The Power of Transformation
Wind, Sun and the Economics of Flexible Power Systems

Simon Müller
Analyst, System Integration of Renewables
Renewable Energy Division

International Energy Agency

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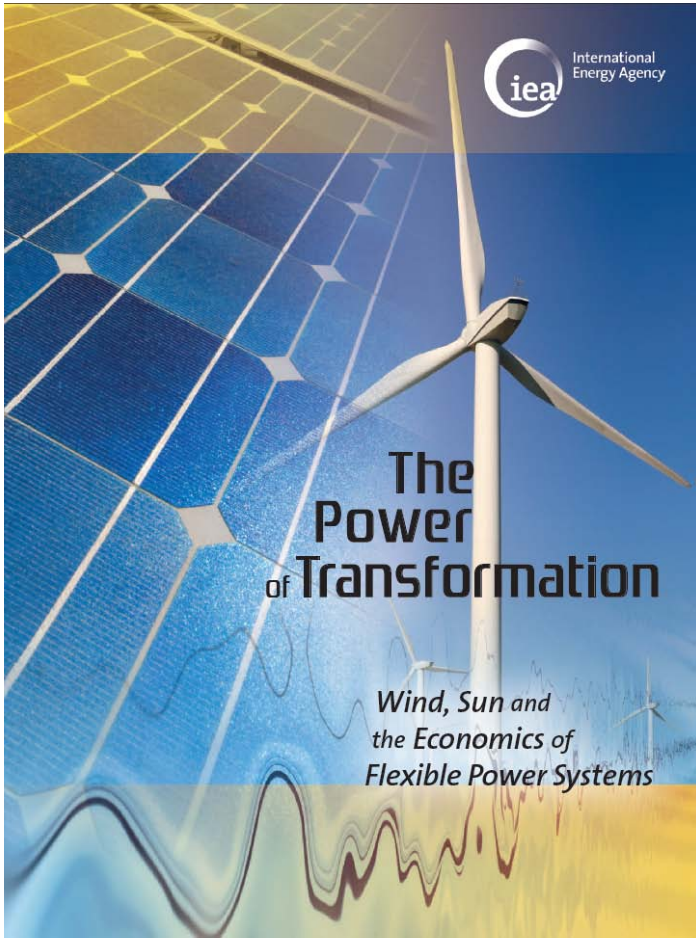
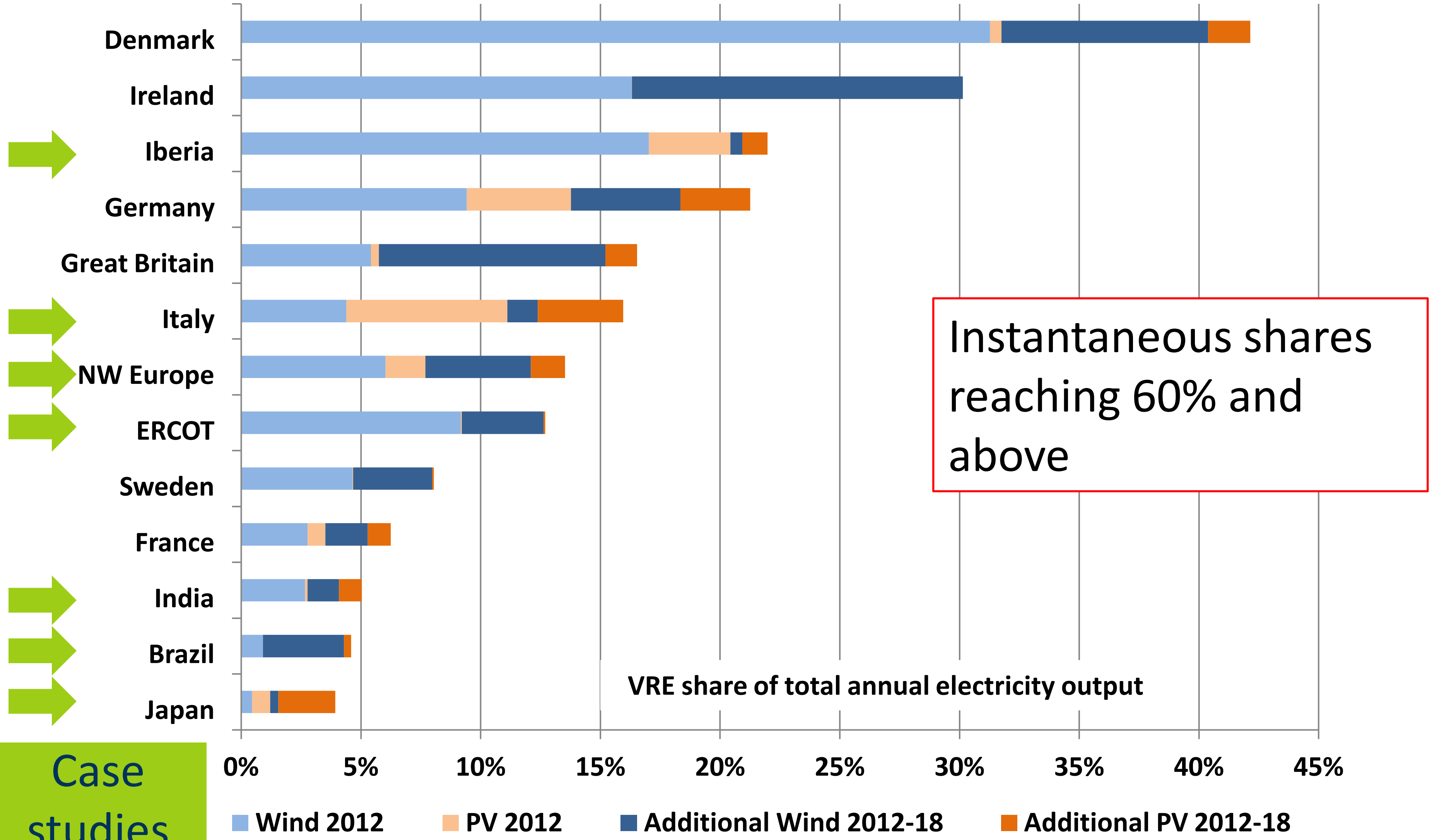
The Grid Integration of Variable Renewables Project - GIVAR

- Third project phase at a glance
  - 7 case studies covering 15 countries, >50 in-depth interviews
  - Technical flexibility assessment with revised IEA FAST tool
  - Detailed economic modelling at hourly resolution



Large-scale integration accomplished today, but more to come



Case studies

Note: ERCOT = Electricity Reliability Council of Texas, United States

Source: IEA estimates derived in part from IEA Medium-Term Renewable Energy Market Report 2013.

