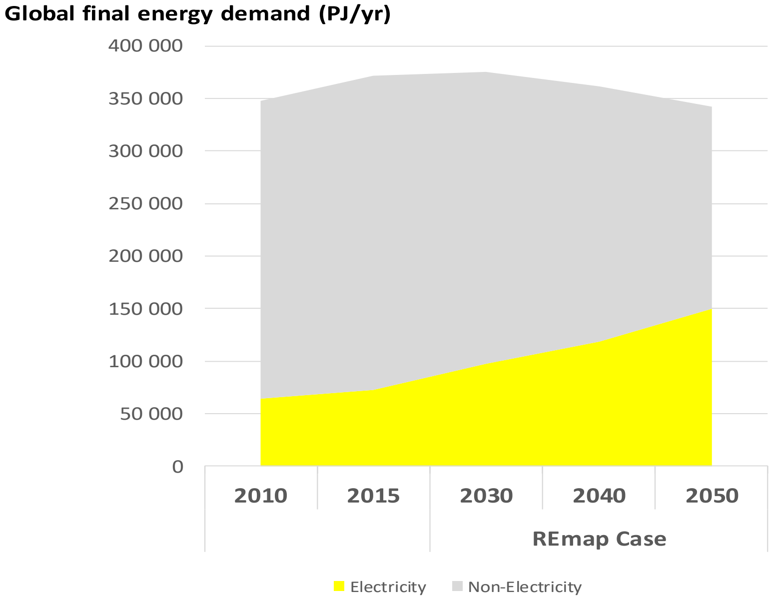
Power Sector Flexibility

Power Sector Transformation Strategies

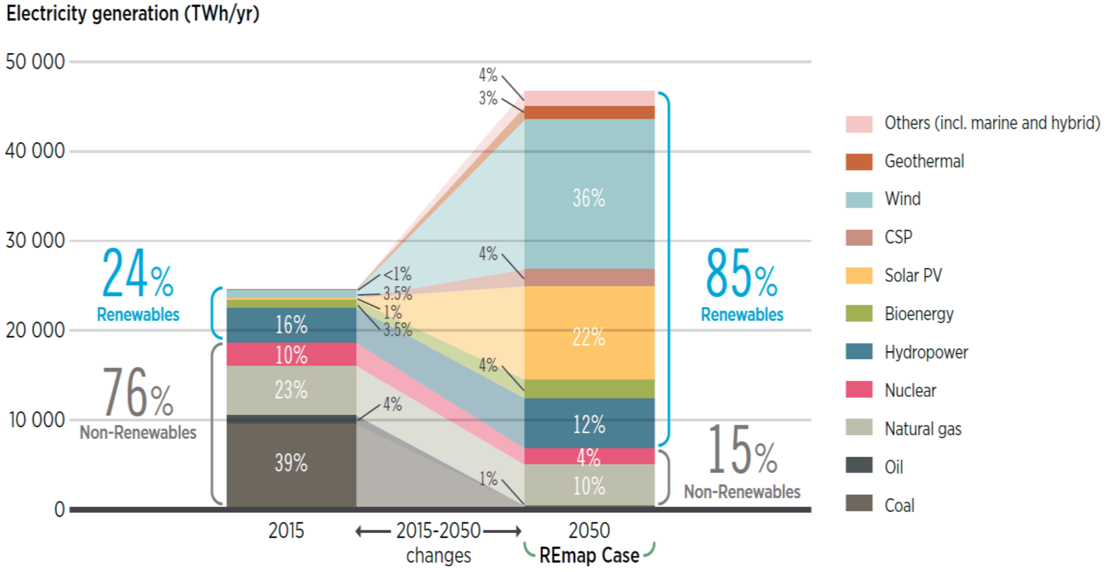
Electrification through sector coupling and dominance of VRE in the future electricity mix are key for the energy transition

