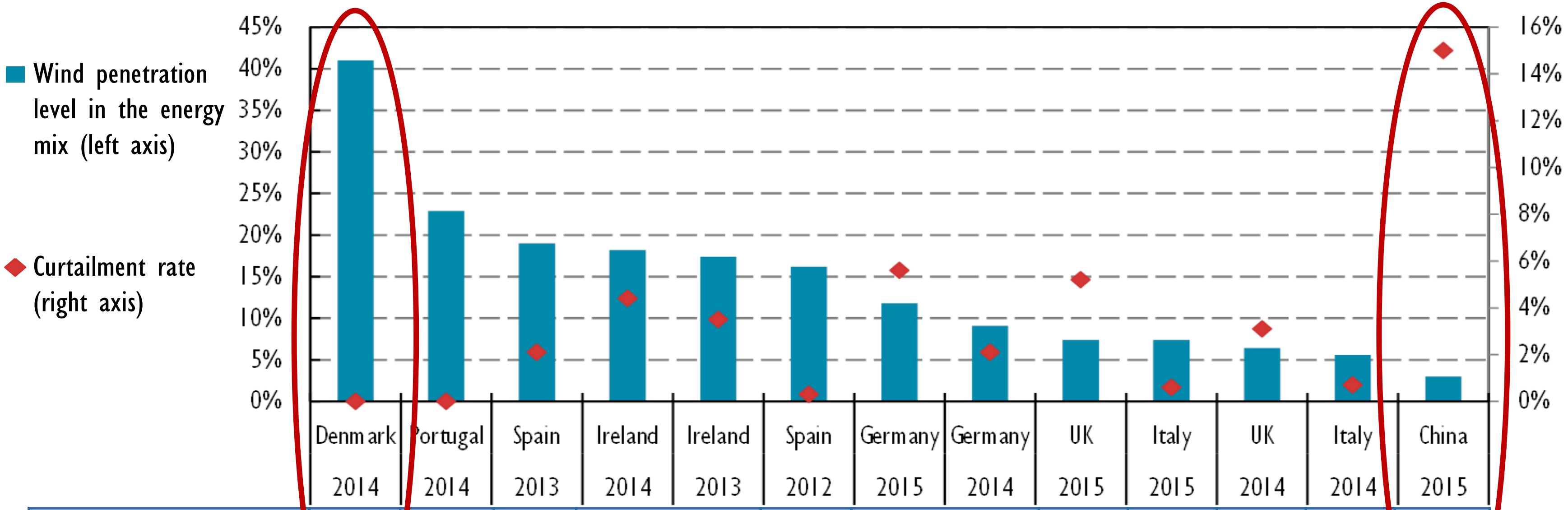
Additional Slides

… but also challenges

Wind penetration and curtailment in selected countries, 2012-2015



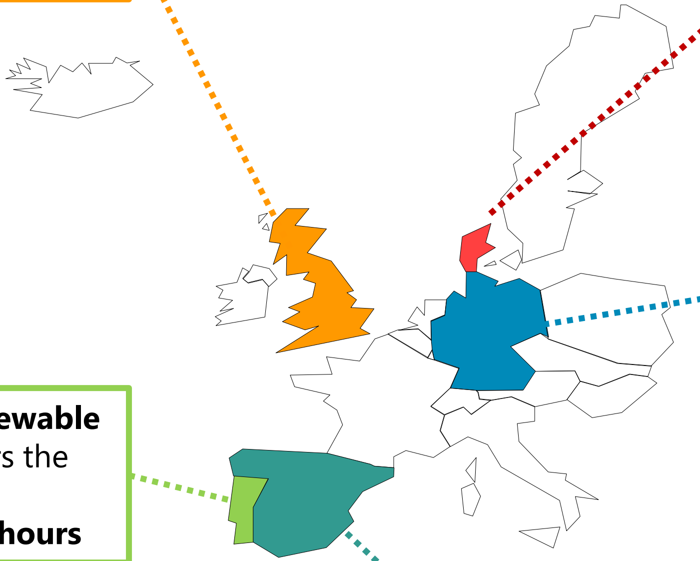
Grids	+	+	+	o	+	o	o	o	o	o	o
Generation	+	+	+	+	+	o	o	+	o	+	-
Operation	+	+	+	+	+	+	+	+	+	+	-

