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Key Technical Considerations for Variable Renewable Energy in Long-term Planning

Astana, Kazakhstan

Background material for the workshop

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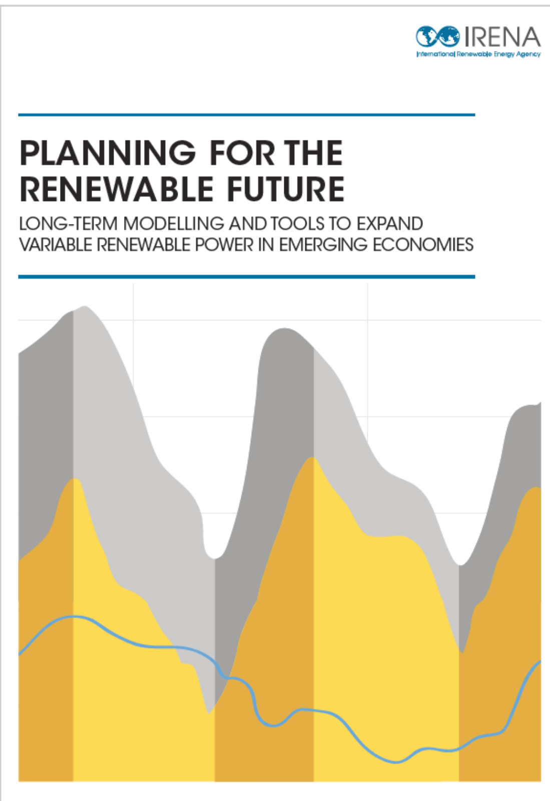
Addressing Variable Renewables In Long-term planning (AVRIL) project



Long-term planning with VRE

Long-term generation expansion models

- » Primarily focused on economic assessment of options
- » System-wide optimization
- » Reduced representation of operational aspects
- » Does not necessarily answer "reliability" questions

Government

"Deploying variable renewables (VRE) is beneficial."

"Our country should adopt ambitious long-term VRE targets."

Energy planning officials

System operators

"VRE's short-term variability endangers power system reliability"

"There is an upper limit of X% VRE"

Addressing VRE in long-term planning (AVRIL) project

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Based on expert inputs

» IEW 2014, 2015

» AVRIL expert meeting

» Interviews

In consultation with energy planners in North Africa, and Latin America

» First deep-dive meeting with member countries – this meeting

AVRIL project: Key starting question

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How does long-term generation expansion planning need to change when aiming for a high share of VRE?

» Planning impacts of VRE's distinct features

What needs to change?

