# Flexible Power Systems to Integrate Large Shares of Renewables

## The Value of Interconnections

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**IEA-SGCC Dialogue on Global Energy Interconnection**

**“Global Energy Interconnection- Smart Grids and Beyond” 21-22 July 2015, Beijing, China**

# Interaction is key

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

yrs

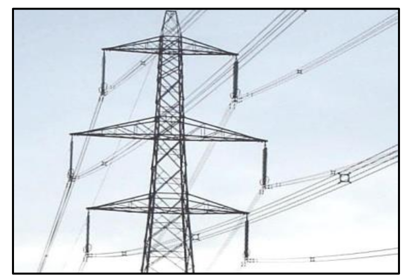
sec

100s km

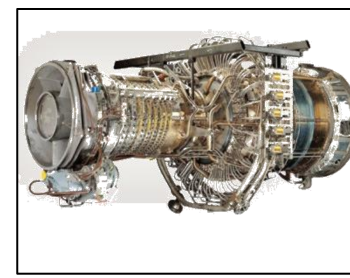
1 km

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

Grids



Generation



Storage

Demand Side

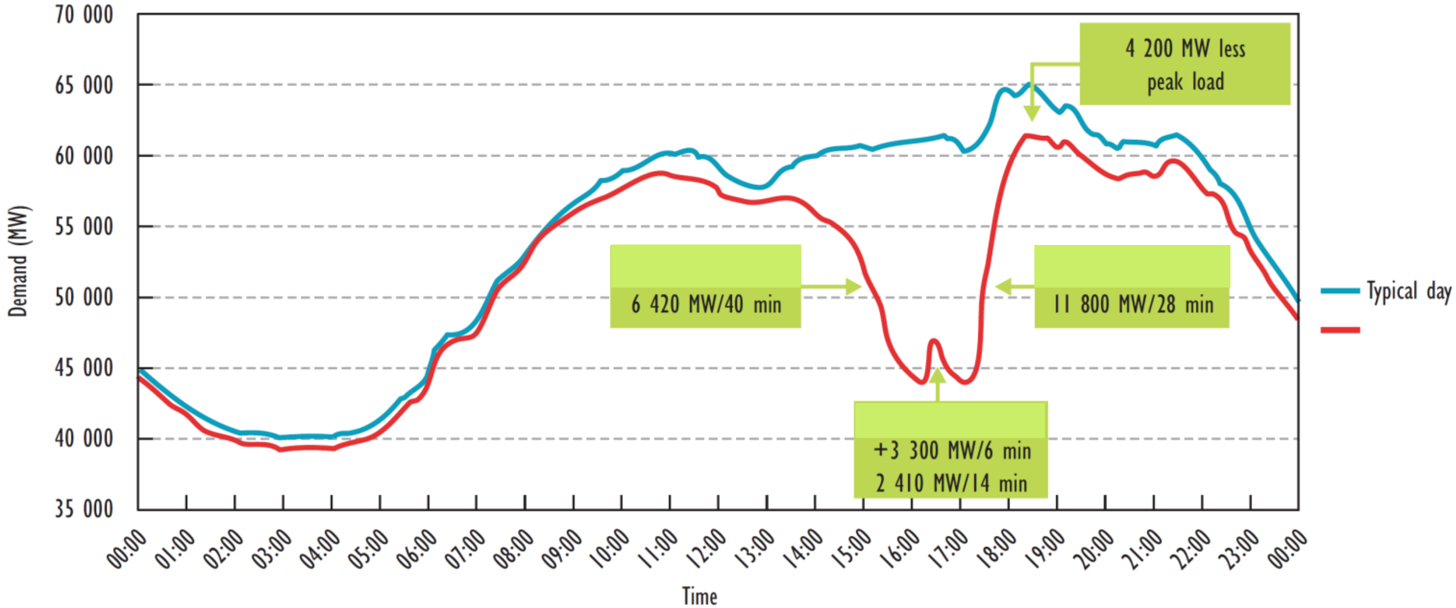


# No problem at 5% - 10%, if …

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