Curtailment levels are a good indicator for successful VRE integration – growing curtailment signals shortfalls in power system flexibility

Recent renewable integration milestones…

Scotland, 14 August 2016 : Daily **wind power production exceeded demand**

Denmark, 2 September 2015: The Western Danish power **system runs without centralised power generation** for the first time



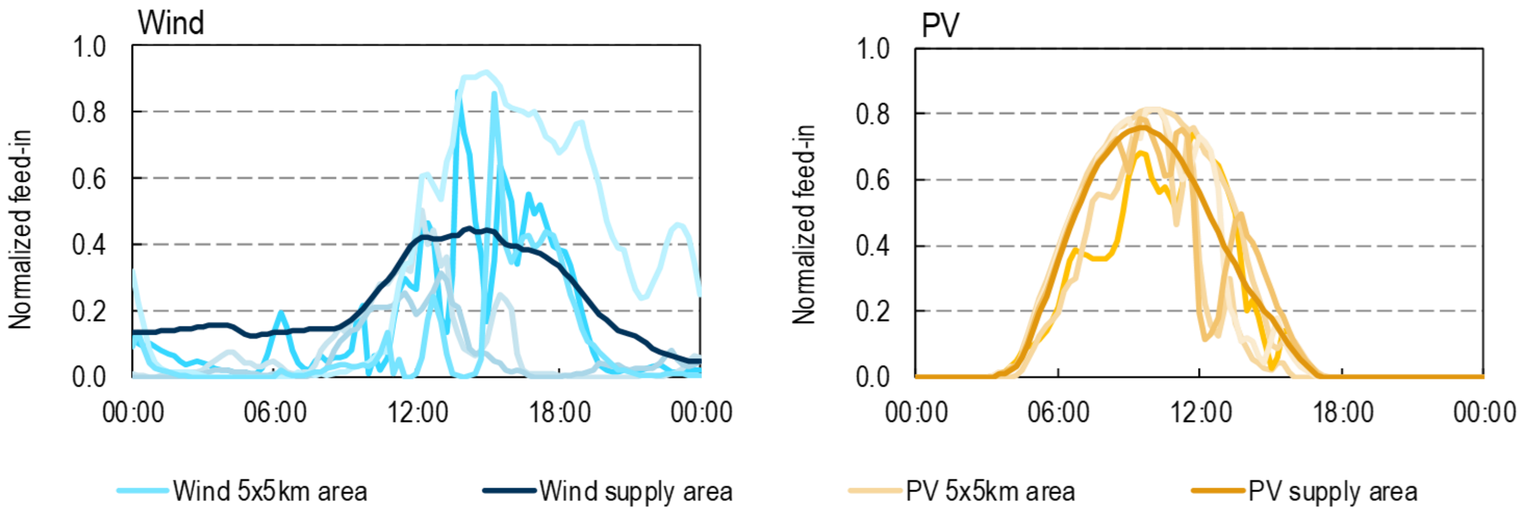
Germany, 8 May 2016: **Wind and solar PV** cover the equivalent of approx. **75% of power demand**

Portugal, 7-11 May 2016: **Renewable energy** (including hydro) covers the equivalent of **100% of power demand for 107 consecutive hours**

Spain, 28 February 2016: For the first time, **wind power provides upward balancing reserves**

