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 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.

Source: Global Energy Transformation: A Roadmap to 2050, IRENA, 2018
Impacts of Variability and Uncertainty into Power Systems Operations

Variability
- Steep down and up ramping
- Overgeneration and inertia issues
- Loss of load
- VRE Curtailment

Uncertainty
- Forecast errors
- Operational reserve is required

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

» 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

- 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
Plan early for high shares of VRE. Develop pathways. Unlock existing flexibility: 
- Improve operations 
- Market restructuring 
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

**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

**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
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**

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<thead>
<tr>
<th>Optimal capacity expansion</th>
<th>FlexTool expansion</th>
<th>Capacity expansion models (PLEXOS-LT®, Opt-Gen®)</th>
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<td>Grid studies (Power Factory®, PSS/E®)</td>
<td>Dispatch models (PLEXOS-ST®, SDDP®)</td>
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<td>FlexTool dispatch</td>
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4Developed by the International Atomic Energy Agency (IAEA)
5Developed 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
Front runners: DK: 40% / IE: 20%  
• Low national storage  
• High PPs Flexibility  

Same measures but at different times!  
Also different measures!

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Potential Technical-Max SNSP

First grid code for Non-Synchronous

Specific grid code for First grid code (general)

Regulation Power Market

First grid code for wind

Improved Flex (CHP Plants)
Denmark

- Statistics on fault and failures
- Measures to reduce electrical heating (prohibited in buildings)
- Taxes on ELC 3 times higher natural gas or oil
- 80s
- 90s

- Interconnection Norway and Germany
- Interconnection Nordic countries

- Decouple Power and Heat supply

- PPs Flexibility Improvement of operation management
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- At that time, wind turbines were required to disconnect during abnormal voltage and frequency events

- Denmark joined Nordpool (99-2000)

- 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)

- Great Belt linking DK1 and DK2

- Interconnection Norway and Germany

- PPs Flexibility Improvement of operation management

- Power and Heat supply

- Maintain grid reliability

- Common Nordic market for regulating power managed by the TSOs with a common merit order bidding list.

- 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).

- Encourage ELC consumption for heat

- Incentives to boilers, so ELC production could be "by-passed" at moments of low (or negative) prices allowed in the Nordpool

- 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.

- Encourage ELC consumption for heat

- Ramping flexibility

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Ireland

- **First wind turbine comes online (1992)**
  - Wind generation exceeded hydro for the first time
  - Facilitation of renewables study (Assess technical and operation implications due to Wind)
  - Research on curtailment and to increase SNSP
  - D3 program

- **Maintain grid reliability**
  - After SEM: Effective use of interconnection to manage VRE, increase liquidity and competition
  - Wind security assessment tool
  - Forecast

- **Better cope with imbalances**
  - Adequacy planning and evaluate eventual reliability issues to come
  - FRT improvement: Wind to remain synchronized during recovery as well as the fault clearance period.
  - Ensure frequency and transient stability after a loss of generation or faults due to Wind

- **Conventional flexibility**
  - Reduced minimum levels
  - Split from one large CCGT into two smaller market units.

- **Adequacy and grid development studies (All Island) - 2017**
  - SNSP set at 55%

- **Code for non-synchronous defined FRT**
  - TSO could require a more enhanced FRT capability, or to refuse connection for system security reasons.

- **Creation of SEM (Single Energy Market with NI)**

- **Max SNSP: 50%**

- **First wind turbine comes online (1992)**

- **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


- 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
## Main data gaps for the REmap CESEC power sector analysis

<table>
<thead>
<tr>
<th>Contracting Party</th>
<th>Data gaps for the power sector analysis</th>
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<tbody>
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<td><strong>Albania</strong></td>
<td>• Hourly demand profile from a previous relevant year</td>
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<td>• Hydro inflows with the highest available granularity (e.g., monthly) and pumped hydro storage capacity (if any)</td>
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<td>• Non-renewable generation capacity installed classified by generation type</td>
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