Interaction is key

Properties of variable renewable energy (VRE) ⟷ **Flexibility of other power system components**

yrs

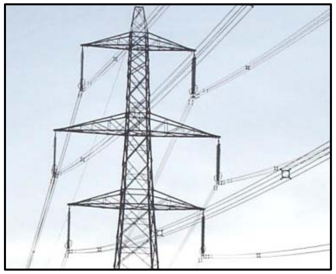
sec

100s km

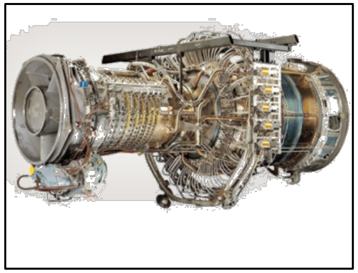
1 km

- **Variable**
- **Uncertain**
- **Non-synchronous**
- **Location constrained**
- **Modularity**
- **Low short-run cost**

Grids



Generation



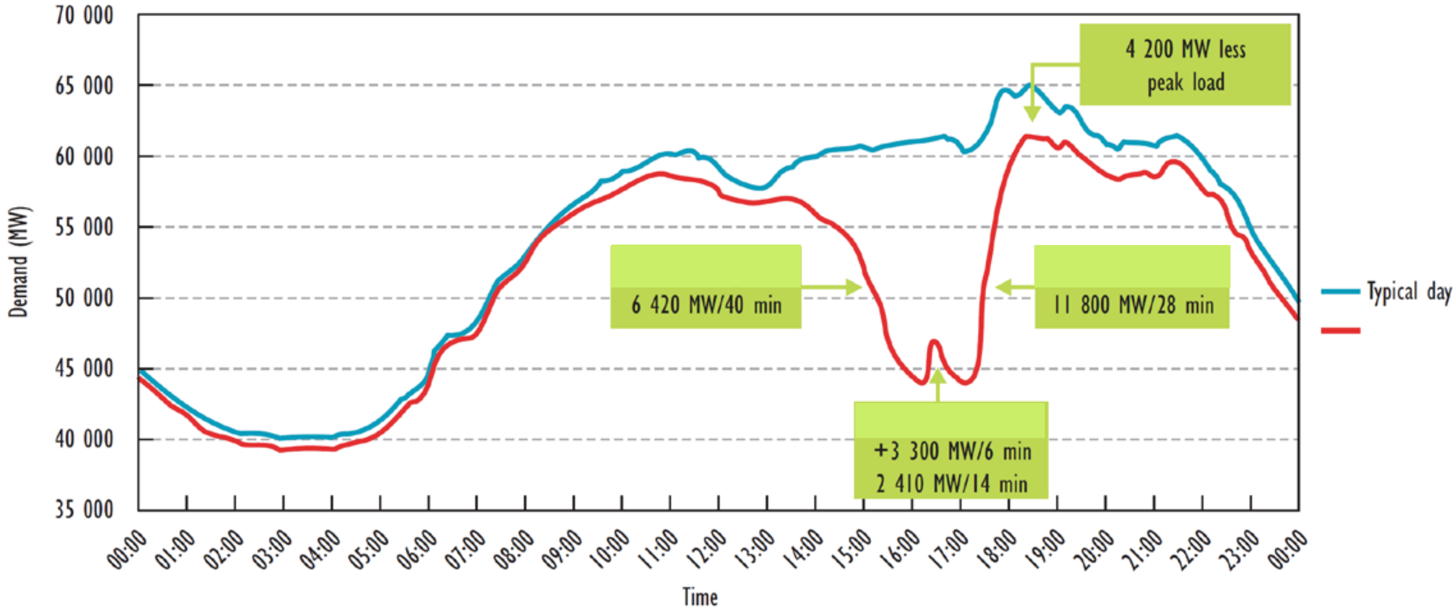
Storage

Demand Side

No problem at 5% - 10%, if …

- **Power systems already deal with a vast demand variability**
  - **Can use existing flexibility for VRE integration**

Exceptionally high variability in Brazil, 28 June 2010



- **No technical or economic challenges at low shares, if basic rules are followed:**
  - **Avoid uncontrolled, local ‘hot spots’ of deployment**
  - **Adapt basic system operation strategies, such as forecasts**
  - **Ensure that VRE power plants are state-of-the art and can stabilise the grid**

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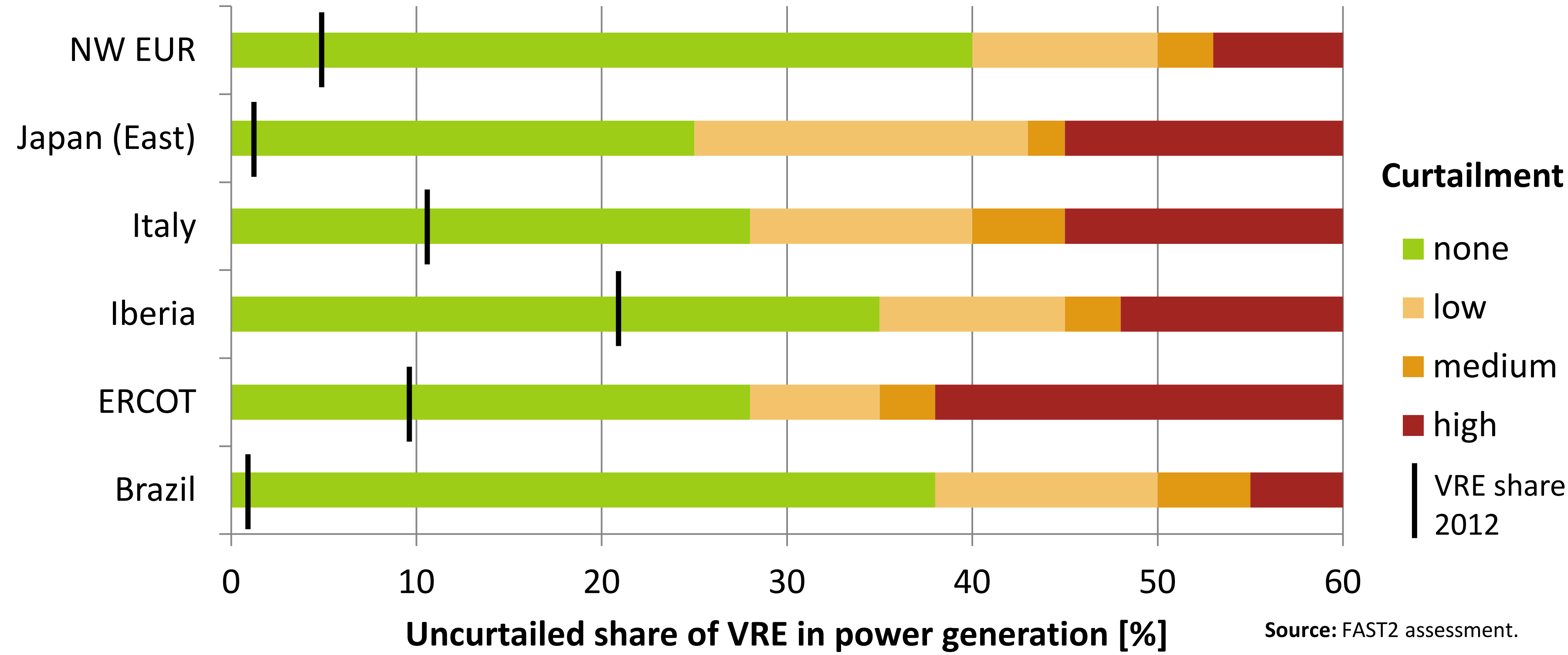
Much higher shares technically feasible