Example: Geographical spread of VRE

VRE output and the benefit of geographical spread, South Africa



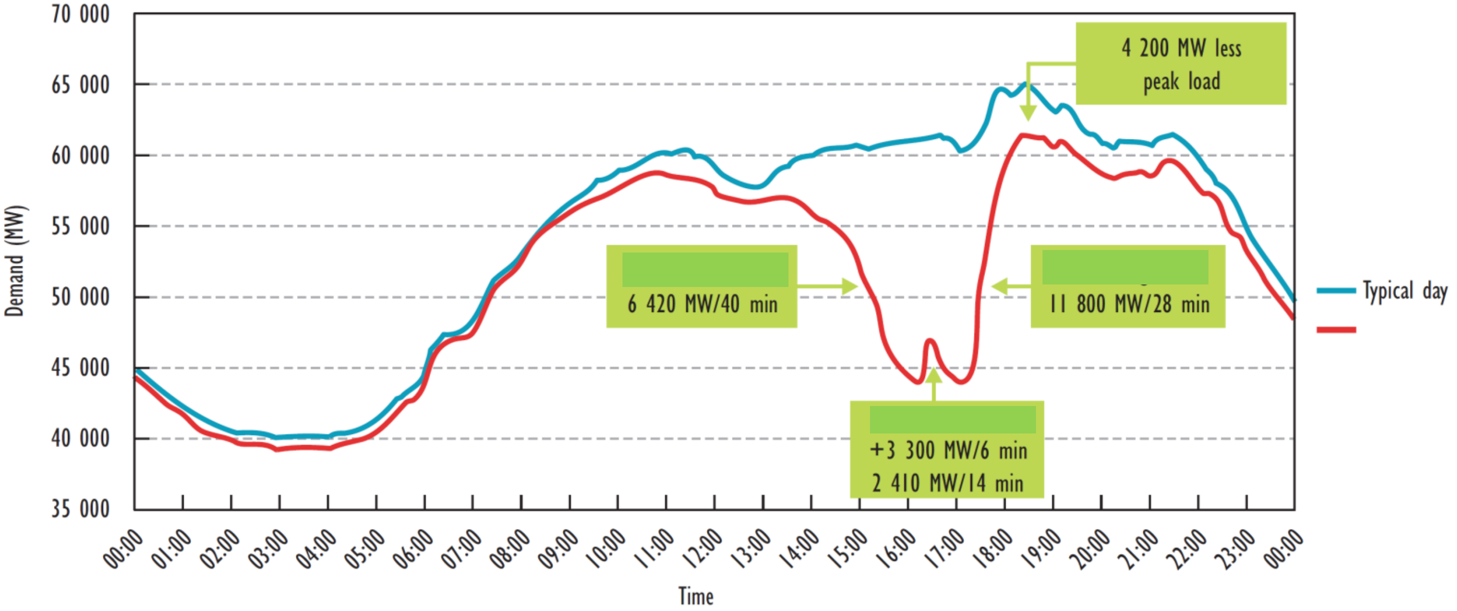
The dispersal of VRE power plants makes their output easier to accommodate. REDZ are a good starting point for the larger implementation of VRE in South Africa.

Phases of VRE system integration

Phase	Description
1	VRE capacity is not relevant at the all-system level
2	VRE capacity becomes noticeable to the system operator
3	Flexibility becomes relevant with greater swings in the supply/demand balance
4	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times
5	Structural surpluses emerge; electrification of other sectors becomes relevant
6	Bridging seasonal deficit periods and supplying non-electricity applications; seasonal storage and synthetic fuels

Variability – a familiar challenge

Exceptionally high variability in Brazil, 28 June 2010



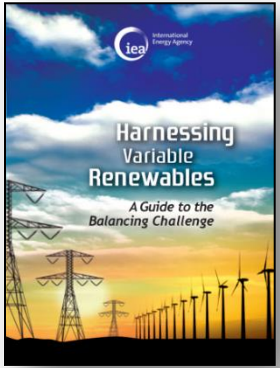
Power systems already deal with demand variability; they have flexibility available from the start.

Source: ONS, Brazil

IEA System Integration of Renewables analysis at a glance

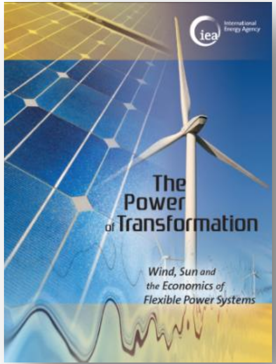
- Formally established as a Unit on 1 June 2016 – build on GIVAR work
- Global expert network covering policy making, engineering and modelling
- Analysis based on extensive research on current global state of play and modelling tools
- Fostering exchange in international fora (G20, CEM) and capacity building