*Exceptionally high variability in Brazil, 28 June 2010*



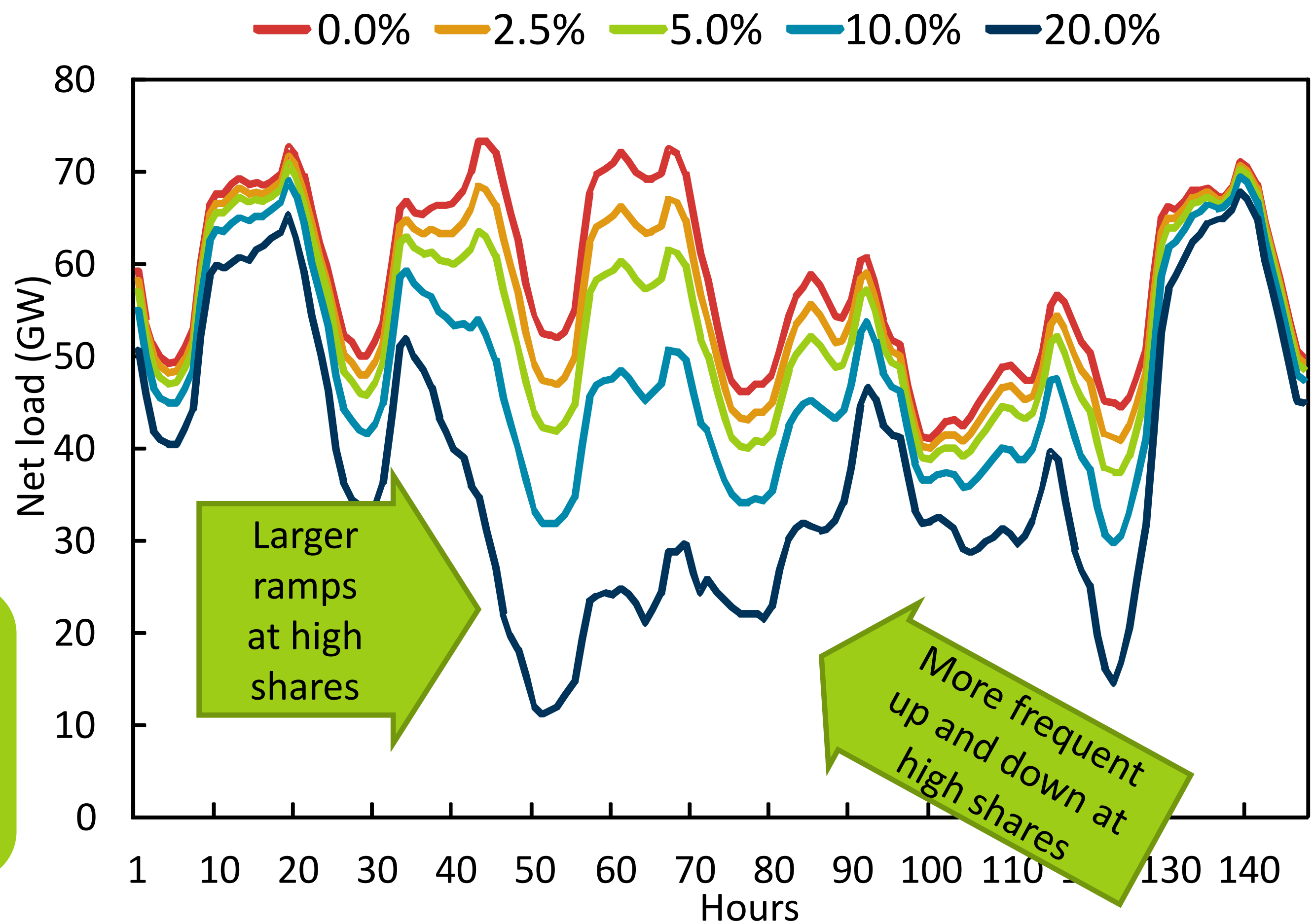

- **No technical or economic challenges at low shares, <u>if</u> basic rules are followed:**
  - **Avoid uncontrolled, local ‘hot spots’ of deployment**
  - **Adapt basic operation strategies, such as using forecasts/predictions of VRE generation**
  - **Ensure that VRE power plants are state-of-the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

# Main persistent challenge: Balancing

- **Higher uncertainty**
- **Larger and more pronounced changes**

**Net load = power demand minus VRE output**

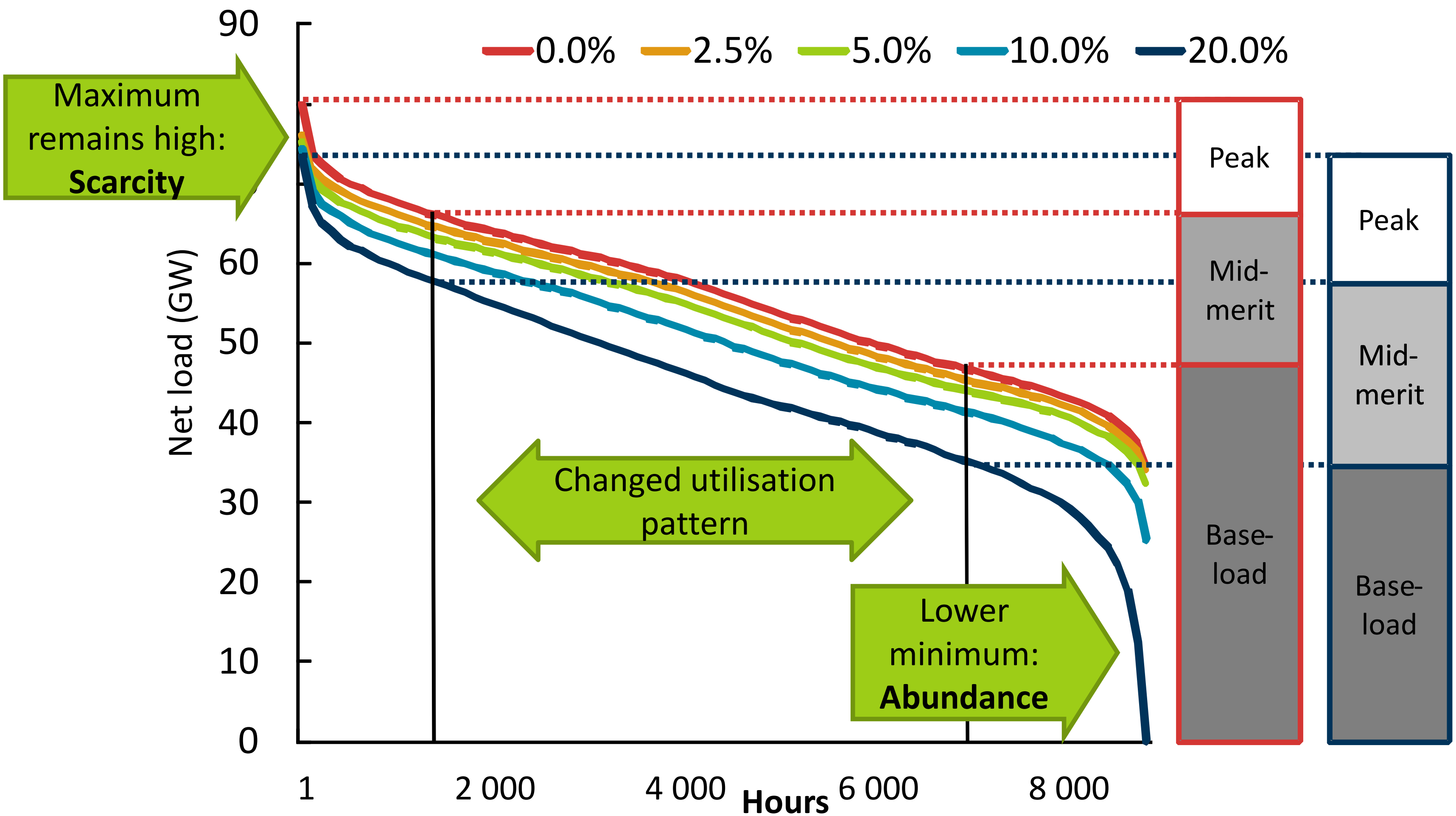
*Illustration of net load at different VRE shares*




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.