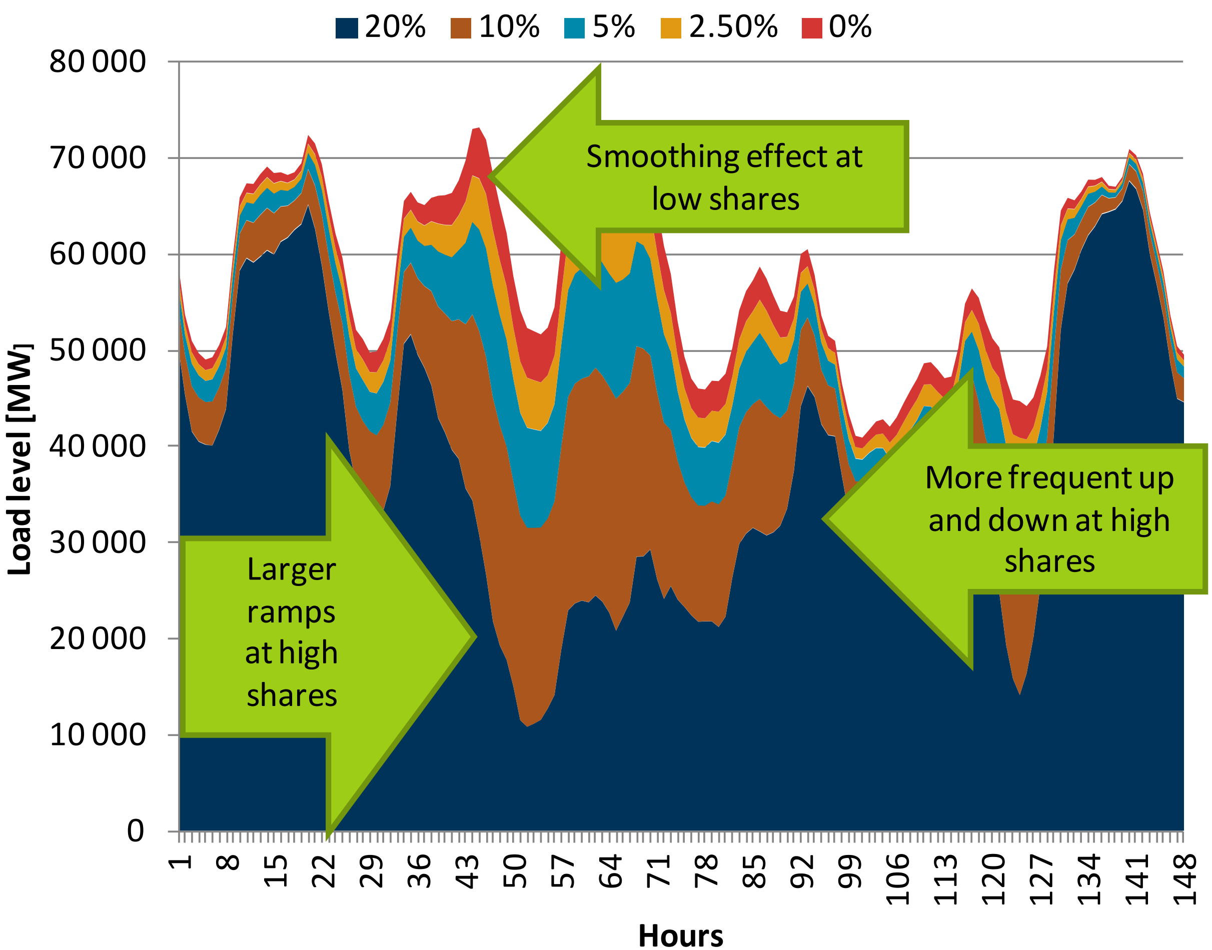
Source: FAST2 assessment.

- **FAST2 assessment: All power systems can take 25% in annual generation already today.**
- **There is no technical limit on how much variable generation a power system can absorb**
  - **But system transformation increased flexibility required for higher shares**