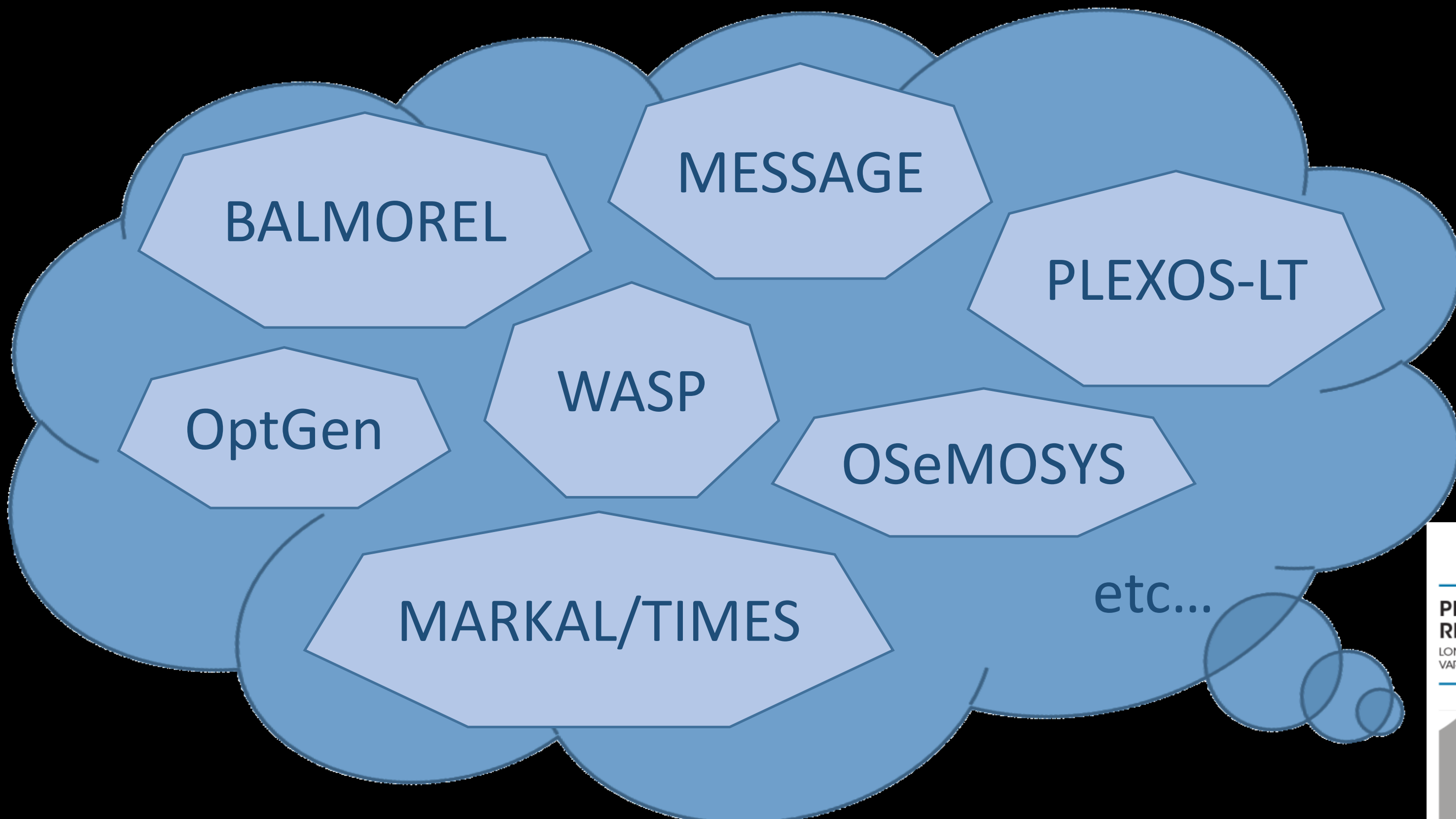
» Institutional aspects (Planning process)

» Techno-economic assessment methodologies (Modelling)

Source: IRENA

Generation capacity expansion planning

Commonly used modeling software



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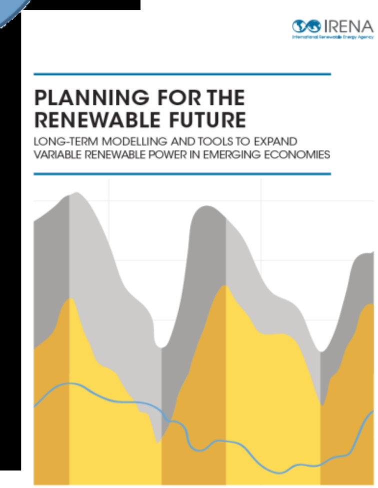
update frequency, user support, and cost



Example of the tools used in the MENA region

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- Generation planning

  WASP (IAEA), OPTGEN (PSR), EGEAS (EPRI), Aurora (EPIS)

- Renewable / geospatial planning

  ArcGIS (ESRI), Patro Solar, SAM (NREL)

- Operational planning

  EMS, SPPD (PSR)

- Transmission planning

  Power factory (Digsilent), PSS/E (Siemense)