REmap Case, 2015-2050

Share of electricity in total final energy consumption



Share of electricity in total final energy consumption

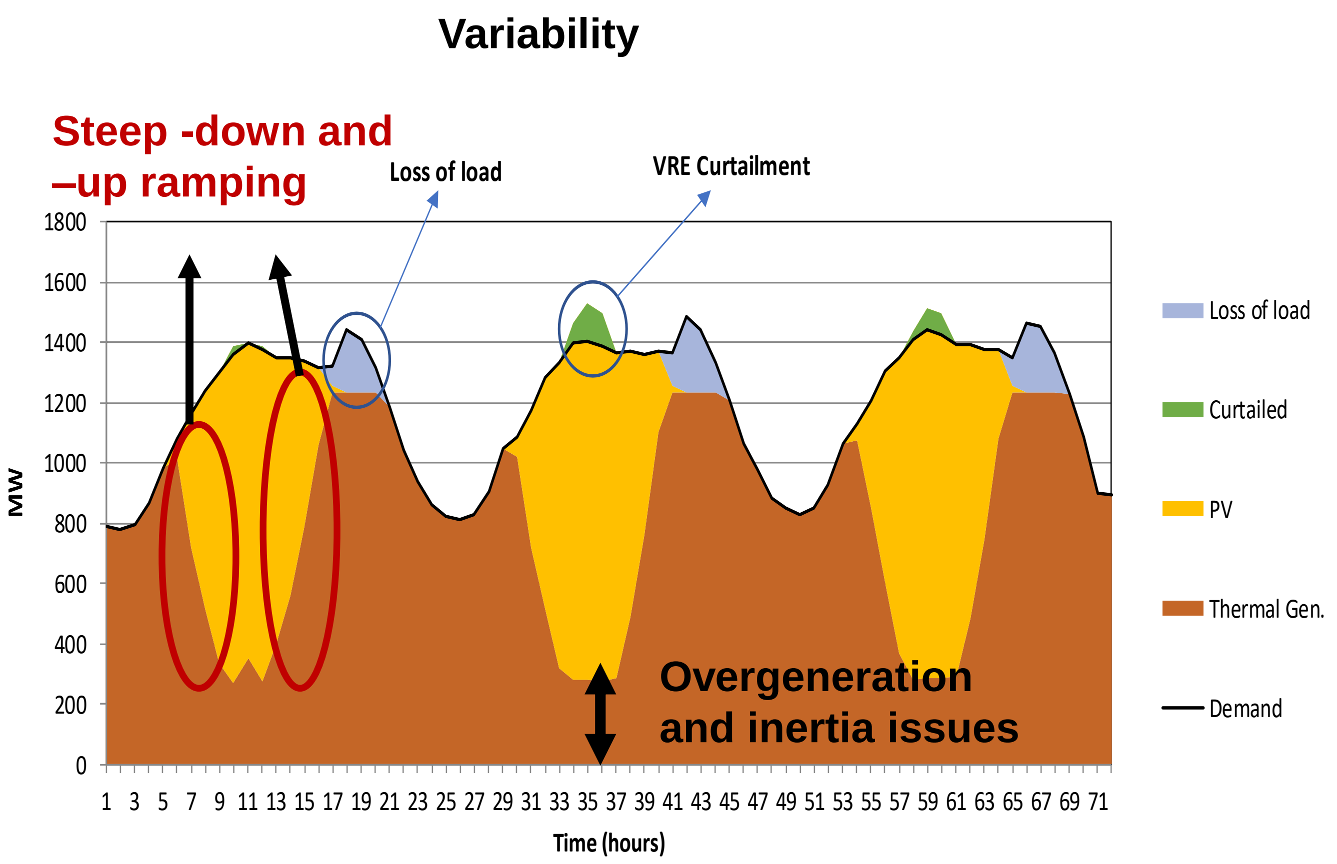


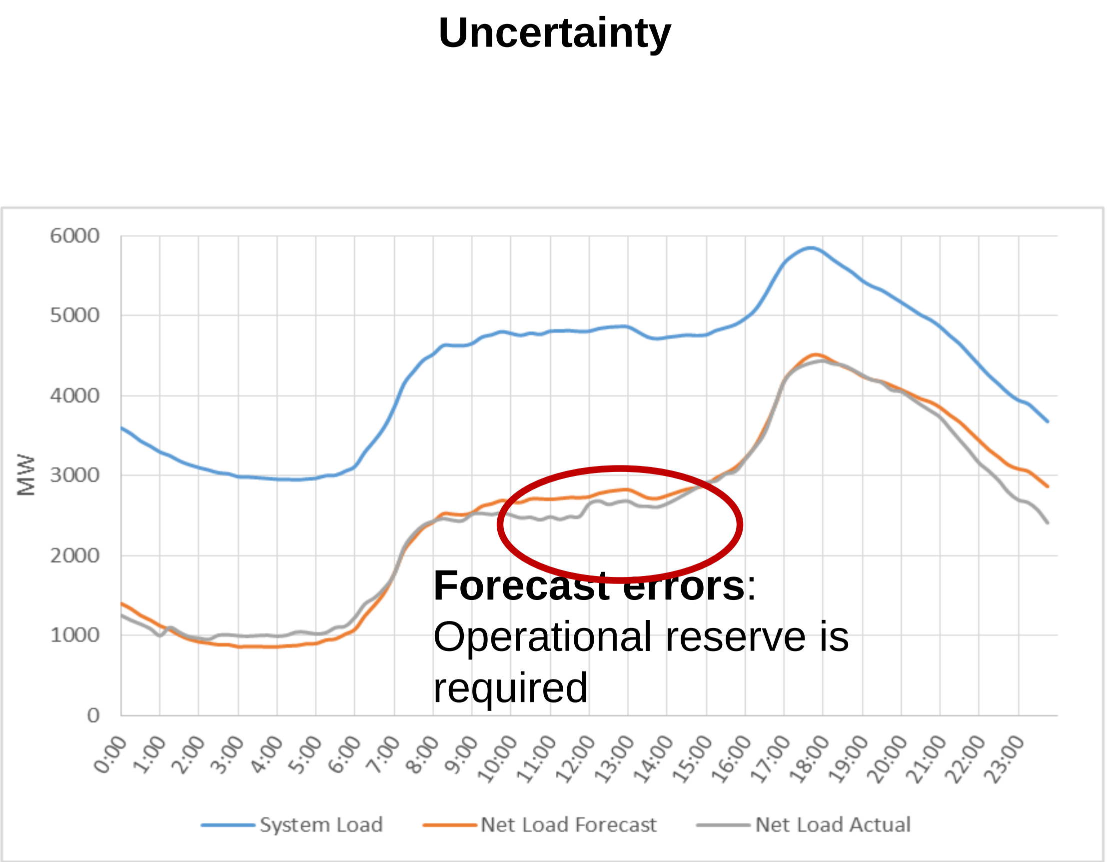
Source: **Global Energy Transformation: A Roadmap to 2050, IRENA**, 2018

- REmap analysis suggests the share of electricity in global final energy demand could nearly triple by 2050 through sector coupling
- Variable renewables like solar and wind power will supply up to 60% of total electricity generation
  - This practically means many countries will have VRE shares more than 60% into their power mix
  - System flexibility issues might arise

Impacts of Variability and Uncertainty into Power Systems Operations

IRENA
International Renewable Energy Agency

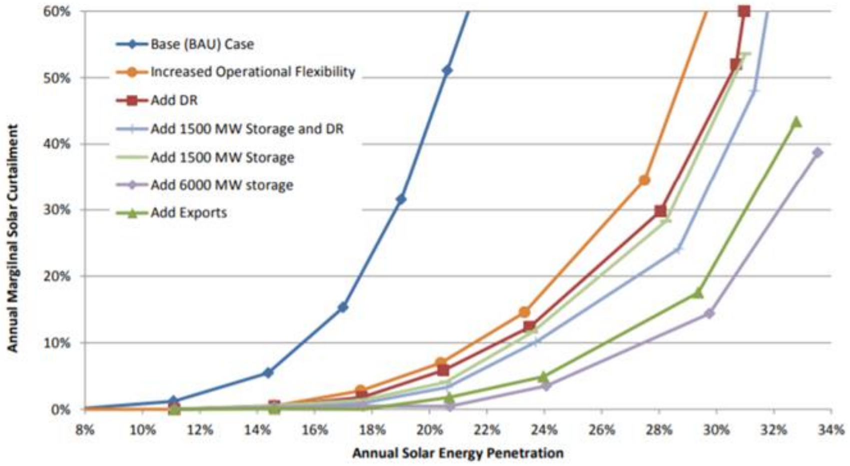




- Operational impacts of VRE
  - Variability: Increased ramp-rates, increased ramping-range, overgeneration
  - Uncertainty: Increased need for operational reserves
  - Indicators of lack of flexibility: VRE curtailment, loss of load, fluctuating/negative electricity prices