Main persistent challenge: Balancing

- Higher uncertainty
- Larger and more pronounced changes

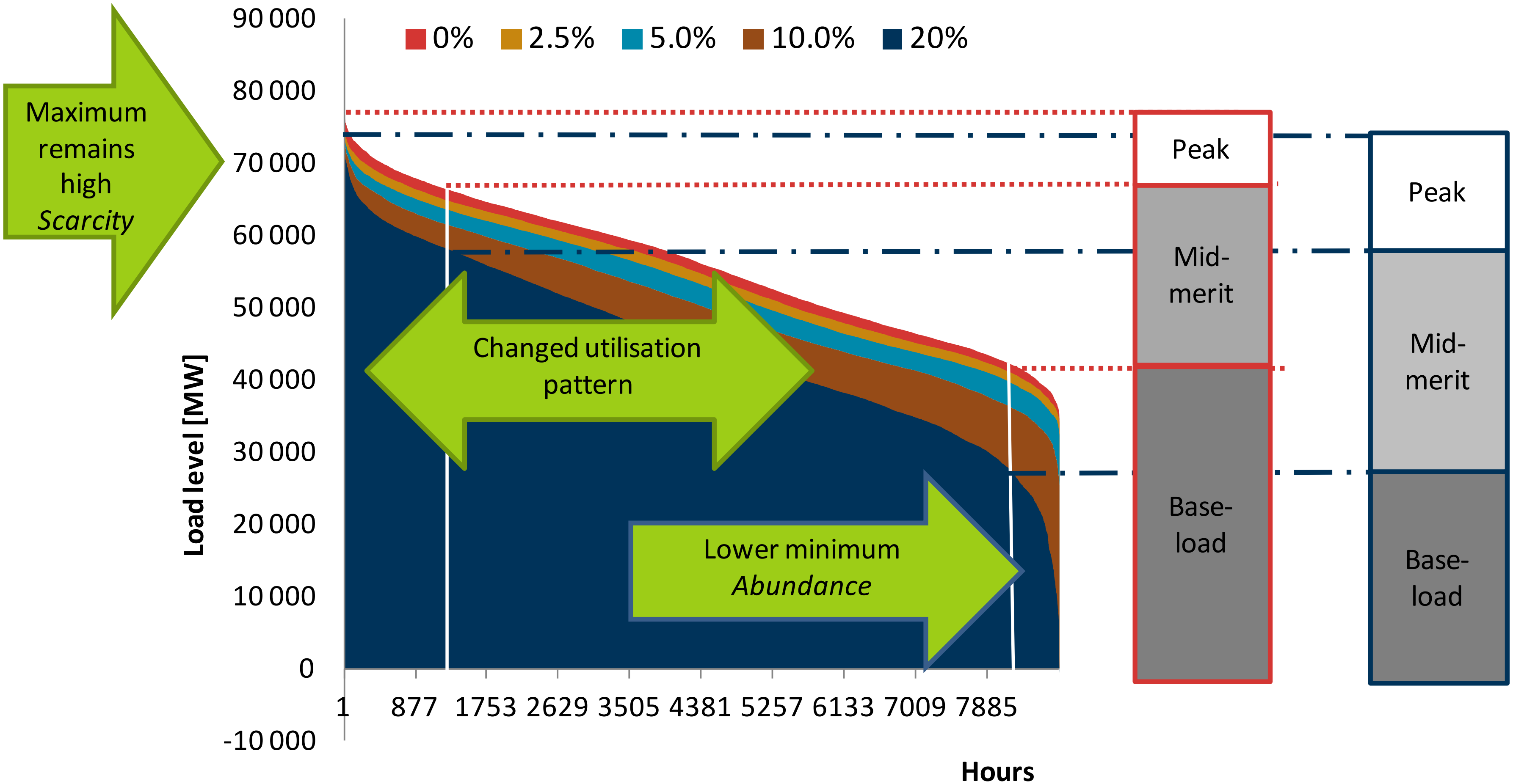
Net-load at different annual VRE shares



Note: Load data and wind data from Germany 10 to 16 November 2010, wind generation scaled, actual share 7.3%. Scaling may overestimate the impact of variability; combined effect of wind and solar may be lower, illustration only.

Main persistent challenge: Utilisation

- **Netload implies different utilisation for non-VRE system**



Note: Load data and wind data from Germany 10 to 16 November 2010, wind generation scaled, actual share 7.3%. Scaling may overestimate the impact of variability; combined effect of wind and solar may be lower, illustration only.

Integration vs. transformation

- Classical view: VRE are integrated into the rest
  - Integration costs: balancing, adequacy, grid

- More accurate view: entire system is re-optimised
  - Total system costs

FLEXIBLE
Power system
- Generation
- Grids
- Storage
- Demand Side Integration

→ <u>Integration is actually about transformation</u>

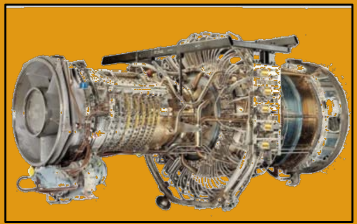
Three pillars of system transformation

Technology spread

Geographic spread

Design of power plants

System friendly VRE

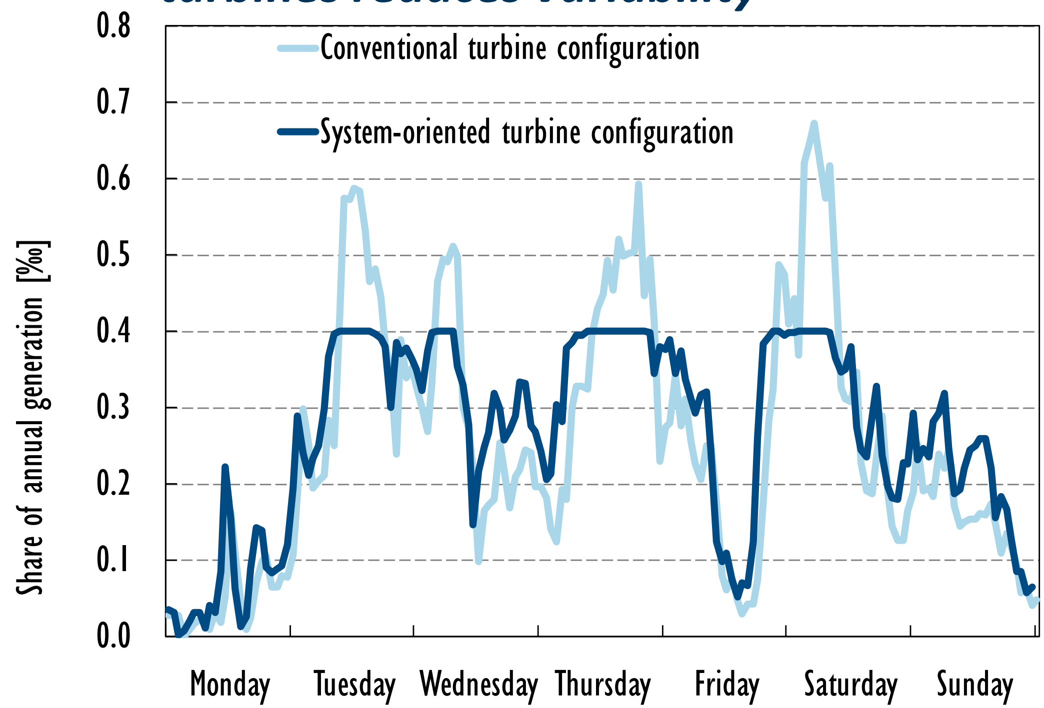
Investments


Operations

1) System friendly (V)RE deployment

- Main idea: minimise total system costs, not VRE generation costs alone!
- 5 aspects:
  - Timing
  - Location and technology mix
  - Technical capabilities
  - System friendly power plant design
  - Curtailment