Example of the tools used in the LAC region

- **Generation planning**
  - **MESSAGE, TIMES** (Argentina, Paraguay, Peru); **OptGen** (Bolivia, Colombia, Ecuador, Peru); **PET** (Chile); **PLEXOS** (Mexico); **WASP** (Uruguay)
- **Renewable / geospatial planning**
  - **PSS/E + MESSAGE, TIMES** (Argentina); **MATRIZ** (Brazil); **PET** (Chile); **PLEXOS** (Mexico)
- **Operational planning**
  - **OSCAR-MARGO** (Argentina); **SDDP** (Bolivia, Colombia, Ecuador, Peru); **NEWAVE** (Brazil); **PCP/PLP** (Chile); **PSS/E** (Mexico); **SimSEE** (Uruguay)
- **Transmission planning**
  - **PSS/E** (Argentina, Mexico, Uruguay); **PowerFactory** (Bolivia, Colombia, Ecuador); **NetPlan** (Peru)

Notes on choice of software

Key differences: model scopes, interfaces, update frequency, user support, and cost

The choice of software is a secondary issue; more important is how to better use them!

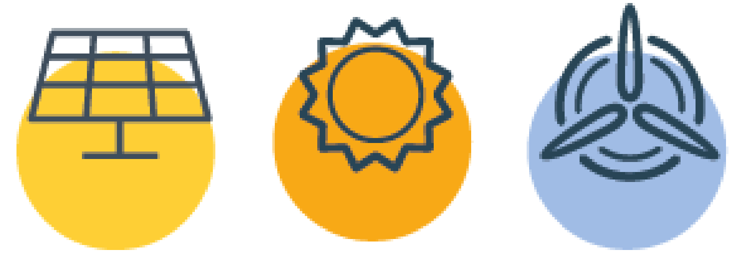
Difficult to make an objective assessment on desirability of one software than others

Discuss with the software developer – and the key software issues for VRE are summarized as 5 check points

Key features of solar and wind

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

Five key technical drivers of optimal VRE deployment in the long-term



- Fast cost reduction
- Firm capacity / capacity credit
- Flexibility
- Transmission investment needs
- Stability consideration

Planning that takes into account long-term cost reduction potential can ensure long-term cost effectiveness of the energy system and avoid technology lock-in.