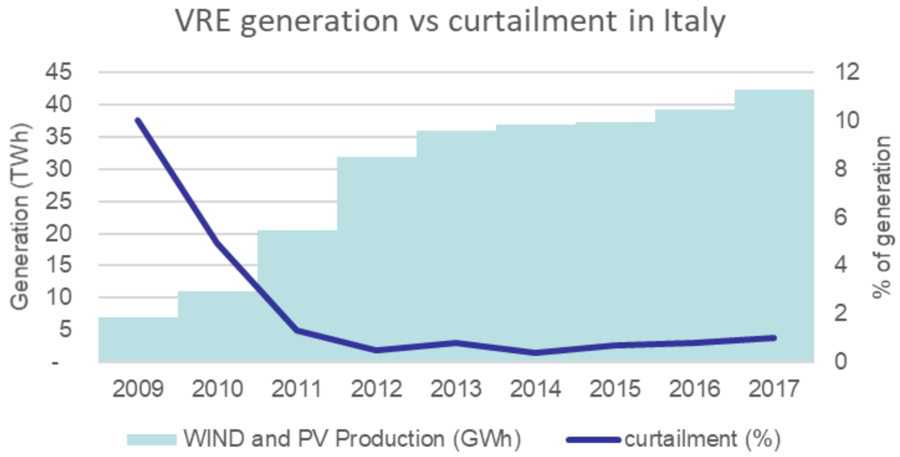
Practical experience has shown it is possible to achieve high share of VRE in a cost effective way

- Denmark and Ireland are frontrunners of wind integration
  - shares of 44% and 27% respectively
  - Synchronous interconnections key for flexibility (NSPS of 65% in Ireland vs instantaneous penetration of 150% in Denmark)
  - Start by unlocking flexibility: Denmark co-optimizes hydro and thermal generation; Creation of intra-day markets and implementation of advanced forecasting; flexible operation of CHPs



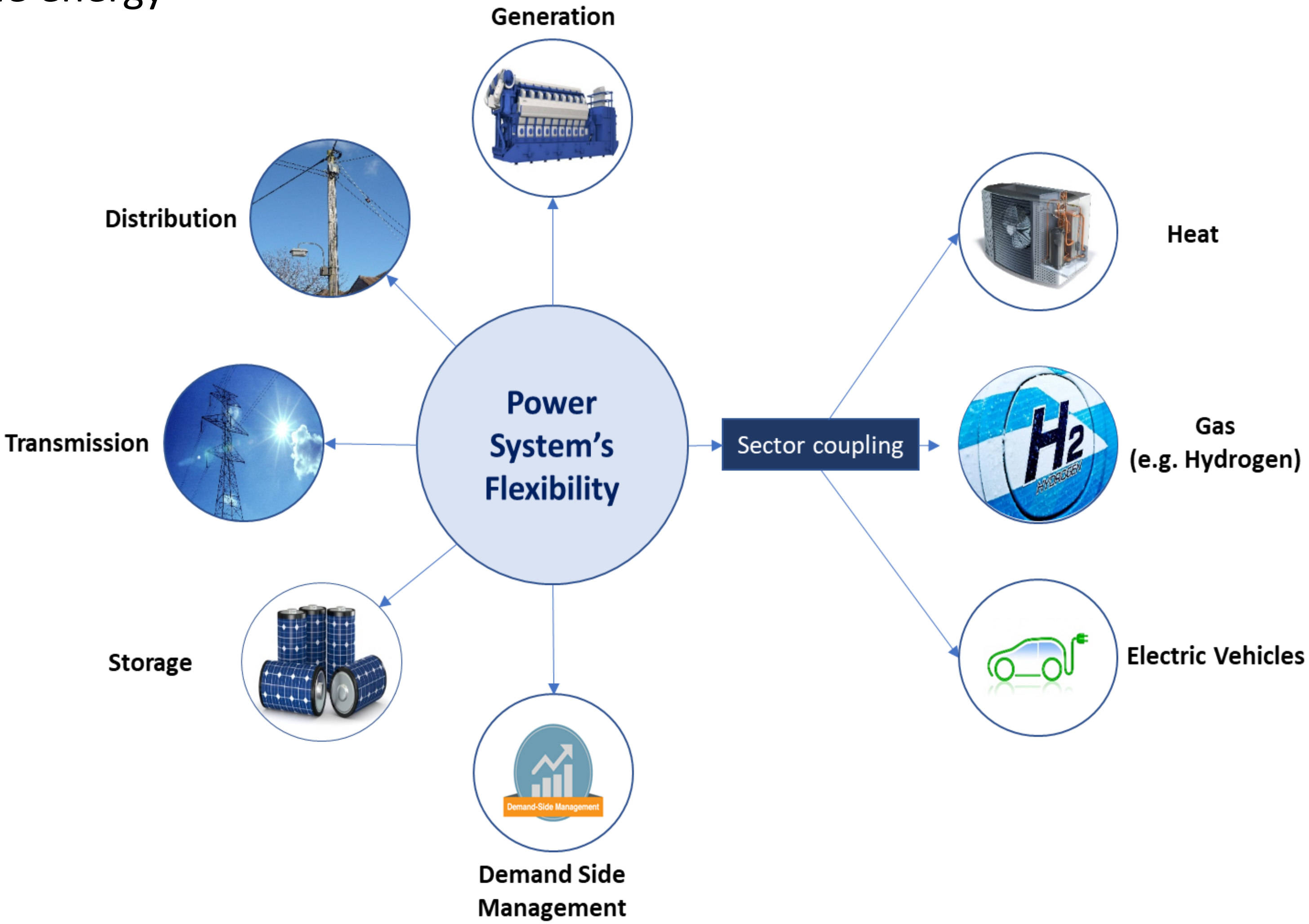
Source: Denholm, Clark, and O'Connell (2016)

- Global lessons learned
  - Plan for flexibility early: Much higher levels of VRE can be integrated in flexible systems (China vs Denmark)
  - Many times cheaper solutions are the most efficient ones-
  - Implement grid codes
  - Weak grid can be an inhibitor
  - Storage is key flexibility attribute (Norway sharing hydro flexibility with other Nordic countries)



Sector coupling is key to transform our energy system towards one dominated by renewable energy

» Flexibility needs to be harnessed in all sectors of the energy system
» Main flexibility sources
  » Generation
    » Hydro, gas
  » Grid
    » Variable rating lines, T&D enhancement
    » Smart Grids
  » Storage
    » Pumped Hydro
    » Batteries
    » V2G
  » Demand
    » Conventional: DSM, aggregation
    » Sector coupling: Heat pumps, boilers, H2
  » Market/Institutional
    » Unlock flexibility/remove barriers
    » Regulation needs to support flexibility