Example: System friendly design of wind turbines reduces variability



→ Cost-effectiveness does not mean cheapest technology where resources are best

Source: adapted from Agora, 2013

Three pillars of system transformation

Technology spread

Geographic spread

Design of power plants

System friendly VRE

2.
Make better use of what you have

Balancing areas and markets: cooperation & consolidation

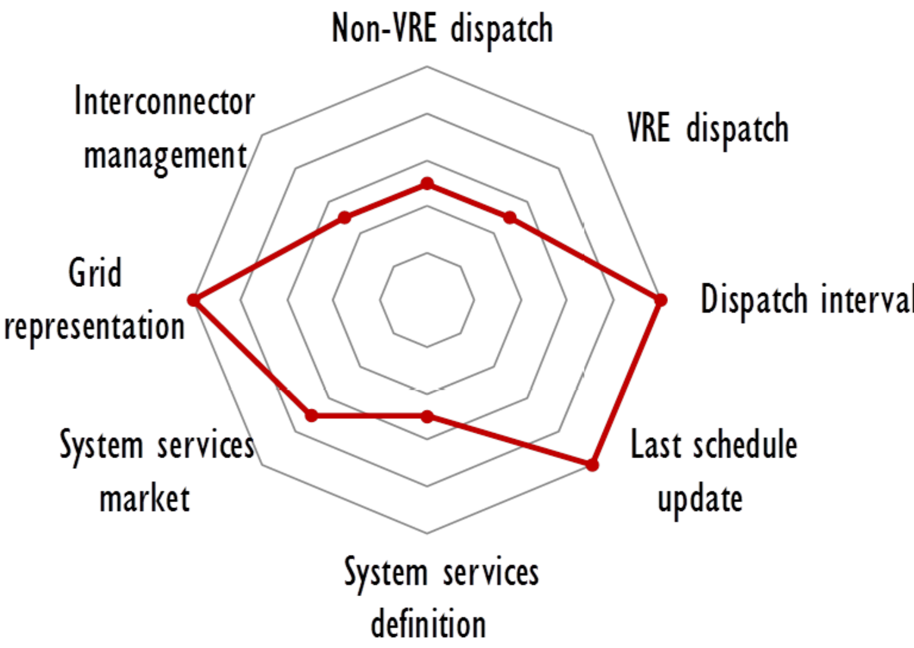
Market and system operations

Operations

2) Better system & market operation

- **VRE forecasting**
- **Better market operations:**
  - **Fast trading**
    Best practice:
    ERCOT (Texas) – 5 minutes
  - **Price depending on location**
    Best practice: United States – Locational Marginal Prices
  - **Better flexibility markets**
    - ***Updated product definitions***
    - ***Full remuneration of services***
    - ***Fully aligned trading of services and wholesale electricity***

Example: ERCOT market design



→ Make better use of what you have already!

Three pillars of system transformation

Technology spread

Geographic spread

Design of power plants

System friendly VRE

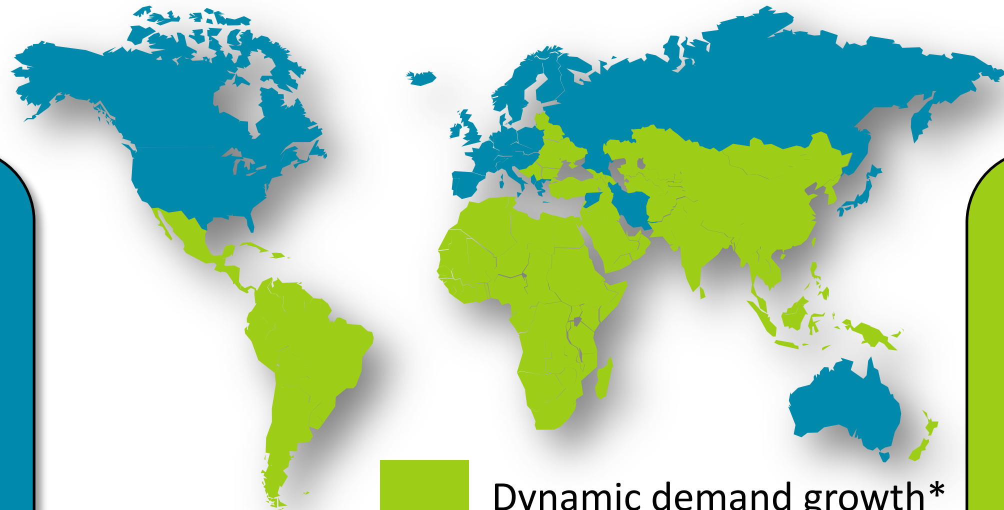
3.
Take a system wide-strategic approach to investments!

Balancing areas and markets: cooperation & consolidation

Market and system operations

Operations

Transformation depends on context



Dynamic demand growth*

Slow demand growth*

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**

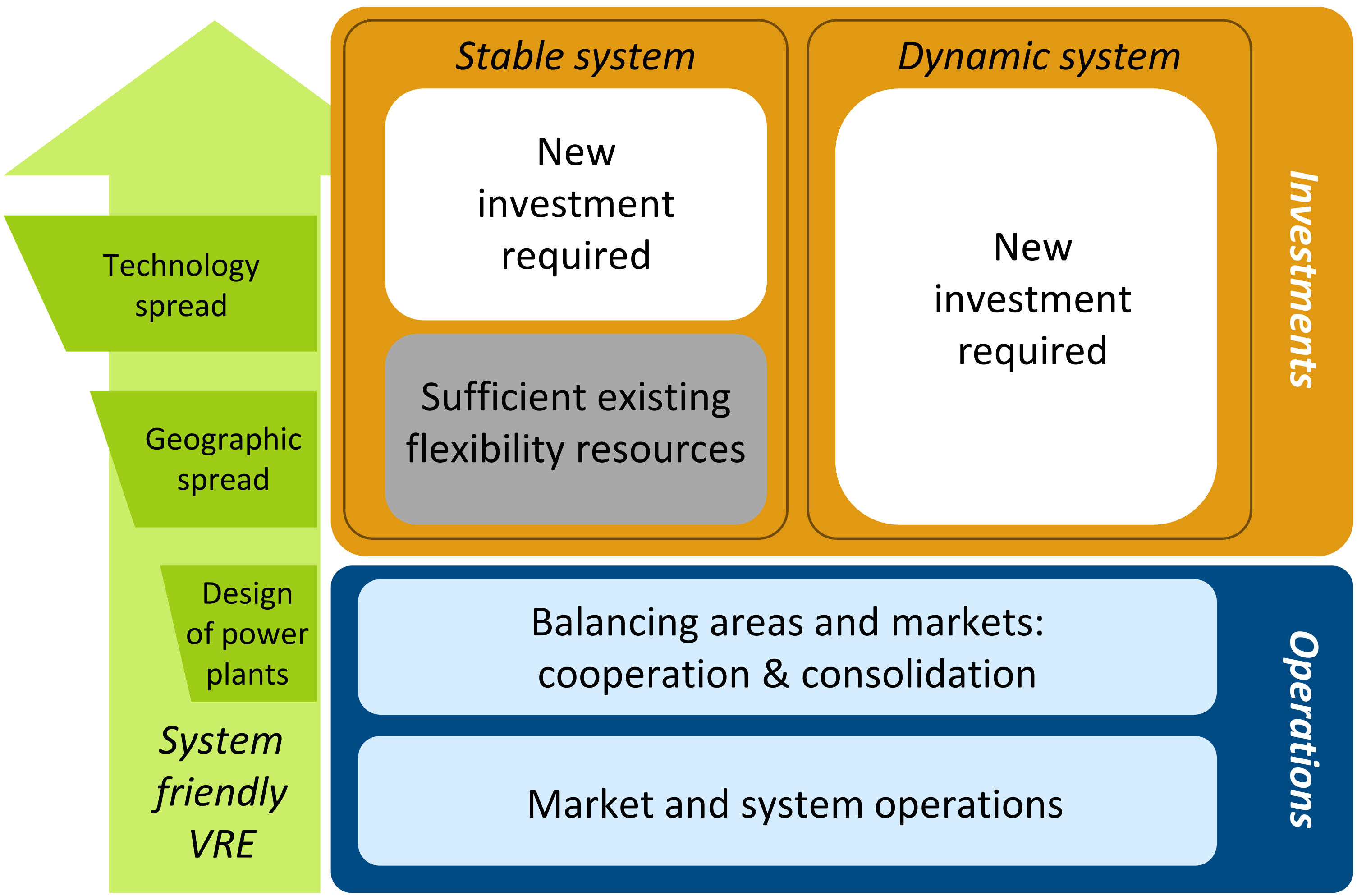
→ **Implement holistic, long-term transformation from onset**