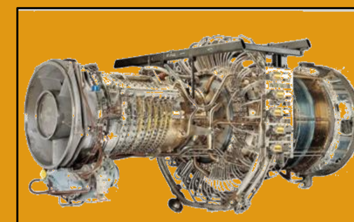
# Three pillars of system transformation

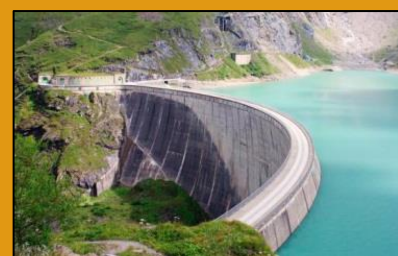
Technology spread

Geographic spread

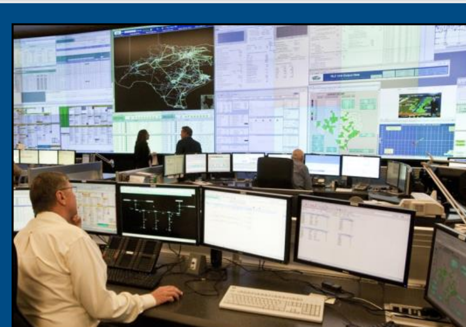
Design of power plants

*System friendly VRE*





***Investments***



***Operations***



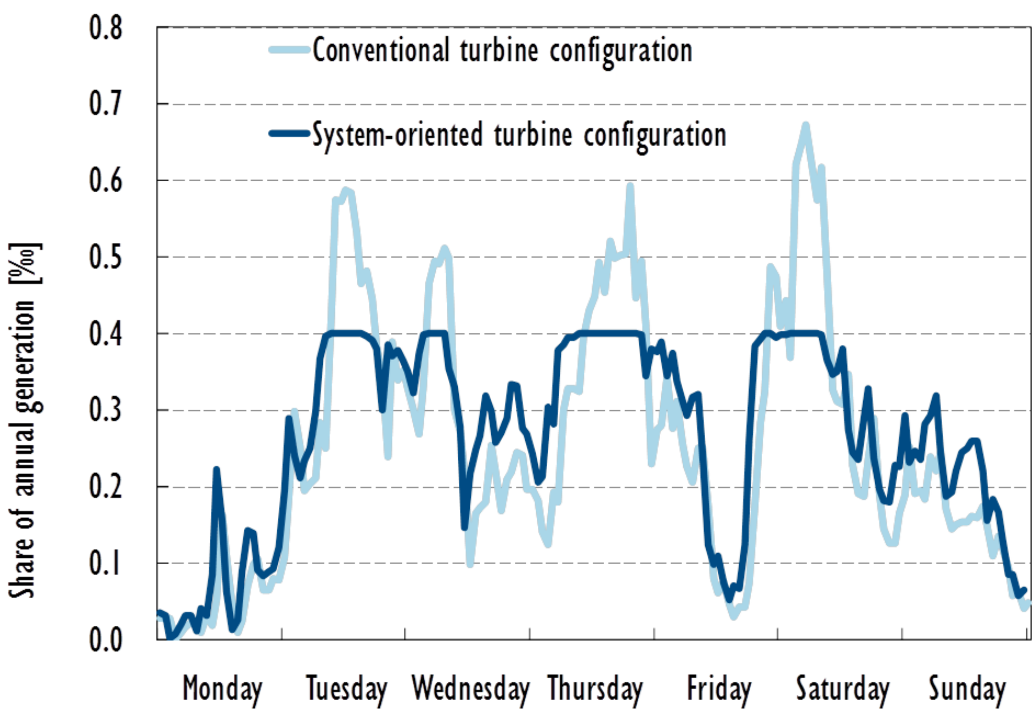
 

# 1) System friendly VRE deployment

- **Wind and solar PV can contribute to grid integration**
- **But only if they are allowed and asked to do so!**

**→ Take a system perspective when deploying VRE**

***Example: System friendly design of wind turbines reduces variability***

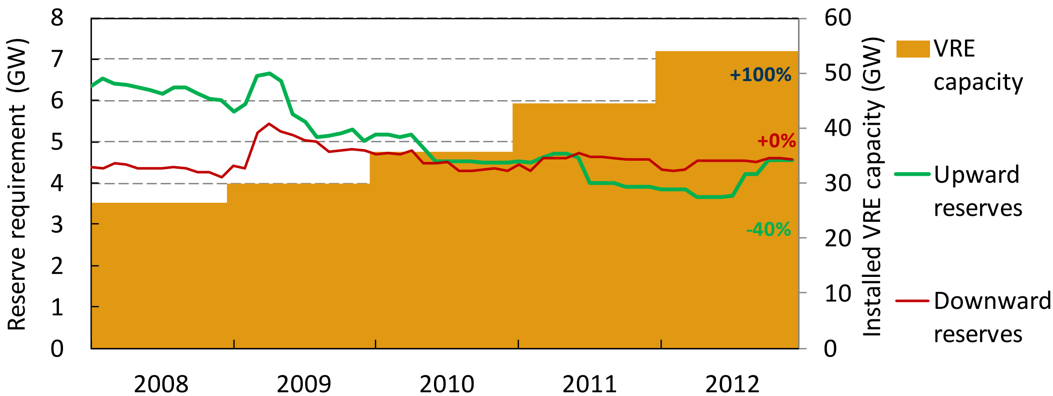



Source: adapted from Agora, 2013

# 2) Better system operation

- VRE forecasting
- Better system operations:
  - Dynamic system scheduling
    *Update schedules close to real time*
  - Dynamic system dispatch
    *Short dispatch intervals*
  - Dynamic use of the grid
    *Update interconnection schedules close to real time; sub-hourly scheduling*
  - Reward flexible operation
    *Make payments based on what is helpful for the system, not just MWh*

*Required frequency restoration reserves in Germany*




- Germany has four balancing areas (historic reasons)
- Reserve sharing mechanism across four areas
- Reduced requirements despite rapid increase of VRE