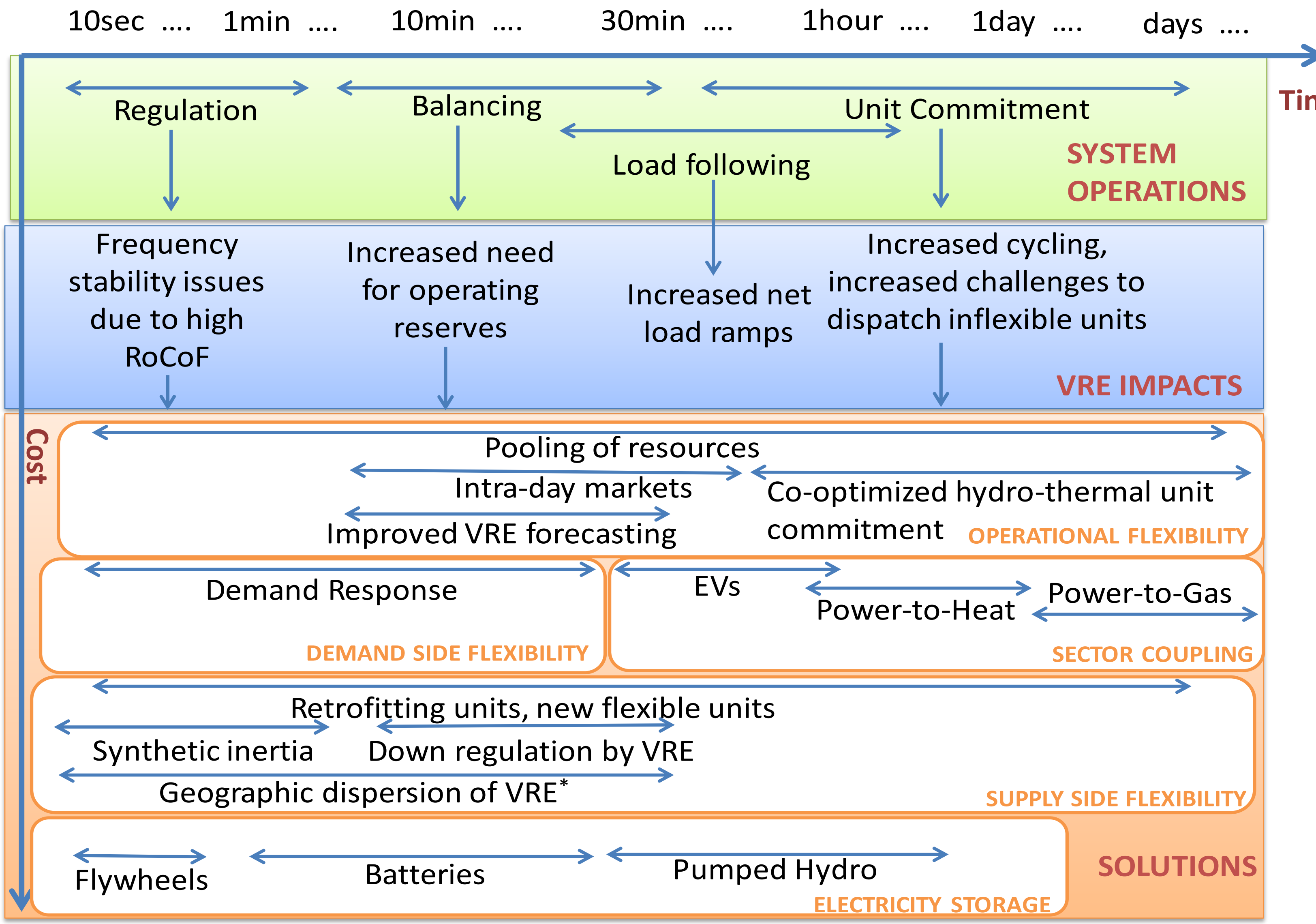


Source: **Power System Flexibility for the Energy Transition, IRENA**, 2018

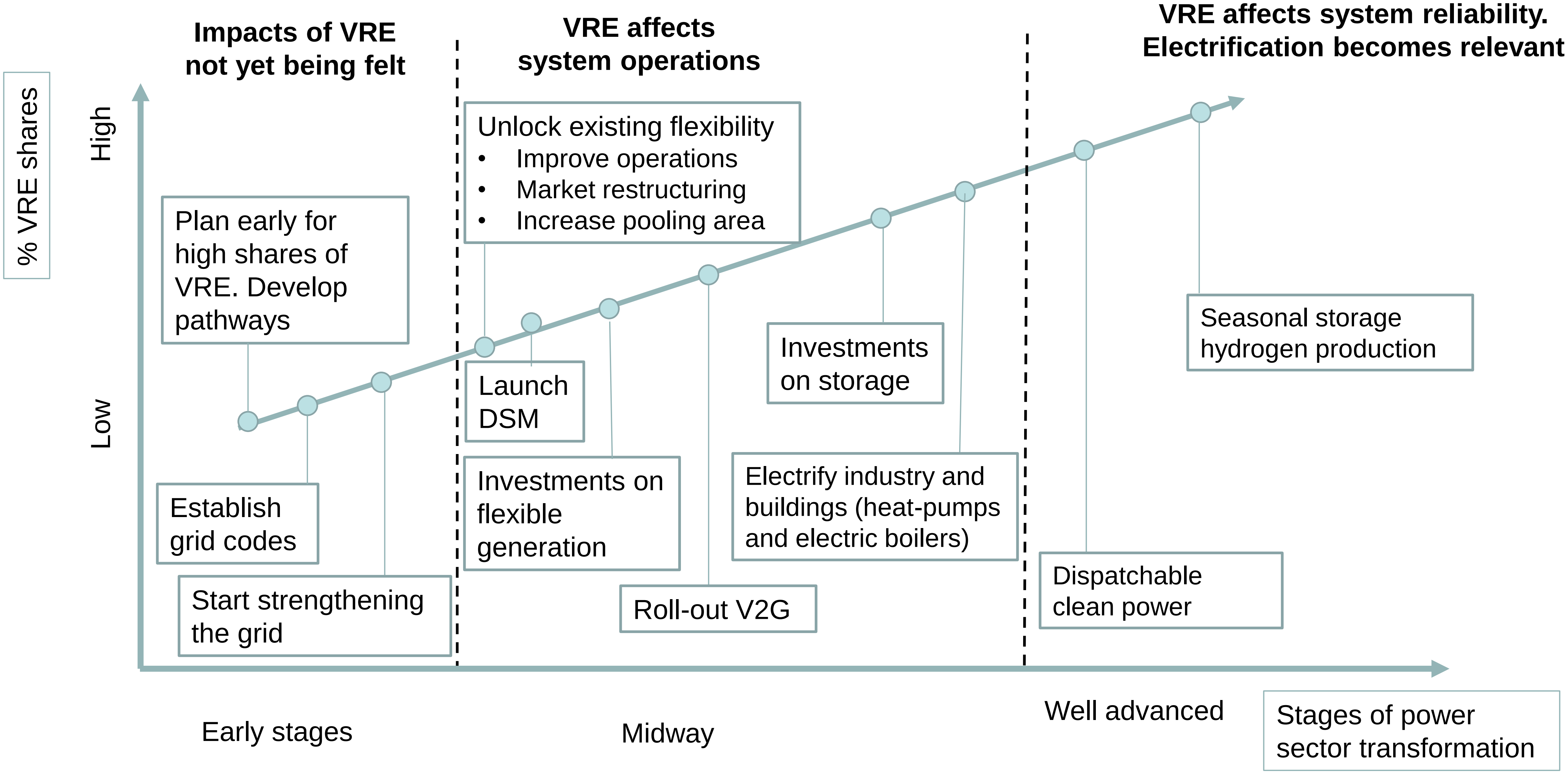
A set of solutions is needed to transform the power sector: Each solution has specific applicability and cost