Recent cost evolution

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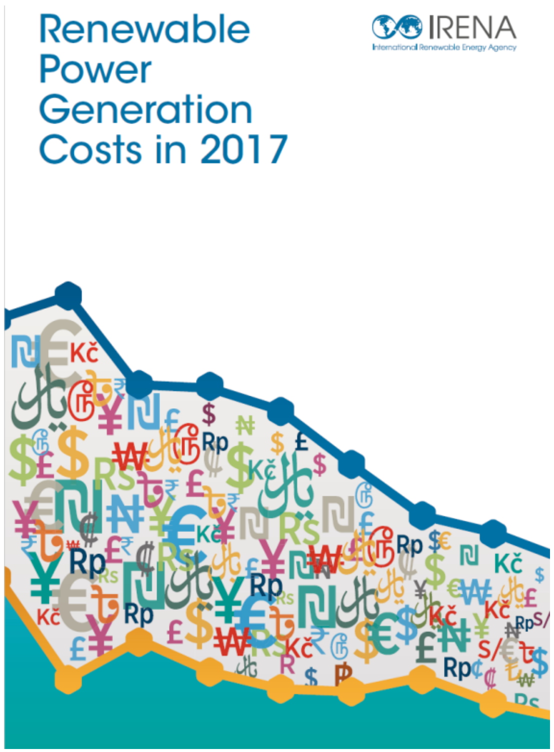
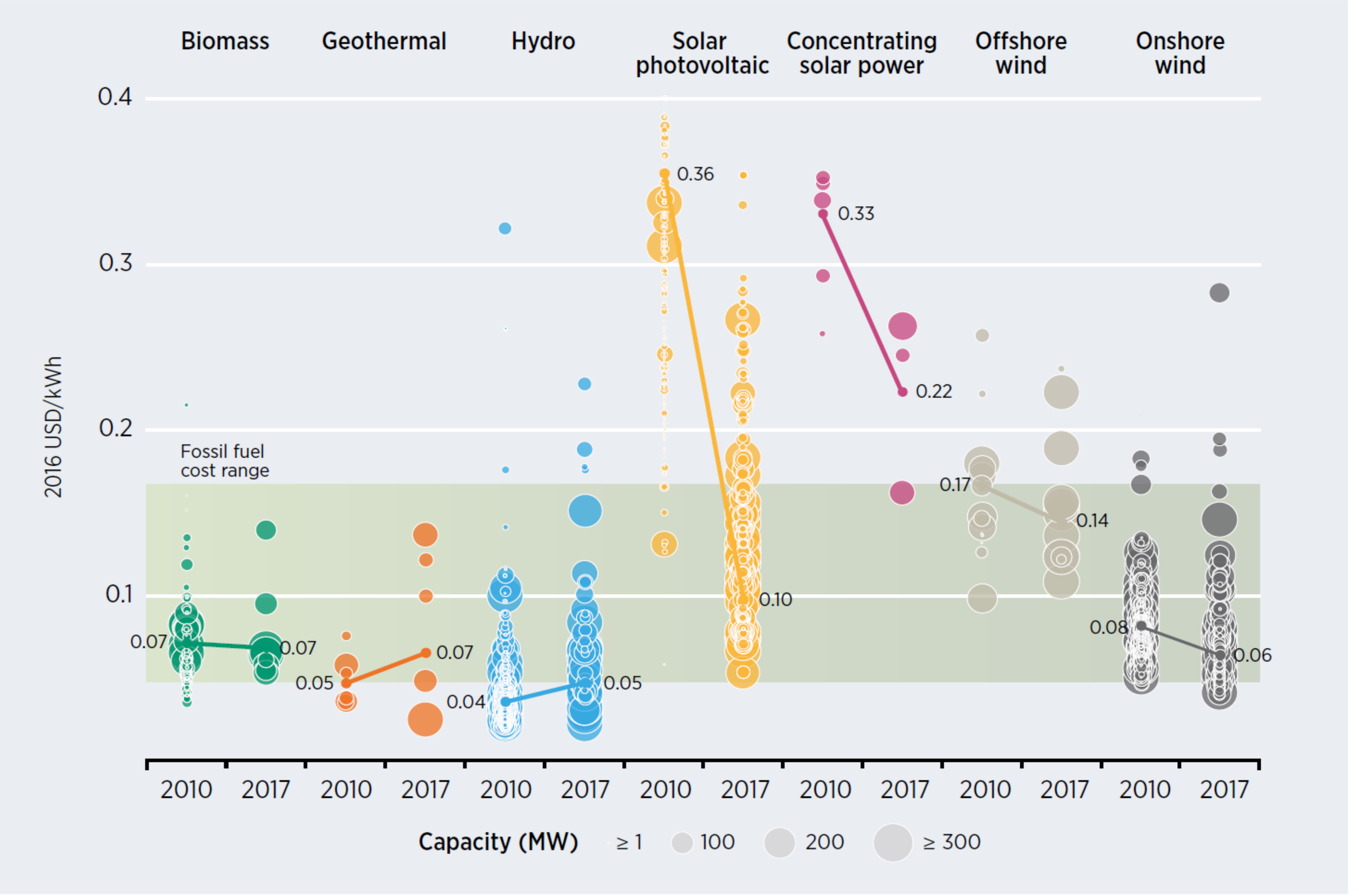