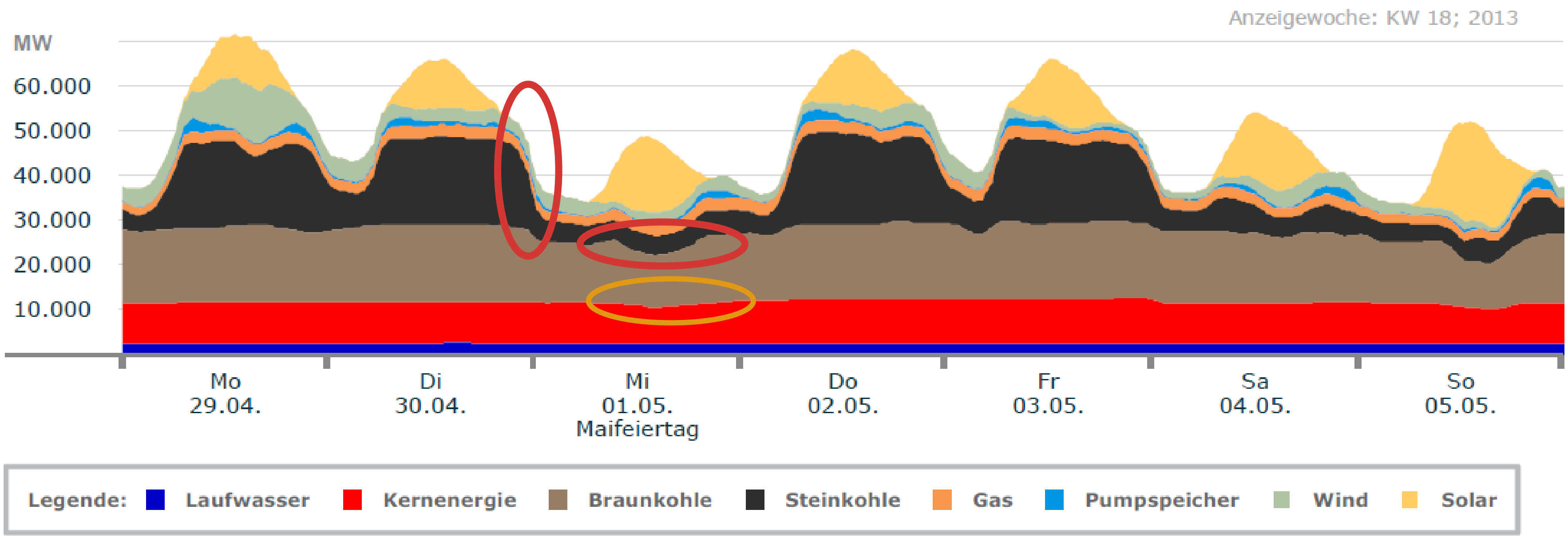
→ **Make better use of what you have already!**



# Flexibility: ask for it.... and it appears

*A sunny 1st May 2013 in Germany – actual production*




Source: Fraunhofer ISE

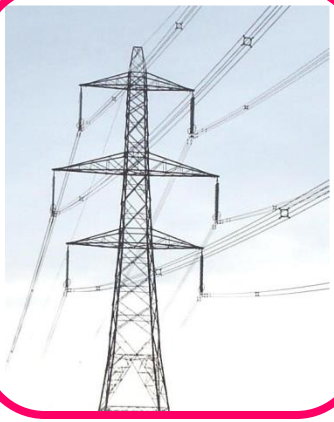
- **German hard coal plants carry most of ramping duty in Germany**
  - **Lignite and nuclear ramp as well, even nuclear at some times**
- **Ramping costs can be minimised at low cost; retrofits are possible e.g. Flexible Coal: Evolution from Baseload to Peaking Plant (NREL, 2013)**

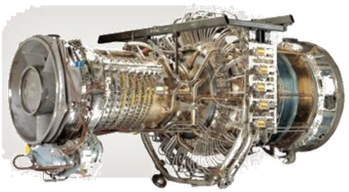


# 3) Investment in additional flexibility

## Four sources of flexibility …





**Grid infrastructure**

**Dispatchable generation**

**Storage**

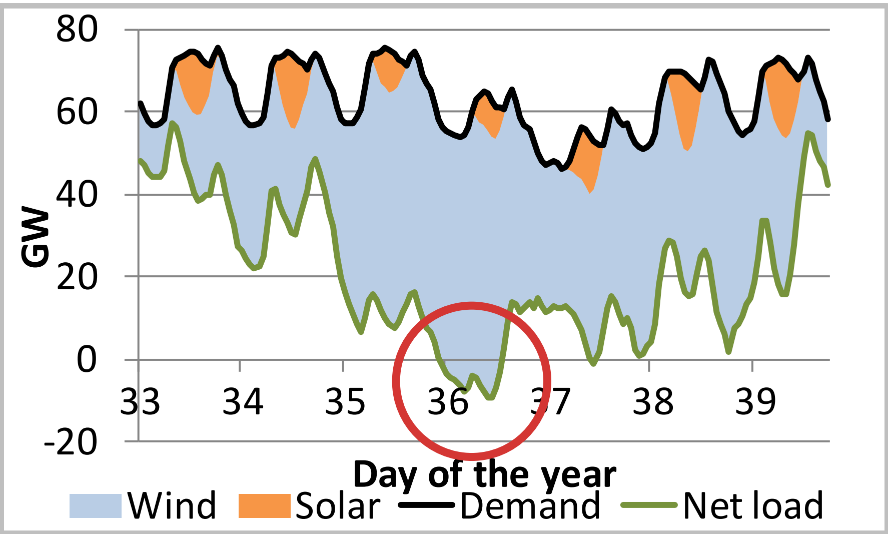
**Demand side integration**



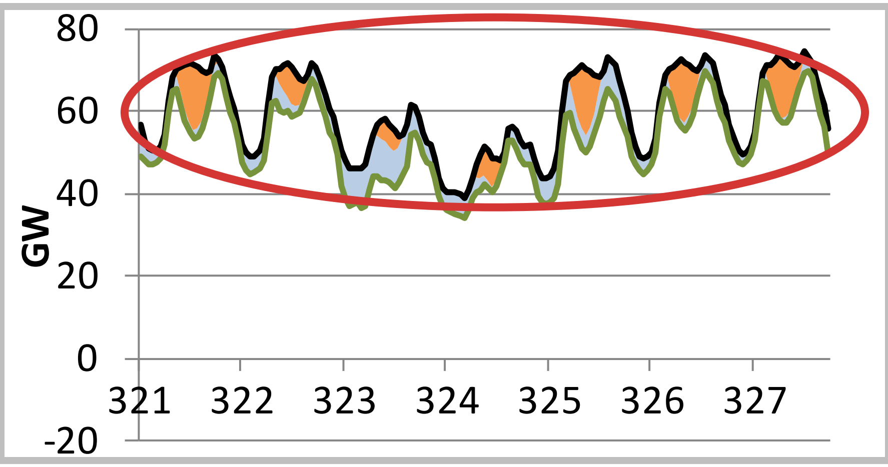
 

# Investments in system flexibility – Need for a mix of solutions

- Abundance
  - Flexible generation ✗ ✗
  - DSI ✓
  - Storage ✓
  - Curtailment ✓




- Multi-day scarcity
  - Flexible generation ✓ ✓
  - DSI o
  - Storage ✓
  - Curtailment ✗ ✗