IRENA
International Renewable Energy Agency

- » Power system operations have specific time frames
- » Variability impacts power system operations at different time frames
- » Each solution has its own applicability. Costs need to be considered when developing a pathway

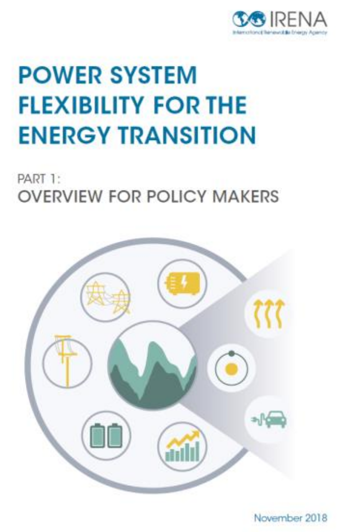


Planning early is key: Each pathway is unique to each power system



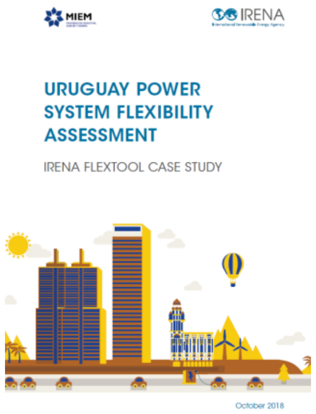
IRENA's Work on Planning for Flexibility

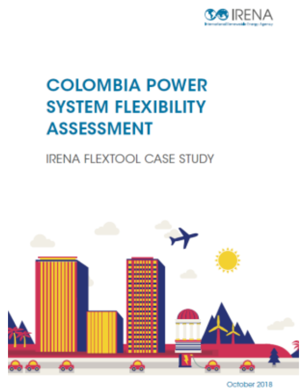
- IRENA supports its member countries in planning for flexibility with providing:
  - An overview for policy makers with a proposed methodology
  - The FlexTool to support analytical work
  - Technical manual for FlexTool users
  - Case studies developed in co-operation with a number of member countries



To be launched the **13th November** in the 16th IRENA Council (Abu Dhabi):

- **Part 1: Overview for policy makers**
- Part 2: Methodology report





Case studies developed

- **Colombia**
- **Uruguay**
- Panama
- Thailand

IRENA's methodology to plan for flexibility: Least-cost approach

IRENA
International Renewable Energy Agency

Step 1: Assess current flexibility

1. **Production cost modeling**
   - Assess current levels of curtailment and loss of load
   - Assess overgeneration incidents and fluctuation of prices
   - Assess cycling of units (start-up ramping and min gen incidents)
   - Assess if operating reserves are adequate

2. **Network studies**
   - Assess if system can efficiently regulate frequency and voltages
   - Assess if system can recover from unexpected events
   - Assess if system has sufficient inertia
   - Assess if transmission elements get overloaded

If flexibility gaps are identified go to step 2. Else, directly to step 3

Step 2: Bridge gaps following least-cost approach

1. **Unlock existing flexibility**
   - Regulatory, market changes
   - Dispatch units based on merit order
   - Train staff at generating units to operate plants flexibly
   - Pooling with neighbors
   - Adjust operating reserves based on new needs

2. **Implement DSM schemes**

3. **Invest in new assets**
   - Transmission enhancements
   - Retrofit existing units
   - Invest on new generation and/or storage

Step 3: Assess future flexibility

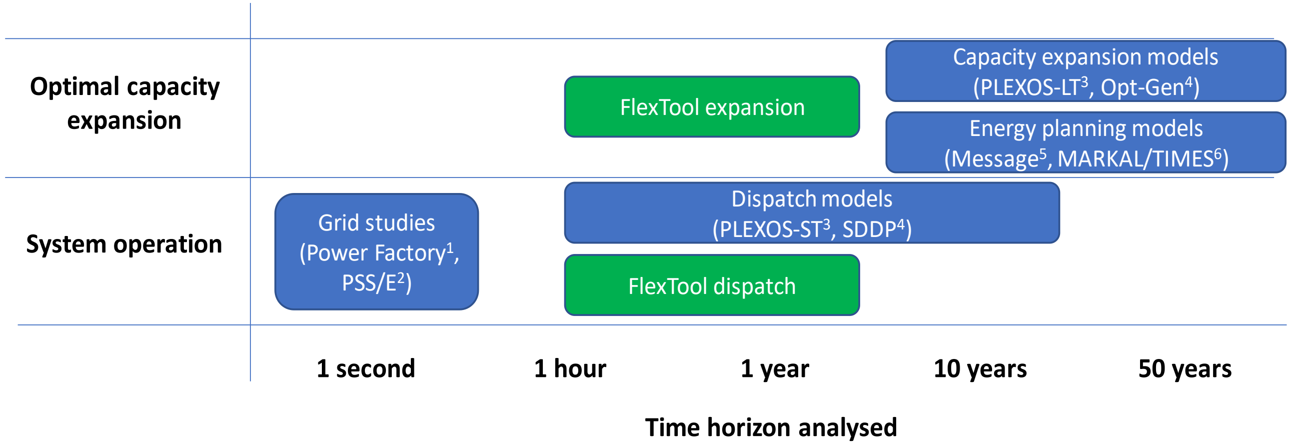
1. **Optimize VRE sitting using geospatial optimization**
   - Optimize VRE capacity mix
   - Estimate VRE production based on location and policy goals
   - Estimate future net-load

2. **Least-cost capacity expansion to identify future assets**
   - Study the net-load to assess needs for cycling
   - Optimize non-VRE capacity mix based on future technologies
   - Identify additional flexibility assets (e.g storage, DSM)
   - Assess benefits of sector coupling

3. **Repeat step 1**
   - Assess operability of long-term plan identified on previous steps