2011



Technical

2014

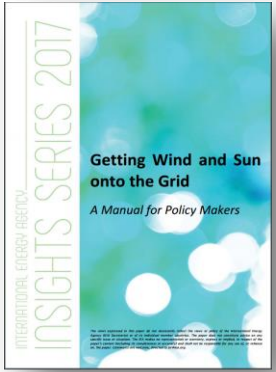


Framework, Technology, Economics

2016

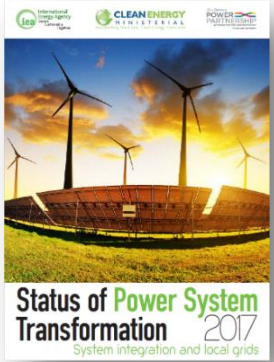
Policy

2017



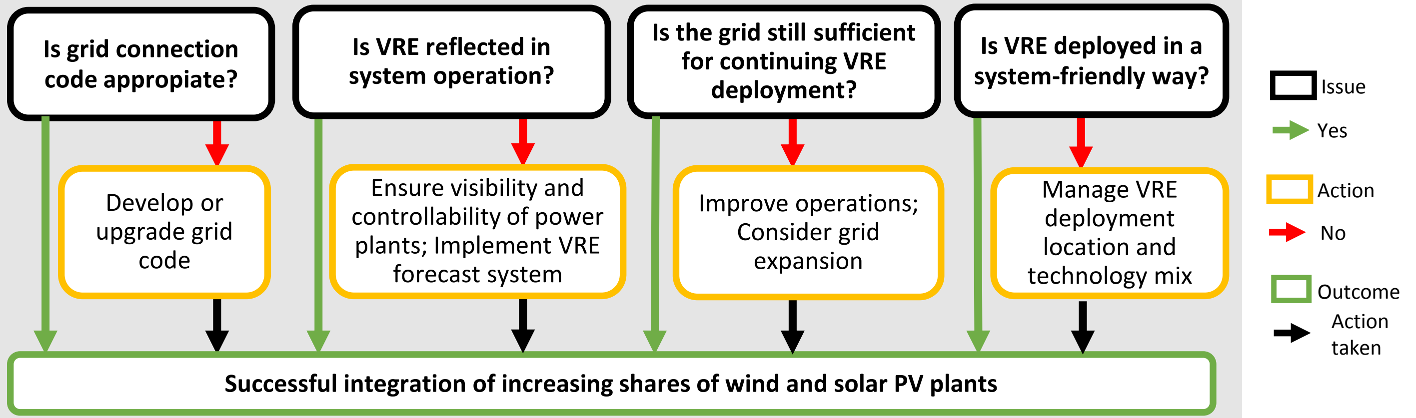
Implementation

2017



Progress & Tracking

Priority during the early phase of VRE deployment