- <u>**No single resource does it all!**</u>

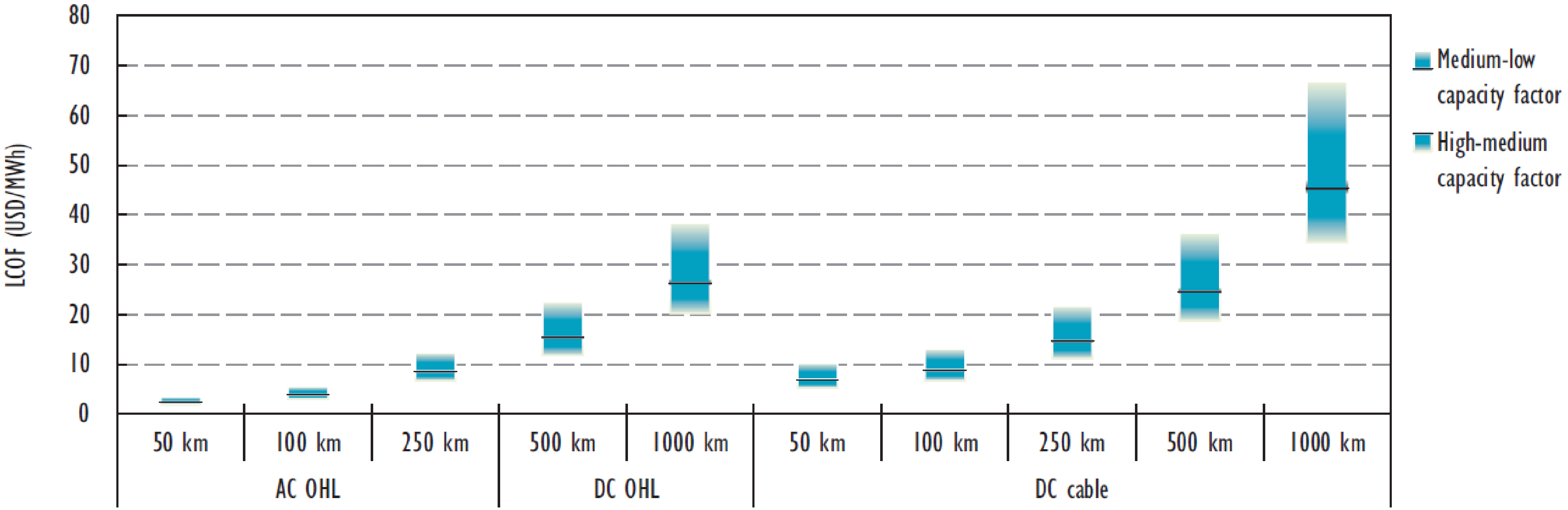
✓ ✓ : very suitable, ✓ :suitable, o : neutral, ✗ ✗ : unsuitable

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

# Flexibility options - Transmission

## *Where do you get inexpensive flexibility?*

- Interconnection can offer low-cost flexibility

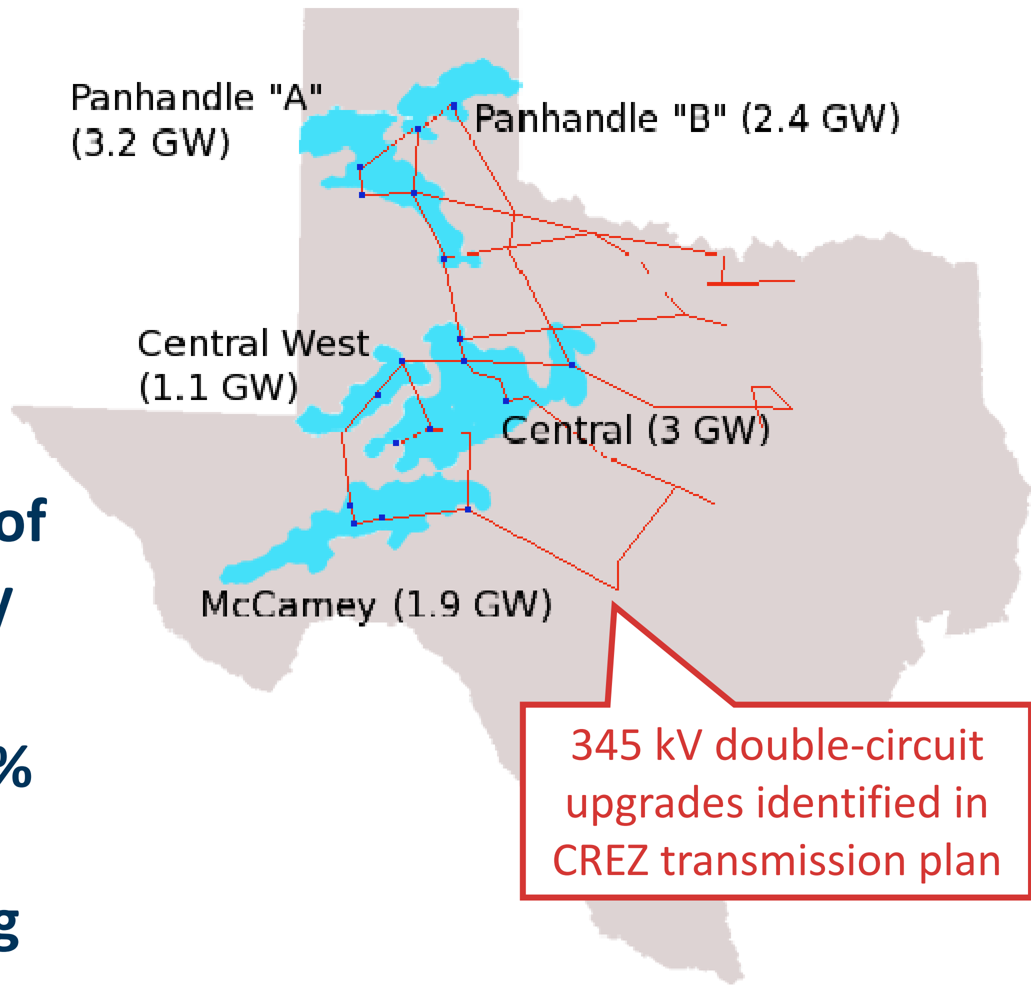



- Grid infrastructure is unique, only flexibility option with a double benefit:
  - Reduces the need for flexibility by smoothing VRE output
  - Increases the portfolio of available flexible resources