→ **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

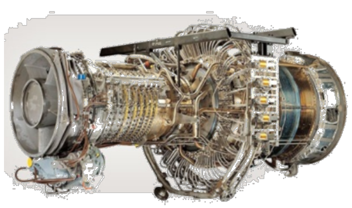
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Three pillars of system transformation



3) Investment in additional flexibility

Four sources of flexibility …



Grid infrastructure

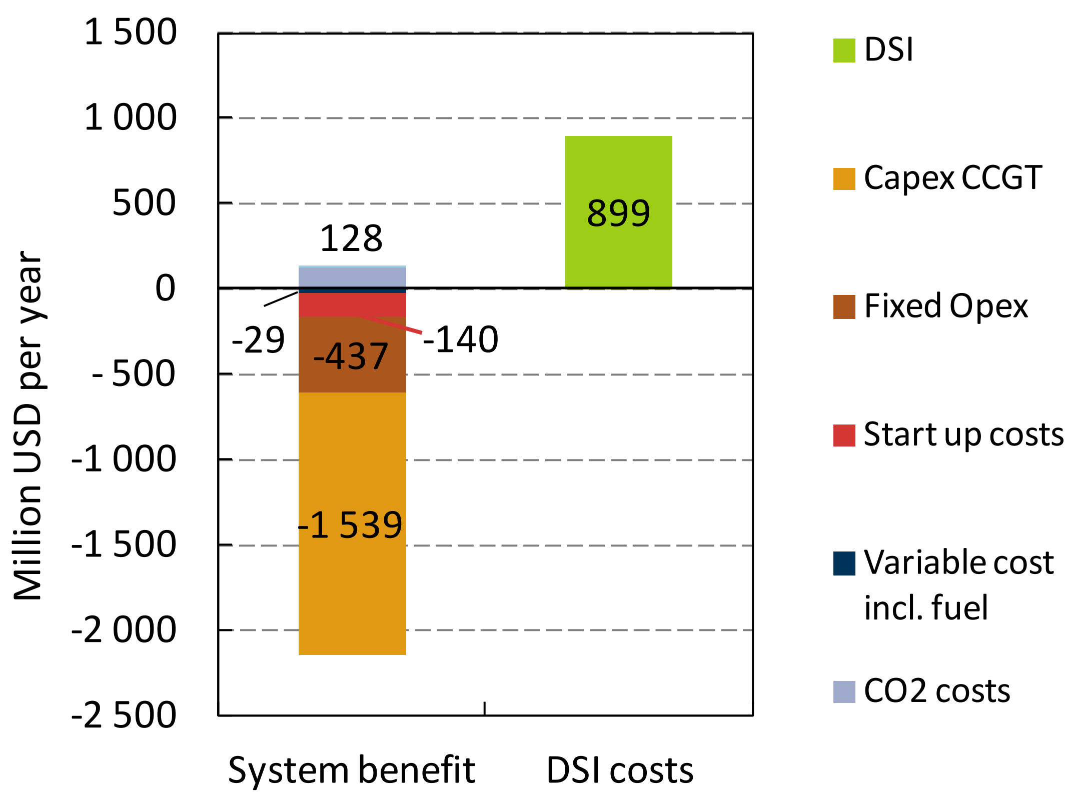
Dispatchable generation

Storage

Demand side integration

Benefit/cost of flexibility options

North West Europe - DSI



DSI assumed to be 8% of annual power demand:

- **71% made of heat and other schedulable demand** (110 TWh)
- **29% EV demand** (44 TWh)

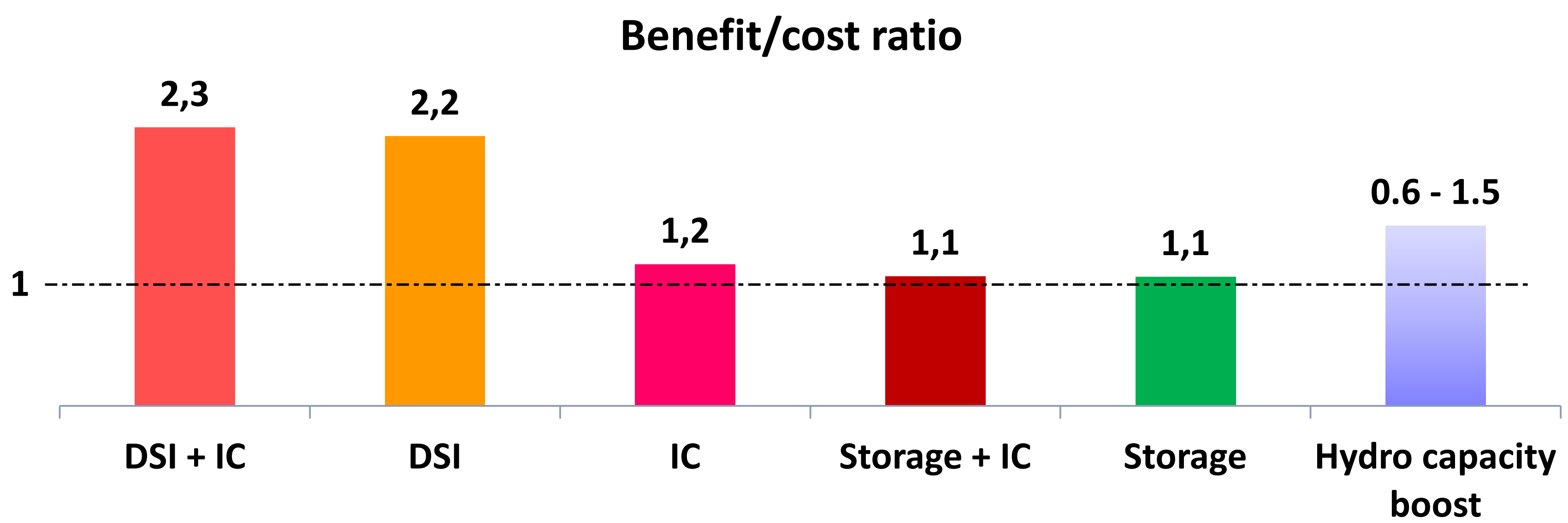
CO_2 price USD 30 per tonne
Coal price USD 2.7/MMbtu
Gas price USD 8/MMbtu