Introduction IRENA's FlexTool

- Main attributes:
  - Performs both short-term (dispatch) to assess flexibility in a given system
  - Performs long-term (generation expansion) optimization to optimize investments that enhance flexibility
  - Representative of real world power system operations
  - **Free and Publicly available**

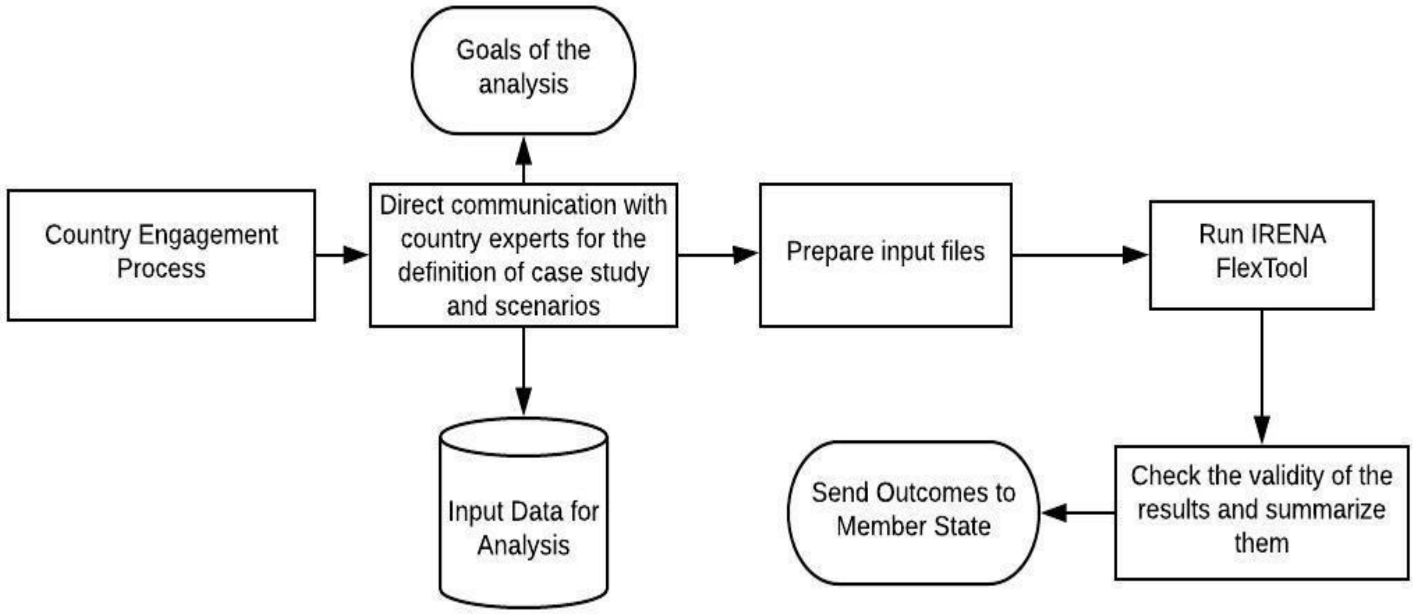


[1]Copyrighted by DIgSILENT GmbH
[2]Copyrighted by Siemens PTI
[3]Copyrighted by Drayton Analytics Pty Ltd, Australia and Energy Exemplar Pty Ltd, Australia
[4]Developed by PSR
[5]Developed by the International Atomic Energy Agency (IAEA)
[6]Developed by the International Energy Agency (IEA)

- The **IRENA FlexTool** was developed by the VTT Technical Research Centre of Finland Ltd to assist IRENA Members in a quick assessment of potential flexibility gaps

IRENA's Country Engagement and Future Work

Engagement process and analysis



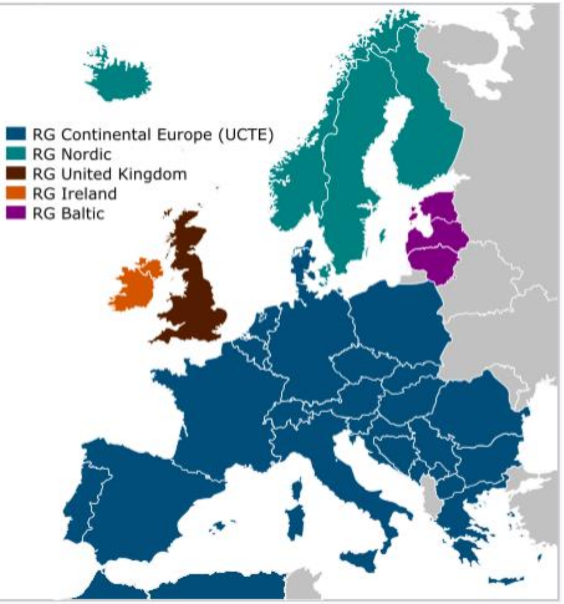
- **Future potential case studies**
  - **Chile, which is a state in accession, expressed interest in a FlexTool analysis focusing on power to hydrogen**
  - **Mexico, expressed interest in a FlexTool analysis and IRENA will share information as a next step**
  - **Other countries showed interest in the II Energy Planners Forum in Santiago de Chile**

The Knowledge Framework: Transition Pathway

Front runners: DK: 40% / IE: 20%

- **Low national storage**
- **High PPs Flexibility**

- **Synchronized Grid (2015)**
  - **DK: 1.28% <-> IE: 74%**
- **Interconnectors (2015)**
  - **DK: 50% <-> IE: 7%**



Same measures but at different times!

Also different measures!

DK

2.2% → 3.5% → 3.8% → 8.3% → 13.9% → 15.6% → 18.4% → 19.8% → 24.4% → 30.9% → 35.8% → 46.0%

Improved Flex (CHP Plants)

First grid code for wind

Regulation Power Market

Wind in Regulation Market

IE

0.2% → 1.1% → 2.6% → 7.1% → 8.4% → 10.5% → 16.2 % → 15.5 % → 17.3% → 19.6 % → 24.3 %