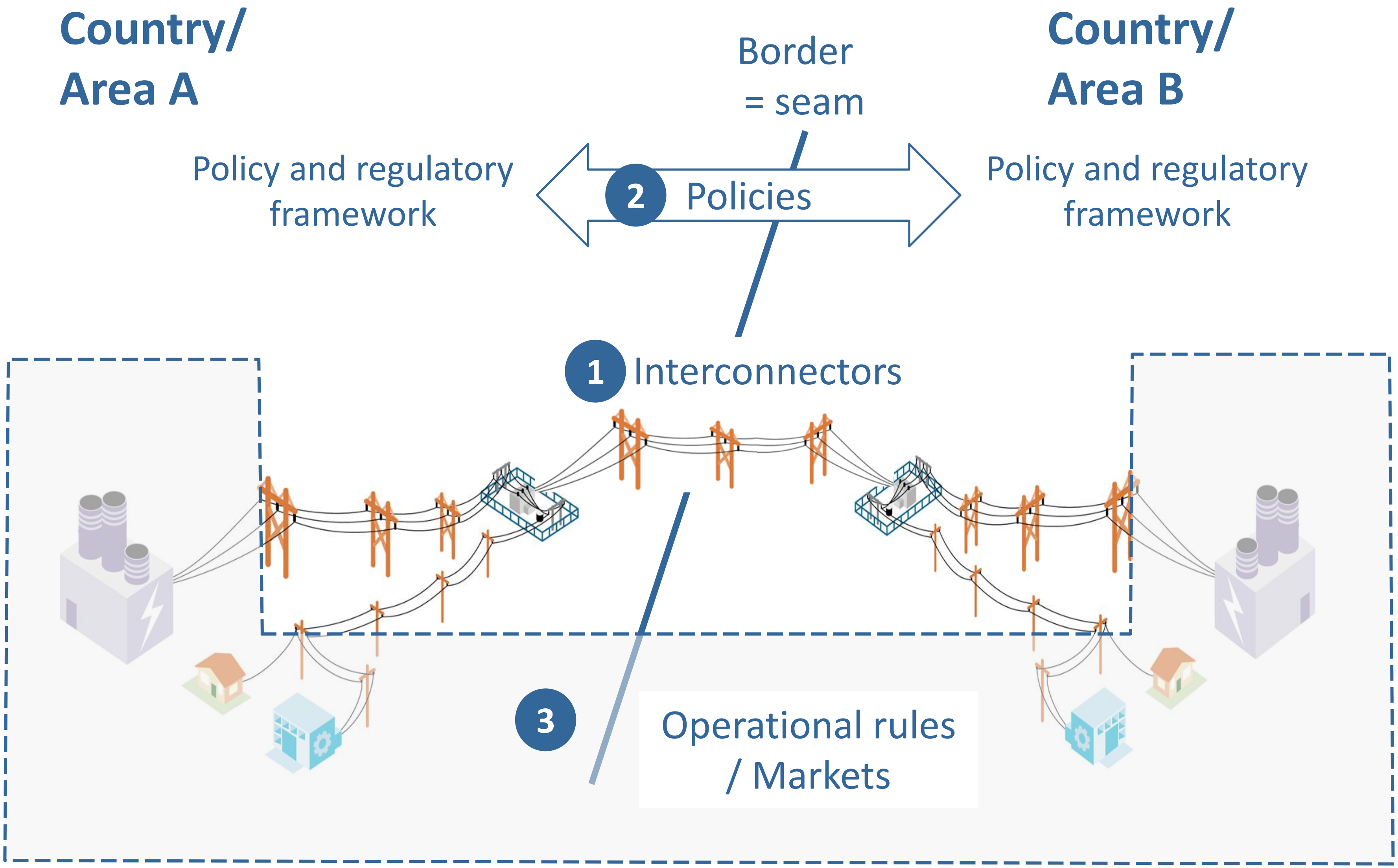
# Transmission – Key for integration

- Competitive Renewable Energy Zones (CREZ), Texas
- Wind plants were built before completing all transmission lines
- Curtailment peaked at 17% of possible annual wind energy output in 2009
- Curtailment reduced to 1.6% in 2013 after implementing upgrade of system operating and expanding the grid