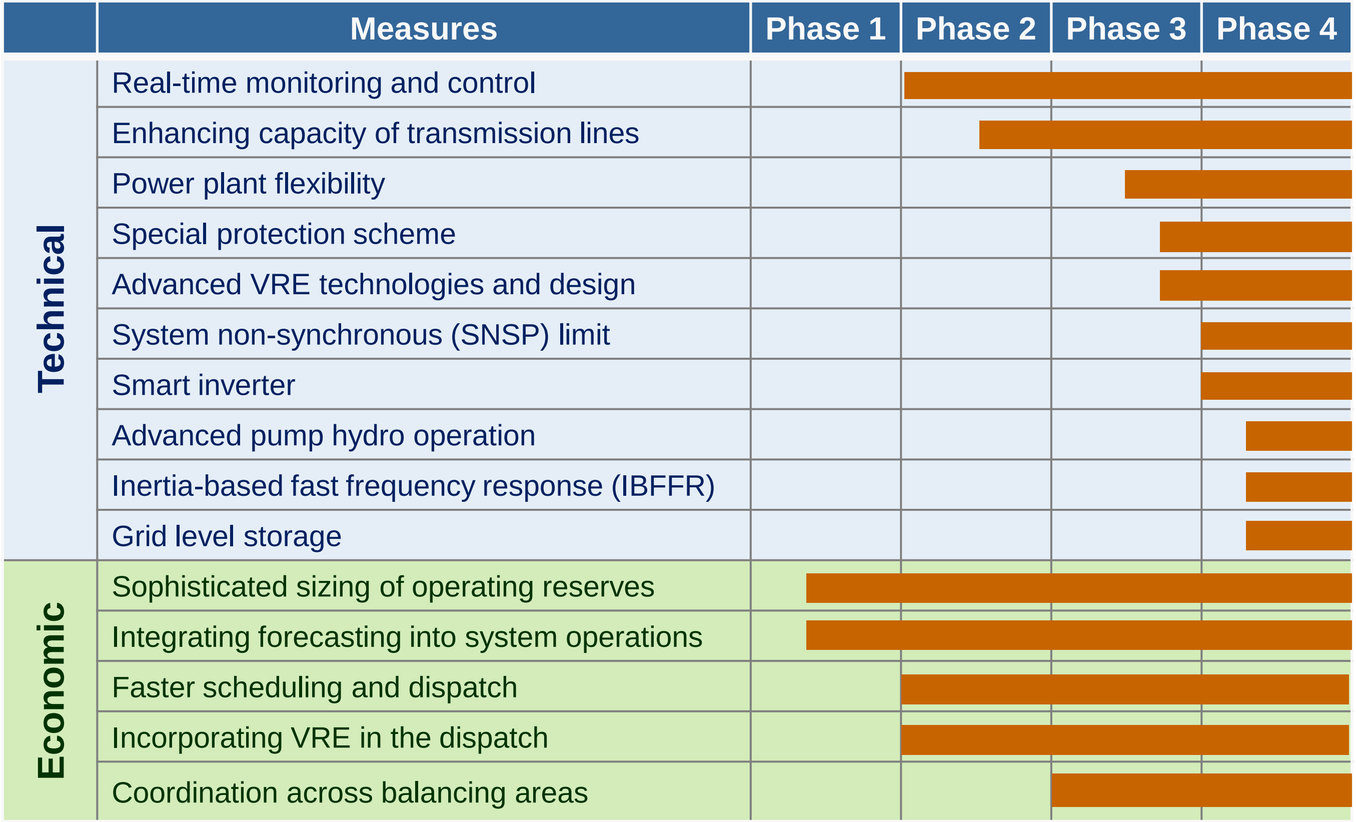
Source: IEA 2017, *Getting wind and sun onto the grid*

Phase 2 of VRE integration

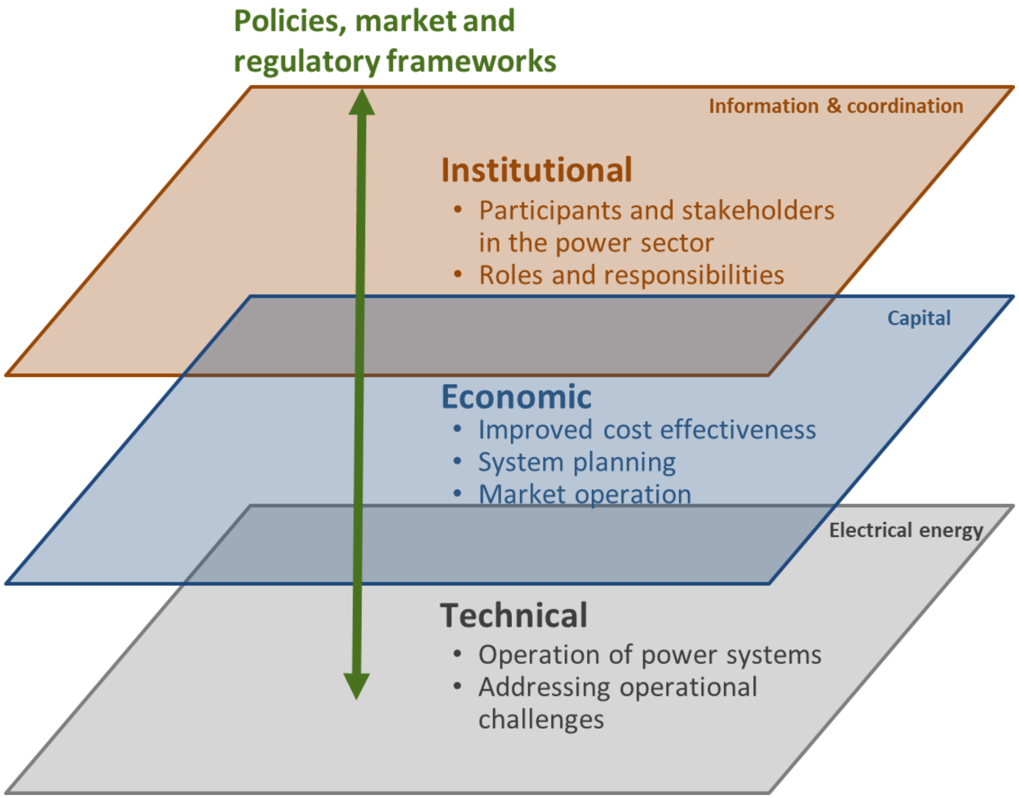
- First instances of grid congestion
- Incorporate VRE forecast in scheduling and dispatch
- Focus on system-friendly VRE deployment