- **Overall system savings of 2.0 bln $/year**
- **DSI costs of 0.9 bln $/year**

Benefit/cost ratio: 2.2

Note: graph represents the differences between DSI scenario (DSI 8% of overall demand) and baseline scenario

Benefit/cost of flexibility options
North West Europe



- **DSI has large benefits at comparably low costs**
- **Interconnection allows a more efficient use of distributed flexibility options and generates synergies with storage and DSI**
- **Cost effectiveness of hydro plant retrofit depend on project specific measures and associated investment needs**

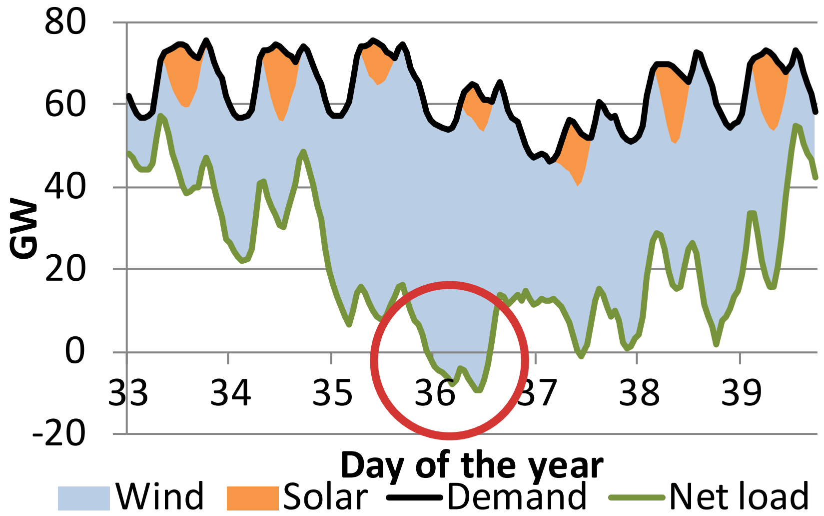
Notes:
1) CAPEX assumed for selected flexibility options: interconnection 1,300$/MW/km onshore and 2,600$/MW/km offshore, pumped hydro storage 1,170$/kW, reservoir hydro 750 $/kW -1,300$/kW (repowering of existing reservoir hydro increasing available capacity). Cost of DSI is assumed equal to 4.7 $/MWh of overall power demand (adjustment of NEWSIS results)
2) Fuel prices and CAPEX ($/kW) for VRE and flexibility options are assumed constant across all scenarios

Source: IEA/PÖYRY

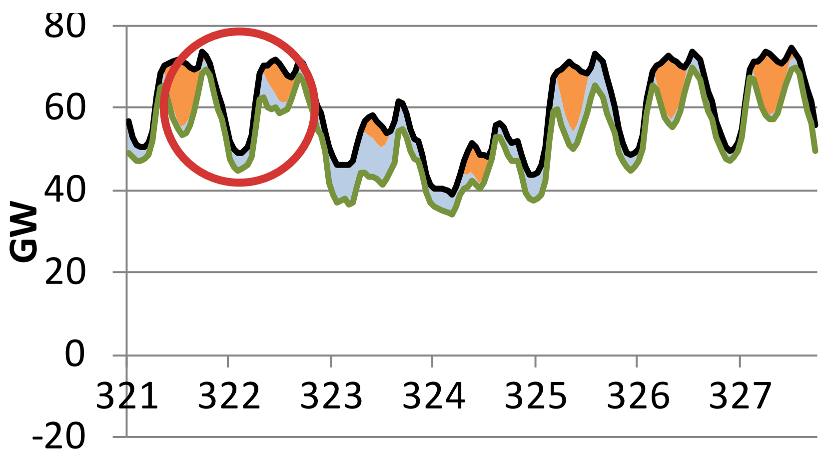
Investments in system flexibility – Need for a suite of solutions

- No single resource does it all!
- Example:
  - Abundance
    - Flexible generation ✗ ✗
    - DSI ✓
    - Storage ✓
    - Curtailment ✓
  - Scarcity
    - Flexible generation ✓ ✓
    - DSI o
    - Storage ✓
    - Curtailment ✗ ✗