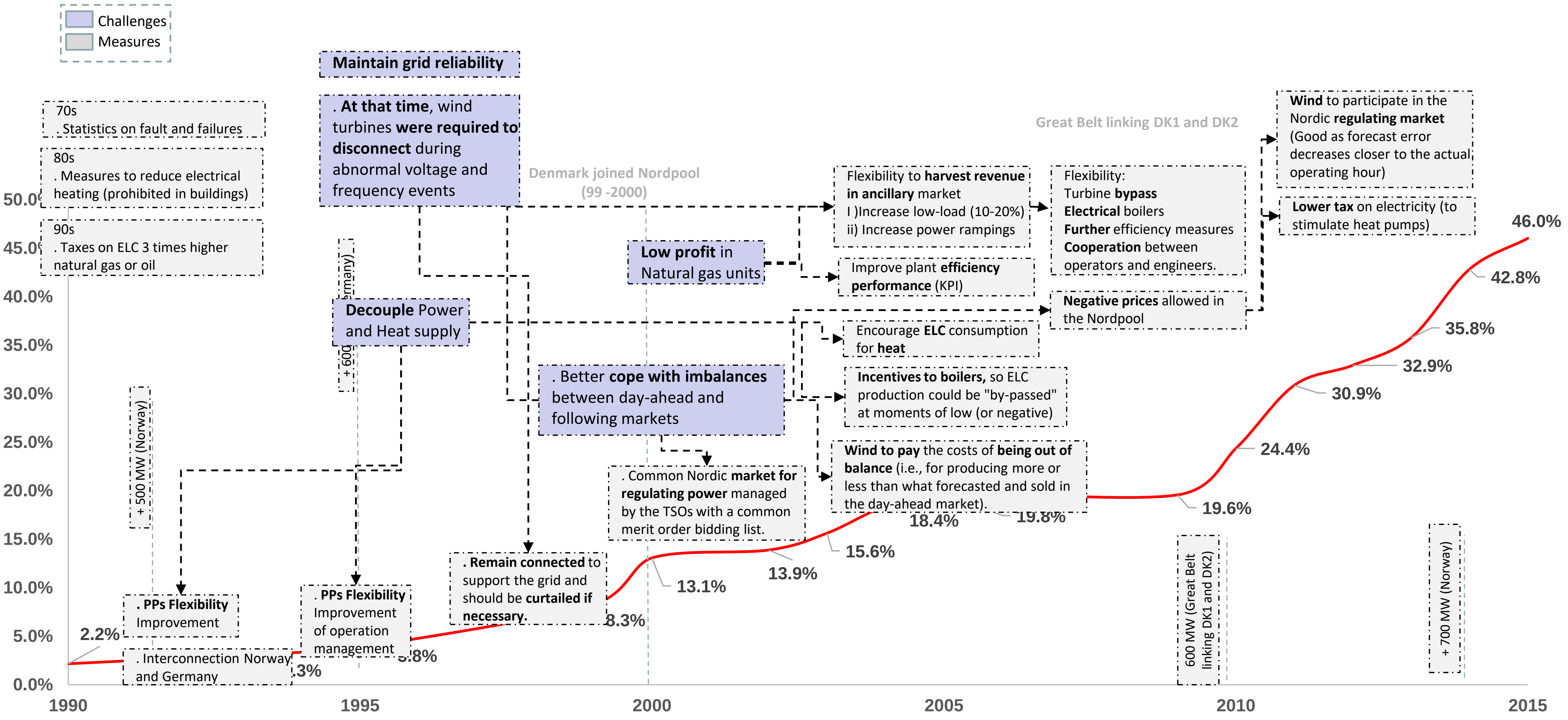
Intention for first grid code

First grid code (general)