The level of adaptation needed to integrate VRE changes according to the level of penetration

Options for addressing power system operation challenges



System transformation for VRE integration

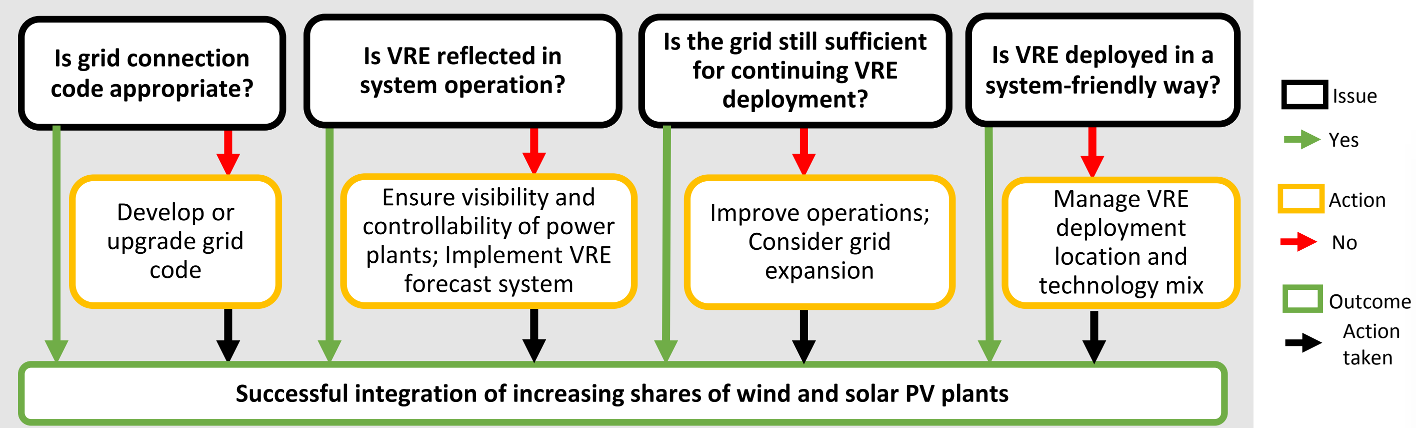


- **Institutional** – different stake holders involved; increased cooperation is key
- **Economic** – system planning; market operations
- **Technical** – operations of power systems

Technical, economic and institutional aspects are linked through policies, markets and regulatory frameworks

Policy implementation

Getting Wind and Solar onto the Grid – A Manual for Policy Makers



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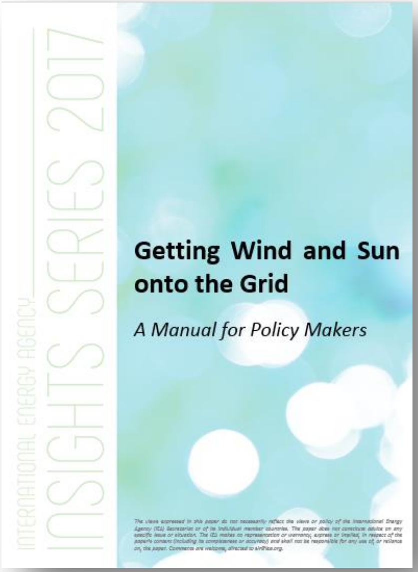
New Publication released March 2017