*CREZ, Texas*

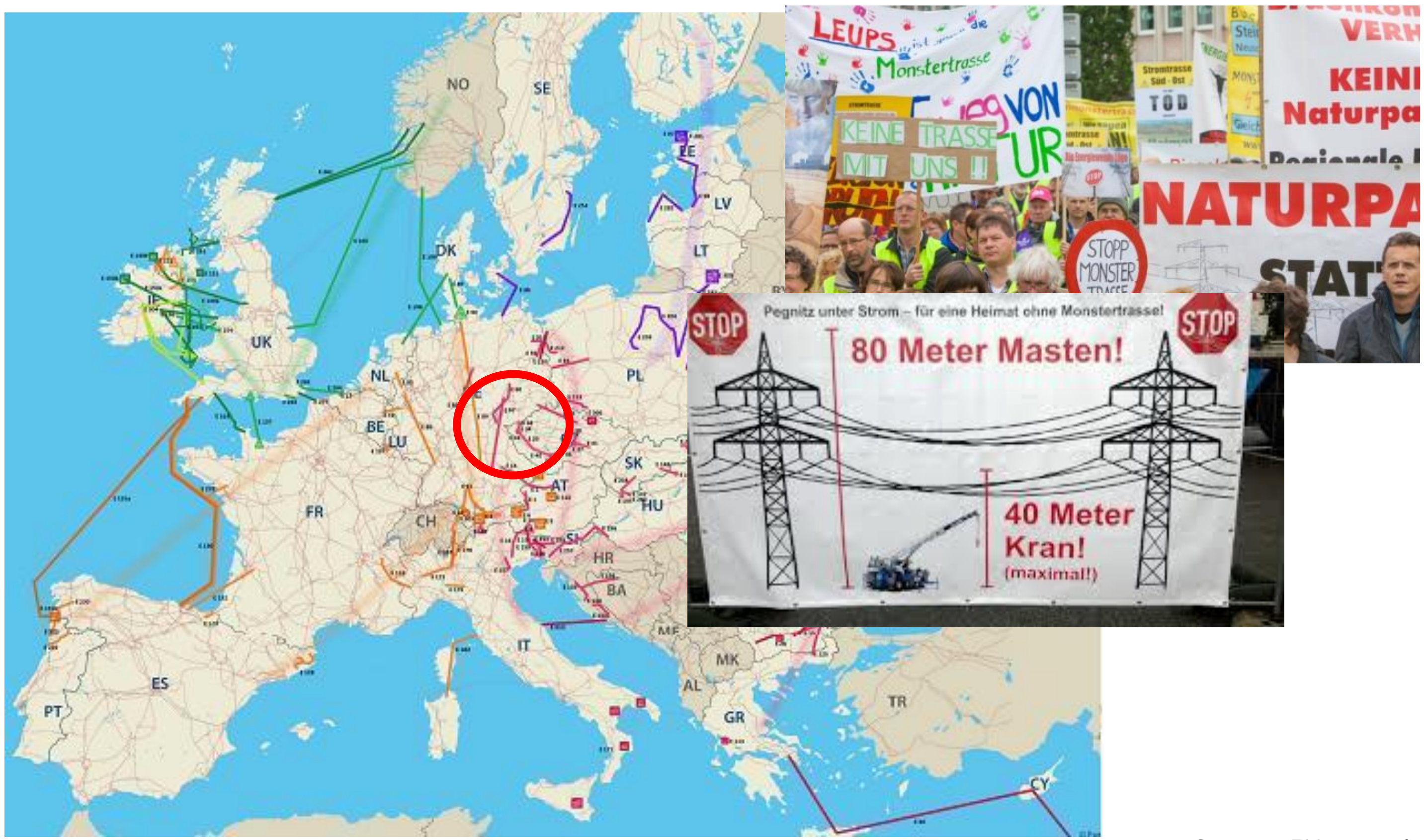



Source: NREL


Country/
Area A
Border
= seam
Country/
Area B
Policy and regulatory framework
2 Policies
Policy and regulatory framework
1 Interconnectors
3
Operational rules
/ Markets

# 1 Interconnectors: developing new lines

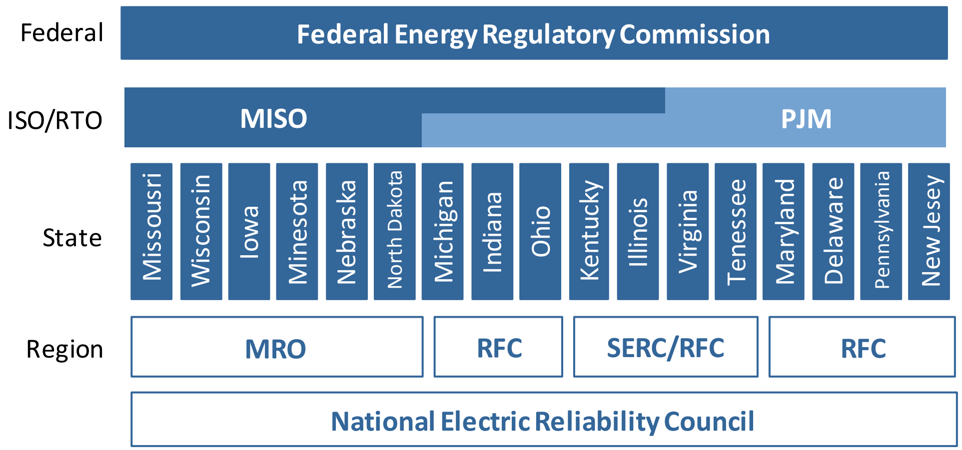
**Transmission Line Candidates to Project of Common Interest (PCI), May 2013**




Source: EU commission

# 2 Policies: regulation of reliability often fragmented

## North America: reliability regulation




## EU: Security of supply directive (2005/89/EC)

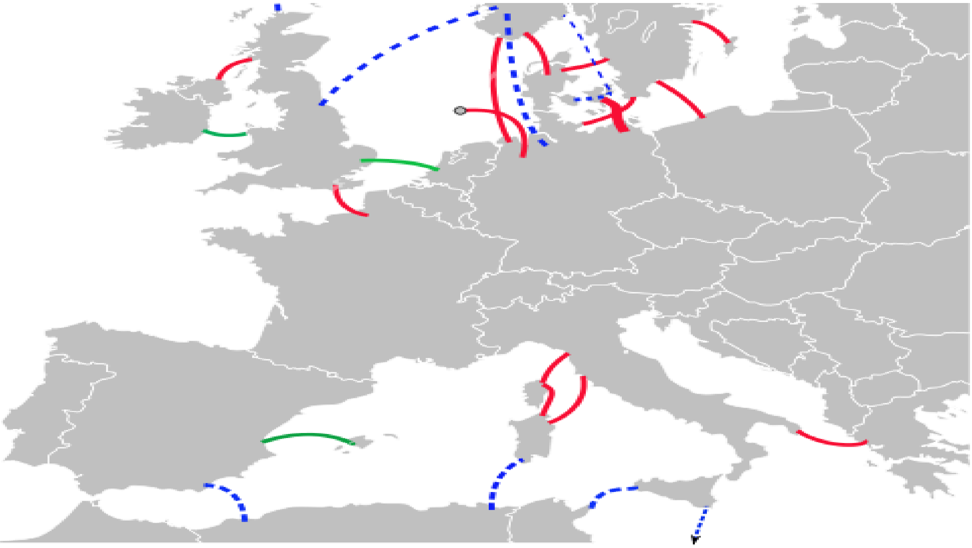
- **Member states are responsible for electricity security**
- *" Member states shall take appropriate measures to maintain a balance between the demand for electricity and the availability of generation capacity"*

# 3 Markets and operations: cross-border management of scarcity and power exchanges

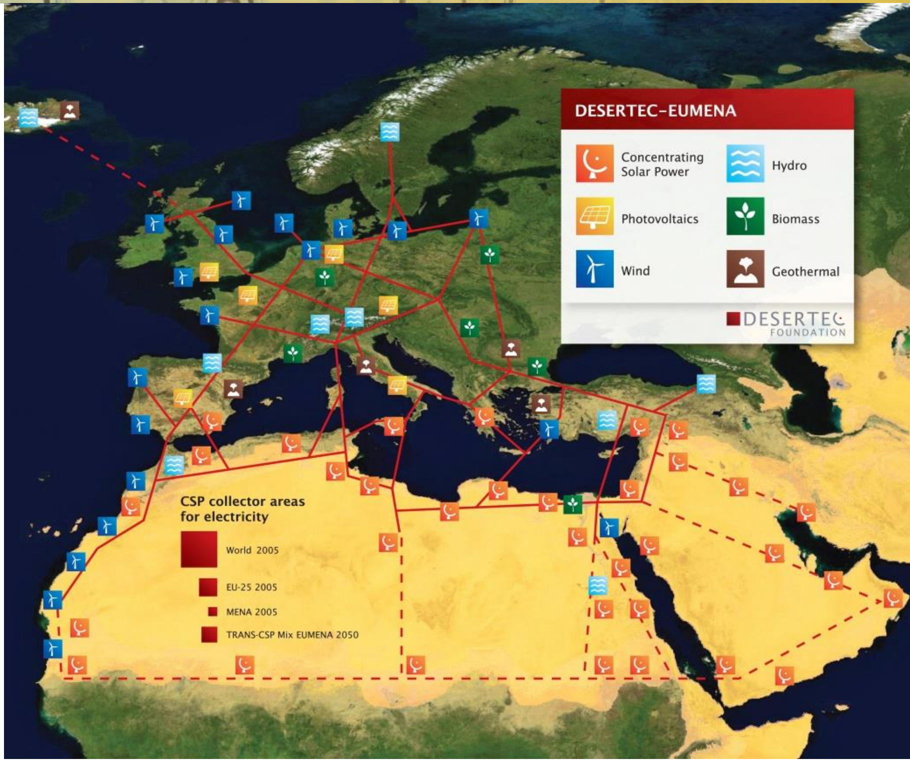
- **Commercial agreements and operational rules**
  - Finding pricing mechanism for electricity exchanges when flows cross borders with very different market design
  - Facilitating dynamic operation of interconnection across different systems
- **Operation under tight system conditions:**
  - Reliability standards
  - Disconnection of interconnectors
  - Prioritization of contracts
  - Load curtailment protocols