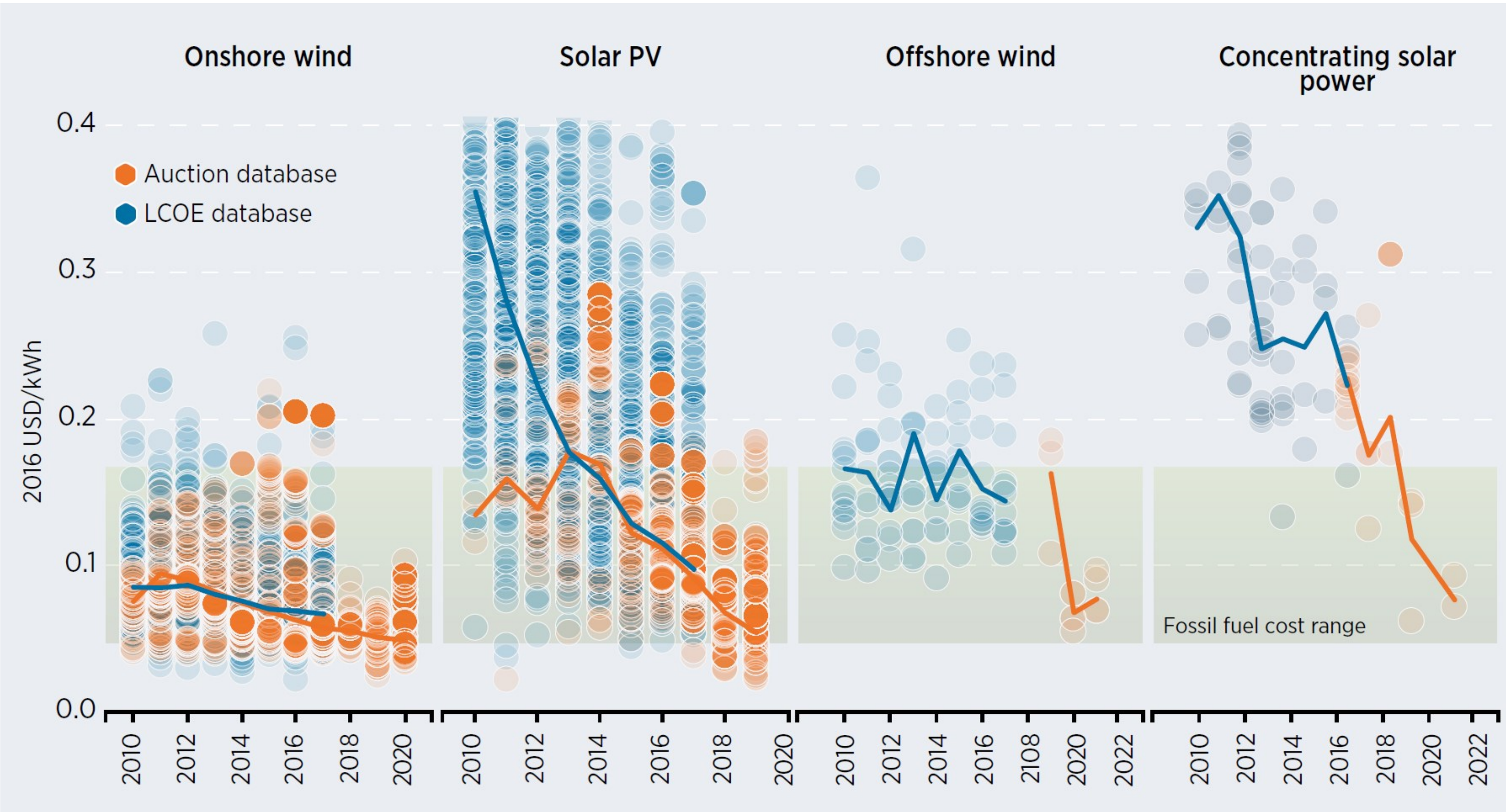
- » Latest trends in the cost and performance of renewable power generation technologies
- » Global results to 2017, country/regional results to 2016
- » Detailed analysis of equipment costs and LCOE drivers
- » Integration of project LCOE and Auction results to look at trends to 2020

Recent cost evolution



Source: IRENA Renewable Cost Database.