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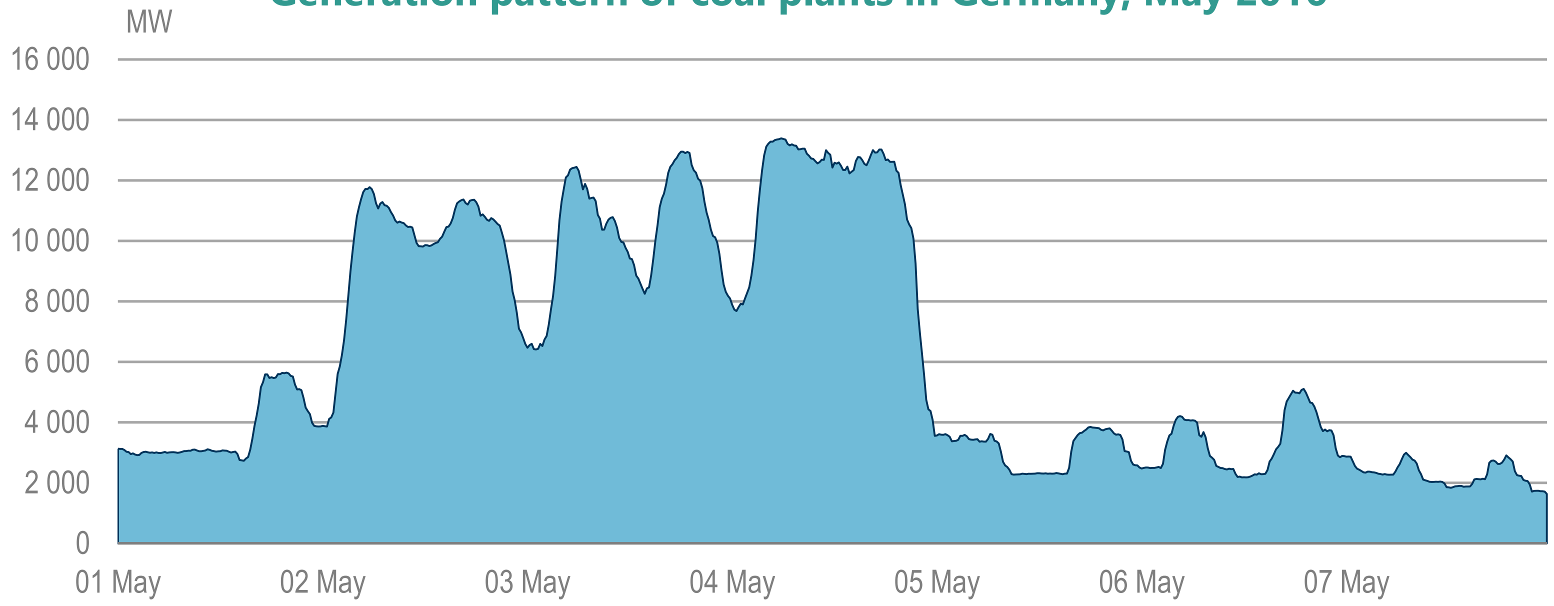
Example of technical measures – Power plant flexibility

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

Generation pattern of coal plants in Germany, May 2016



Power system transformation assessment framework

Aspect	Sub-aspects
Markets and operations	Wholesale level
	Retail level
Planning and infrastructure	Integrated planning frameworks
	Electricity grids
Uptake of innovative technology	Smart technologies
	Flexible resources
	Resource-efficient technologies
Efficiency and sector coupling	Electrification of other sectors
	Energy efficiency

Grid code is important for VRE integration

	Always	Phase One	Phase Two	Phase Three	Phase Four
Typical technical requirements	• protection systems • power quality • frequency and voltage ranges of operation • visibility and control of large generators • communication systems for larger generators	• output reduction during high frequency events • voltage control • FRT capability for large units	• FRT capability for smaller (distributed) units • communication systems • VRE forecasting tools	• Frequency regulation • reduced output operation mode for reserve provision	• integration of general frequency and voltage control schemes • synthetic inertia • stand-alone frequency and voltage control

- Need to ensure the grid code is appropriate for VRE
- Prioritising technical requirements according to the share of VRE
- Need to be in the context of individual power system

Decrease baseload requirements