# (Inter)Continental interconnections
## *Example: DESERTEC concept*

***HVDC link included in 2010 IEA Concentrating Solar Power roadmap***



Source: IEA CSP roadmap, 2010




Source: Desertec foundation

- **Even if technically feasible and possible win-win:**
  - **Costs possibly very high, asset utilisation important factor**
  - **Technology progress may change the picture (CSP/PV cost)**
  - **Agreement on how to share costs can be a huge challenge**
  - **Motivation for ‘transit’ countries can be very low**

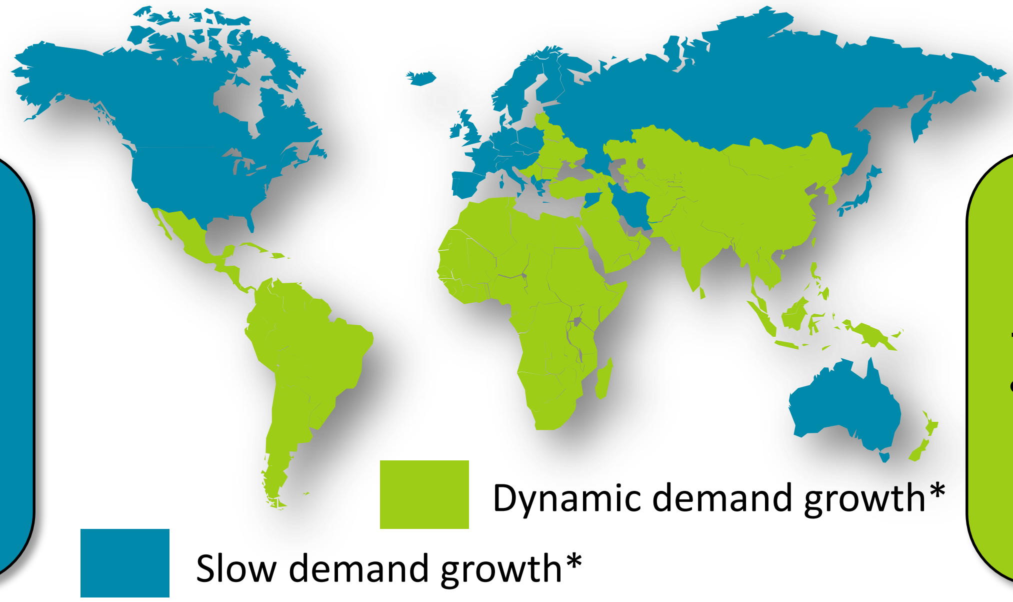
# Integrating wind and solar power
# Conclusions 1/3

- **All countries where VRE is going mainstream should:**
  - Optimise system and market operations
  - Deploy VRE in a system-friendly way to maximise their value to the overall system
- **Countries beginning to deploy VRE power plants (shares of up to 5% to 10% of annual generation) should:**
  - Avoid uncontrolled local concentrations of VRE power plants ("hot spots")
  - Ensure that VRE power plants can contribute to stabilising the grid when needed
  - Use state of the art VRE forecast techniques

# Transformation depends on context
# Conclusions 2/3

## 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**

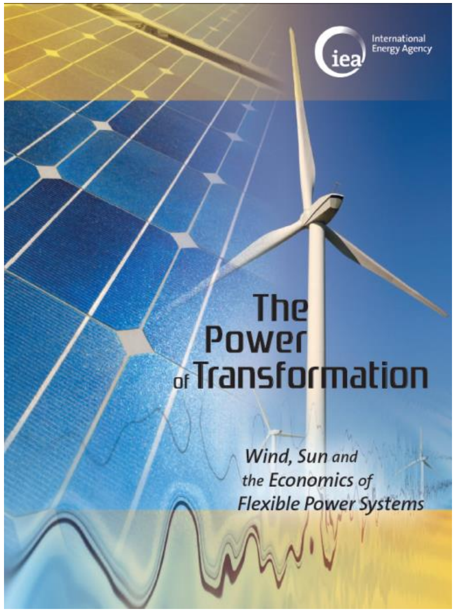
→ **Use proper long-term planning instruments to capture VRE's contribution at system level**

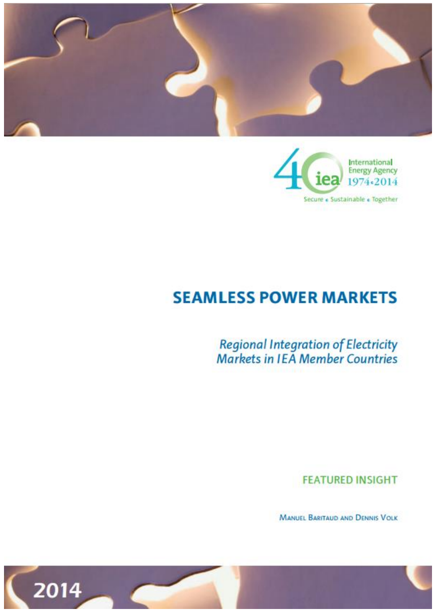
* Compound annual average growth rate 2012-20 , slow <2%, dynamic ≥2%; region average used where country data unavailable

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.

# (Inter)Continental Interconnection Conclusions 3/3

- Large scale transmission links part of the solution for today's and tomorrow's power systems
- Unique value of grid infrastructure
  - Reduces need for flexibility
  - Increases availability of distant flexible resources
- (Inter)continental projects often face large challenges:
  - Building the 'hardware' is not enough, harmonisation of 'software' can be challenging
  - Technology progress may change project economics: Future cost of storage? True potential of demand side?
  - Cost-sharing between countries can be very difficult
  - Will countries rely on each other for security of electricity supply

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