Solar and wind can be abundant …



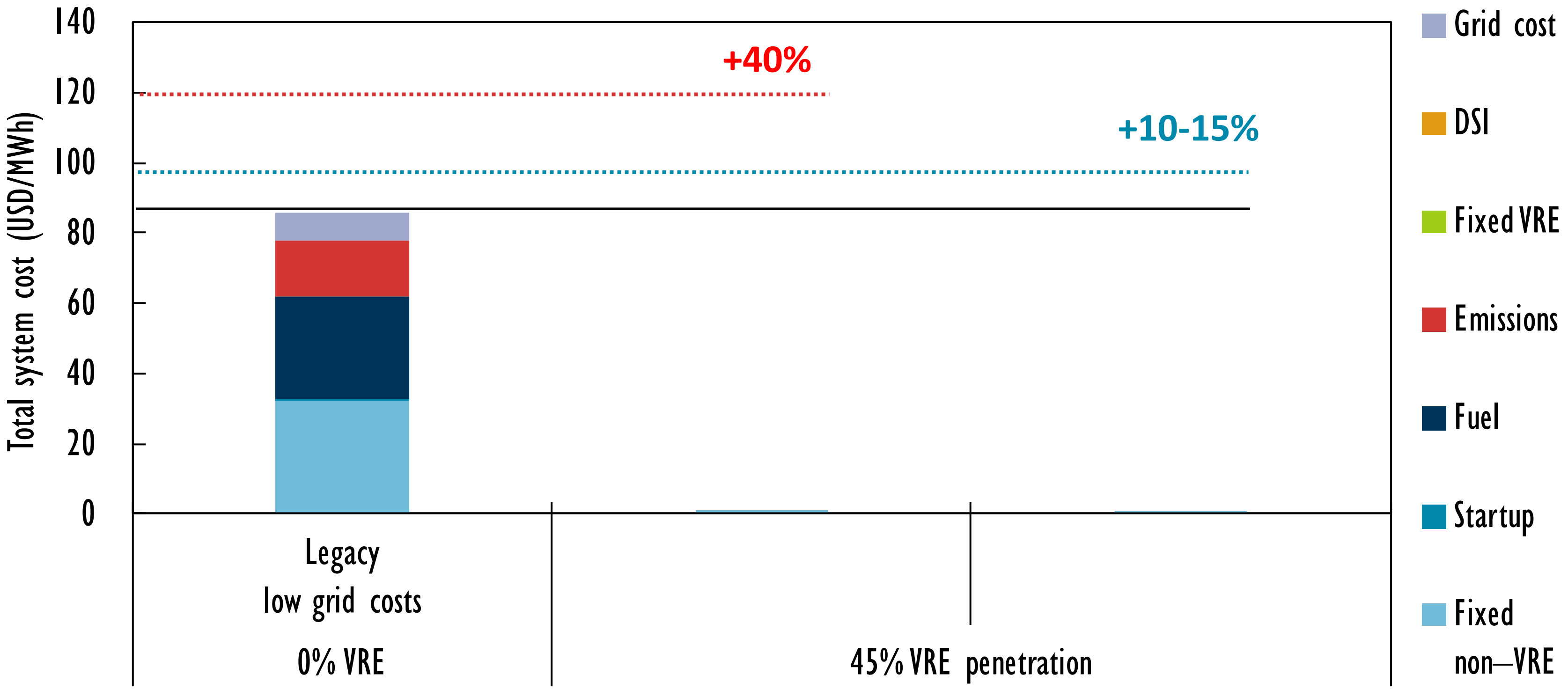
… or scarce.



✓ ✓ : very suitable, ✓ :suitable, o : neutral, ✗ ✗ : unsuitable

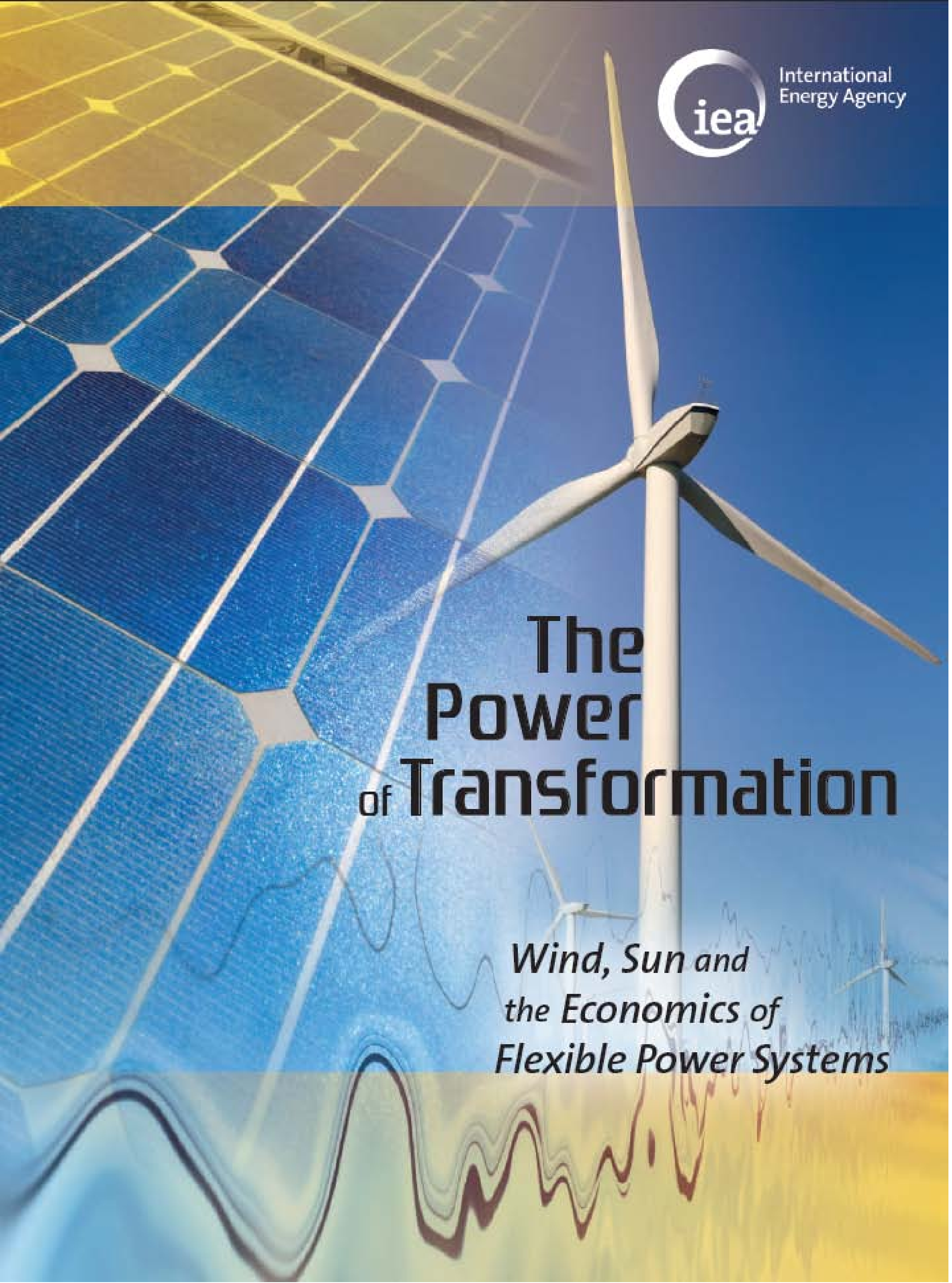
Data: Germany 2011, 3x actual wind and solar PV capacity

Cost-effective integration means transformation of power system



Test System / IMRES Model

- **Large shares of VRE can be integrated cost-effectively**
- **But adding VRE rapidly without adapting the system is bound to increase costs**



- **simon.mueller@iea.org**