Specific grid code for Non-Synchronous

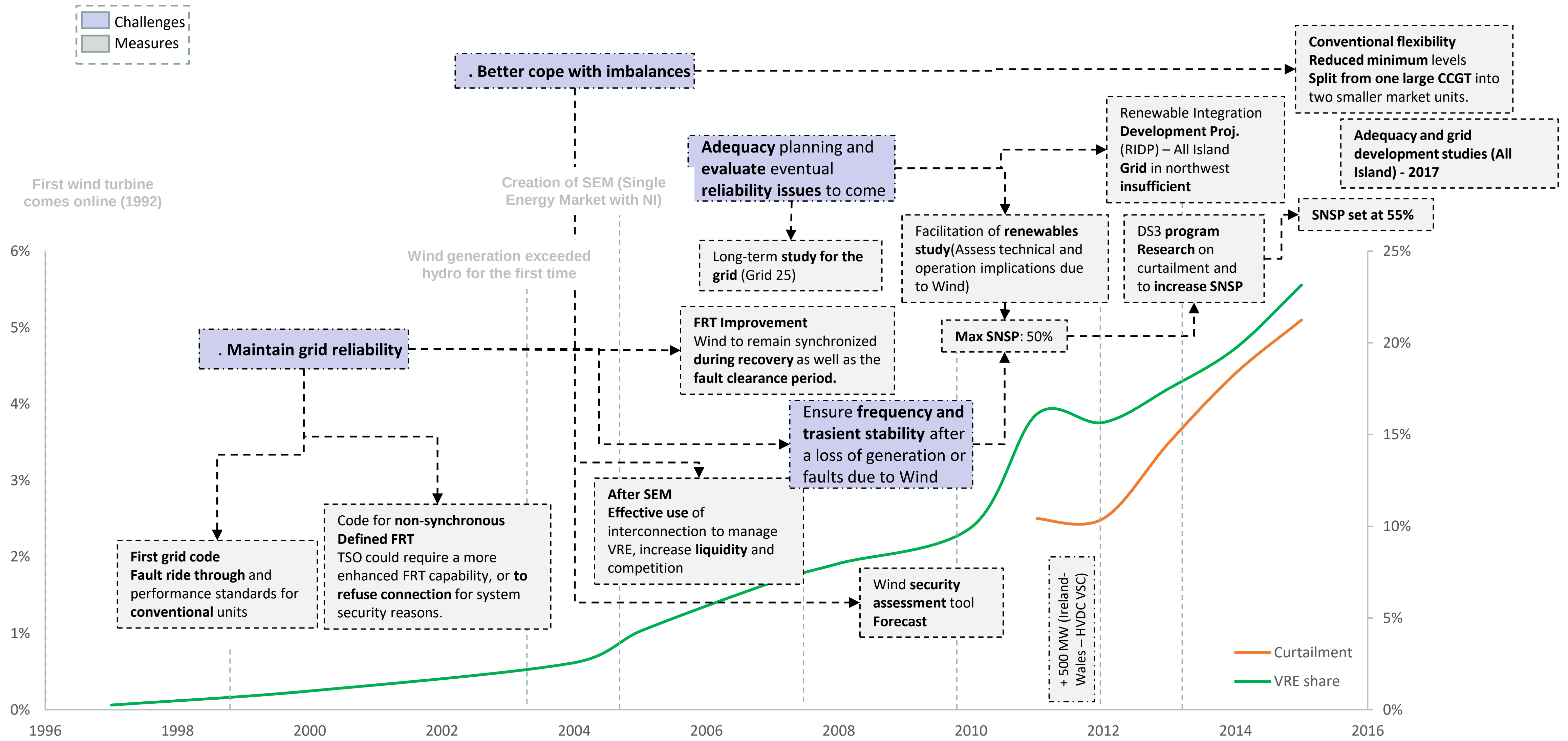
Potential Technical-Max SNSP

Denmark



Challenges
Measures
70s
. Statistics on fault and failures
80s
. Measures to reduce electrical heating (prohibited in buildings)
90s
. Taxes on ELC 3 times higher natural gas or oil
Maintain grid reliability
. At that time, wind turbines were required to disconnect during abnormal voltage and frequency events
Denmark joined Nordpool (99 -2000)
Great Belt linking DK1 and DK2
Decouple Power and Heat supply
Low profit in Natural gas units
. Better cope with imbalances between day-ahead and following markets
Flexibility to harvest revenue in ancillary market
I)Increase low-load (10-20%)
ii) Increase power rampings
Improve plant efficiency performance (KPI)
Flexibility:
Turbine bypass
Electrical boilers
Further efficiency measures
Cooperation between operators and engineers.
Wind to participate in the Nordic regulating market (Good as forecast error decreases closer to the actual operating hour)
Lower tax on electricity (to stimulate heat pumps)
Negative prices allowed in the Nordpool
Encourage ELC consumption for heat
Incentives to boilers, so ELC production could be "by-passed" at moments of low (or negative)
Wind to pay the costs of being out of balance (i.e., for producing more or less than what forecasted and sold in the day-ahead market).
. Common Nordic market for regulating power managed by the TSOs with a common merit order bidding list.
. Remain connected to support the grid and should be curtailed if necessary.
. PPs Flexibility Improvement
. PPs Flexibility Improvement of operation management
. Interconnection Norway and Germany
+ 500 MW (Norway)
600 MW (Great Belt linking DK1 and DK2)
+ 700 MW (Norway)
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1990
1995
2000
2005
2010
2015
2.2%
8.3%
13.1%
13.9%
15.6%
18.4%
19.6%
24.4%
30.9%
32.9%
35.8%
42.8%
46.0%

Ireland



Sources: EIRGRID (2011, 2012, 2013, 2014))

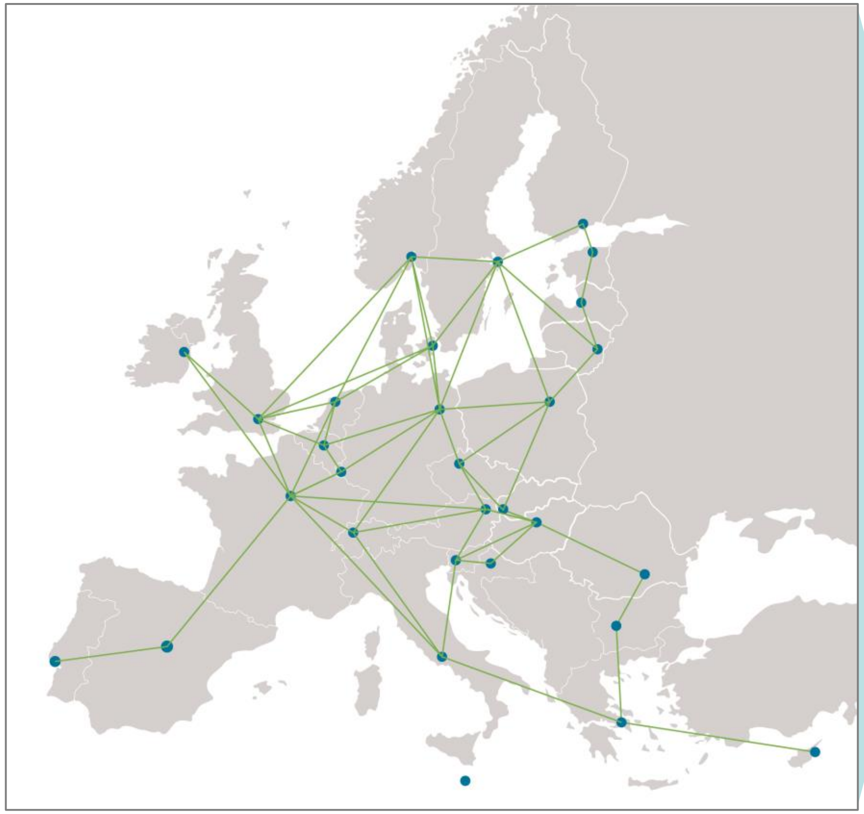
REmap analysis for CESEC

Methodological approach and expected outputs
Ongoing work and data needs
Engagement process, timeline

Ongoing work: expansion of the EU-wide power sector model to all CESEC members

Europe-wide power system dispatch model

- Generation capacities in 2030
- Interconnection between Member States
- Power demand profiles per Member State
- RE generation profiles per Member State



- RE curtailment levels
- Wholesale prices
- Cross-border trade
- Interconnector congestion
- Operation of conventional plants
- Emissions intensity

Collins, S., Saygin, D., Deane, J.P., Miketa, A., Gutierrez, L., Ó Gallachóir, B. and Gielen, D (2018) Planning the European power sector transformation: The REmap modelling framework and its insights. Energy Strategy Reviews, forthcoming.

Main data gaps for the REmap CESEC power sector analysis

Contracting Party	Data gaps for the power sector analysis
Albania	• Hourly demand profile from a previous relevant year • Hydro inflows with the highest available granulatiry (*e.g.*, monthly) and pumped hydro storage capacity (if any)
Bosnia and Herzegovina	• Hydro inflows with the highest available granularity (*e.g.*, monthly) and pumped hydro storage capacity (if any)
Kosovo*	• Hydro inflows with the highest available granularity (*e.g.*, monthly) and pumped hydro storage capacity (if any)
Macedonia	• Hydro inflows with the highest available granularity (*e.g.*, monthly) and pumped hydro storage capacity (if any)
Moldova	• **Hourly demand profile from a previous relevant year together with growth expected for 2030** • **Non-renewable generation capacity installed classified by generation type** • **Interconnection capacity with other countries**
Montenegro	• Hydro inflows with the highest available granularity (*e.g.*, monthly) and pumped hydro storage capacity (if any)
Serbia	• Hydro inflows with the highest available granularity (*e.g.*, monthly) and pumped hydro storage capacity (if any)
Ukraine	• **Hourly demand profile from a previous relevant year together with growth expected for 2030** • **Non-renewable generation capacity installed classified by generation type** • **Interconnection capacity with other countries**

www.irena.org

www.twitter.com/irena

www.facebook.com/irena.org

www.instagram.com/irenaimages

www.flickr.com/photos/irenaimages

www.youtube.com/user/irenaorg

Emanuele Taibi

Power Sector Transformation Strategies

ETaibi@irena.org