RE costs and auction results are now at or below fossil fuel cost range



Source: IRENA Renewable Power Generation Costs 2017

How reality surpassed expert projections

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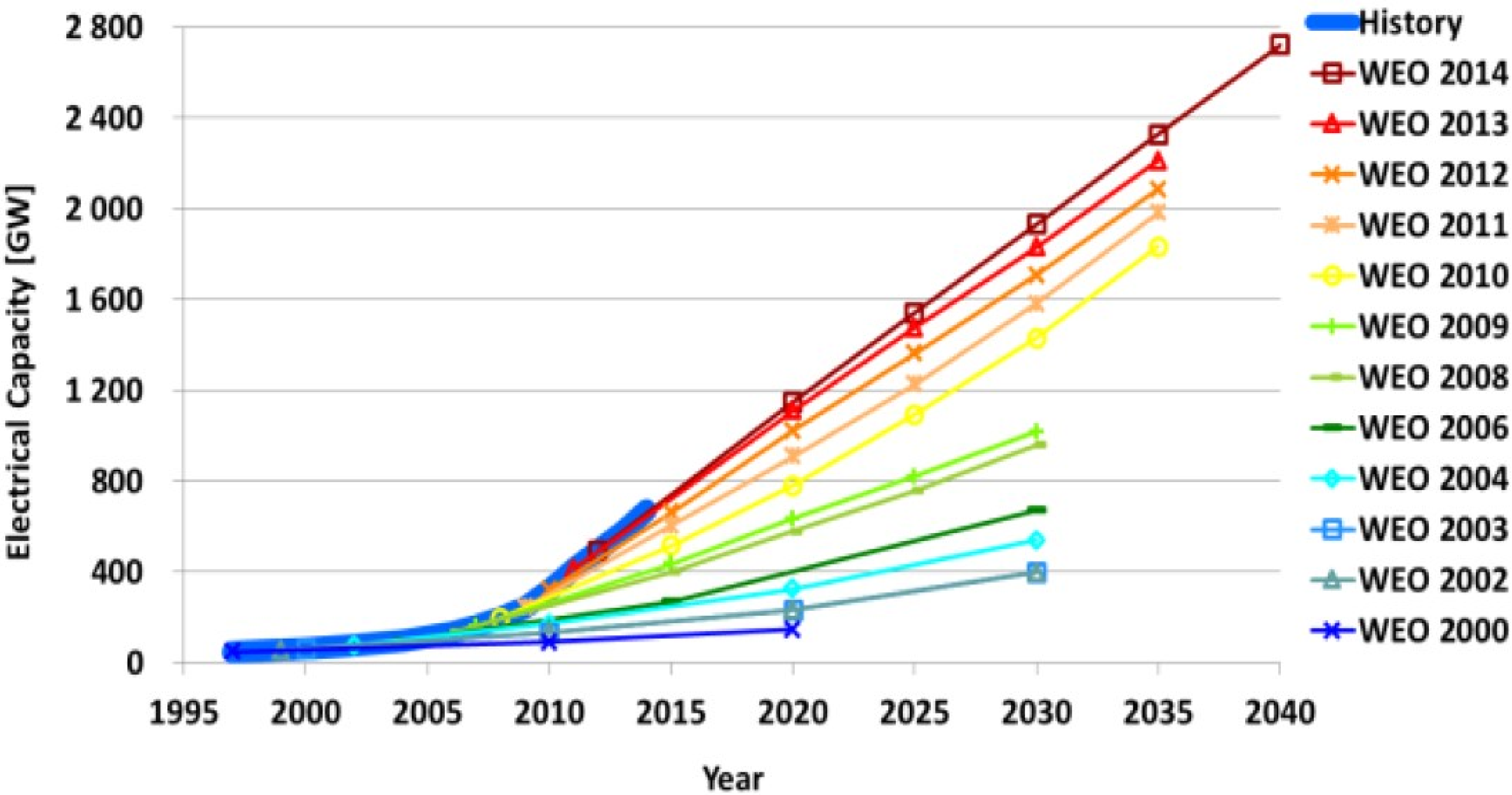
WEO: World Energy Outlook from IEA



Source: Metayer et. al (2016), The projections for the future and quality in the past of the World Energy Outlook for solar PV and other renewable energy technologies; and Gilbert et. al (2016), Looking the wrong way: Bias, renewable electricity, and energy modelling in the United States

