Long-term capacity expansion planning with variable renewable power

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Planning for the Global Energy Transition

Objective:
To help improve RE representation in global/regional scenarios and national master plans

Three components:
1. Consolidation of data, methodologies, and good practices (guides and manuals)
2. Supporting application of methodologies (country case studies)
3. Capacity building in the use of methodologies
Energy planning: Focus areas for techno-economic analysis

**Generation expansion planning**
- Future energy mix and investment path
- Compliance with long-term energy policy goals
- Political consensus making
- Linked often with non-power sector planning

**Geo-spatial planning**
- Generation siting and long-term transmission development needs

**Dispatch simulation**
- Fuel and operation cost calculation
- Market and regulation design

**Technical network studies**
- Static analysis for load flow
- Dynamic analysis for stability
**Time dimensions of power sector planning**

**Typical time resolution**
- Seasonally to sub-daily
- Seasonally to sub-daily (Static)
- Hourly to sub-hourly
- Sub-hourly to sub-seconds

**Typical time frame**
- Generation expansion planning: 20-40 years
- Geo-spatial planning: 5-20 years
- Dispatch simulation: Weeks-years
- Technical network studies: Snapshot

**Planning time horizon**
- Near-term
- Long-term

Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies
Generation expansion planning

Example of the tools
- MESSAGE
- PLEXOS-LT
- BALMOREL
- WASP
- OPT-GEN

Department of Energy
Regulatory commission
Utility
Specialized agency

Philippine Energy Plan 2012-2030
Kenya Vision 2030
2015 Integrated Resource Plan
Volume I
March 2011
March 31, 2015

IRENA
International Renewable Energy Agency
Features of generation expansion planning model

- Cost minimization over a long-time horizon
- Capacity build up with time steps of 1-5 years
- Limited time resolution
- Limited spatial resolution

Example of models with advanced approaches

<table>
<thead>
<tr>
<th>Model name</th>
<th>Region</th>
<th>No. of time slices</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEMS + CEEM</td>
<td>Germany</td>
<td>432</td>
</tr>
<tr>
<td>DIMENSION + INTRES</td>
<td>Europe</td>
<td>192</td>
</tr>
<tr>
<td>DIMENSION</td>
<td>Europe</td>
<td>7200</td>
</tr>
<tr>
<td>US-REGEN</td>
<td>US</td>
<td>50</td>
</tr>
<tr>
<td>LIMES-EU+</td>
<td>Europe &amp; Middle East and North Africa</td>
<td>49</td>
</tr>
<tr>
<td>URBS-EU -</td>
<td>Texas (US)</td>
<td>8064</td>
</tr>
</tbody>
</table>

Total of 32 slices
Planning tools

Long-term generation expansion models
(time resolution: hours – seasons)

Geo-spatial planning models
(time resolution: hours – seasons)

Production cost models
(time resolution: minutes – hours)

Static grid models
(time resolution: single point)

Dynamic grid models

Generation and network capacities
Network topology
Highly-resolved dispatch and operational details
Steady state grid currents and voltages

Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies
VRE in the planning process

**VRE PROPERTIES**
- Non-Synchronous
- Location-constrained & distributed
- Uncertainty
- Variability

**SYSTEM PROPERTIES**
- Frequency & Voltage response provision
- Voltage control needs
- Transmission capacity needs
- Flexibility needs
- Flexibility needs
- Firm capacity provision

**PLANNING STAGES**
- Geo-spatial planning & Technical network studies
- Geo-spatial planning & Technical network studies
- Dispatch simulation
- Generation expansion planning

Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies
Key features of solar and wind

» Rapid cost reduction
» Firm capacity / capacity credit
» Flexibility
» Transmission investment needs
» Stability consideration

Typically not well covered in “traditional” generation expansion planning models and methodologies
Typical planning sequence

- **Long-term generation expansion models**
  - Firm capacity
- **Geo-spatial planning models**
  - New transmission
- **Production cost models**
  - Flexibility
- **Static grid models**
  - Transmission enhancement
- **Dynamic grid models**
  - Stability

- Generation and network capacities
- Network topology
- Highly-resolved dispatch and operational details
- Steady state grid currents and voltages

- Low detail/ Wide scope
- High detail/ Narrow scope
With variable renewable energy...

**Feedback from all the levels**

**Long-term generation expansion models**
- Firm capacity

**Geo-spatial planning models**
- New transmission

**Production cost models**
- Flexibility

**Static grid models**
- Transmission enhancement

**Dynamic grid models**
- Stability

**Network topology**
- Generation and network capacities
- Highly-resolved dispatch and operational details
- Steady state grid currents and voltages

Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies
It is important to do it right from the beginning!

How? 

Coordinated planning across planning bodies

Improve long-term energy planning modeling methodologies by incorporating key VRE features

Key elements of the subsequent steps can be pre-analyzed in a simplified manner
Long-term planning check list – plan for “operability with high VRE”

- **Firm capacity** (adequate generation fleet)
- **Flexibility** (balancing for secure operation)
- **Transmission investment needs** (adequate transmission infrastructure)
- **Stability** (robustness to withstand contingency)

Best practices to better represent the VRE investment implications in long-term capacity expansion models
IRENA activities in the long-term planning with VRE

Technical workshops to discuss the best practices in long-term planning with VRE
- Key planning concepts
- Practical modelling

Joint long-term planning studies
- Pilot projects on institutional capacity building in developing and updating long-term generation expansion plan

LAC AVRIL follow up meeting
USAID training events
IEW meeting

Swaziland energy planning capacity building
Regional capacity building events with partners (IAEA, UN, etc)
REmap flexibility study
Best practice – VRE integration

Market design, regulation, business models

- Forthcoming Report: *Adapting electricity market design to high shares of VRE* (Q2 2017)
- Country regulatory advice
- Power sector innovation landscape report (Q4 2017)

Long term, least cost capacity expansion plan

- Best practices in long-term scenario-based modelling* report, *Planning for the renewable future*
- Recommendations are to be discussed at a Latin American regional workshop (2017 Q3)

Unit commitment and economic dispatch

- Production cost modeling
- Developing *flexibility assessment* to be applied to 5 REmap countries
- Developing a *global storage valuation framework*, to assess the value of storage in different markets

Grid studies

- Technical network studies
- A guide for *VRE integration studies* is upcoming (2017 Q2)
- Technical assessments for larger systems

Find the optimal pathway for power sector transformation
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