How reality surpassed expert projections: e.g. solar PV costs

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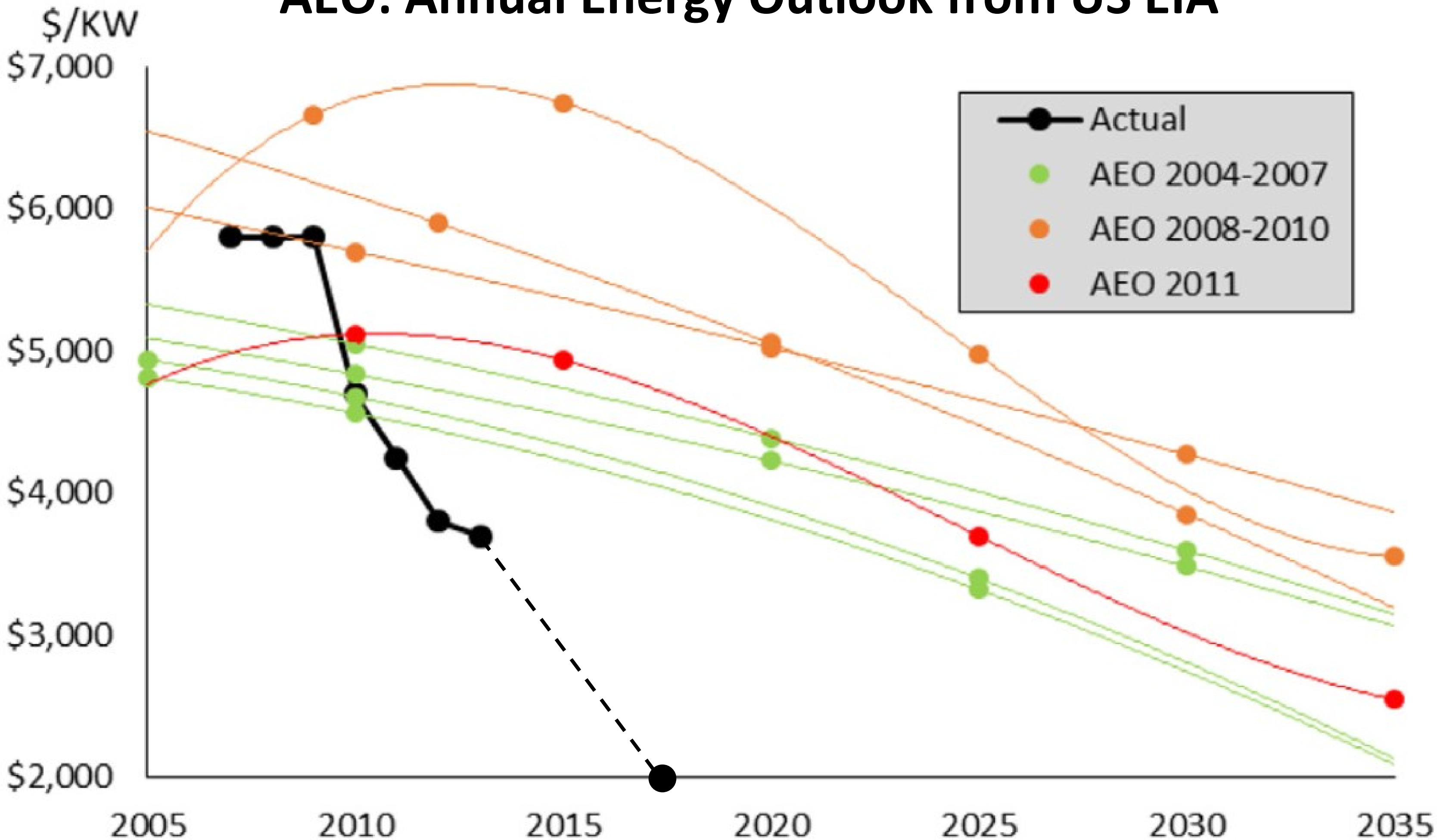
AEO: Annual Energy Outlook from US EIA



Source: Metayer et. al (2016), The projections for the future and quality in the past of the World Energy Outlook for solar PV and other renewable energy technologies; and Gilbert et. al (2016), Looking the wrong way: Bias, renewable electricity, and energy modelling in the United States

Key features of solar and wind

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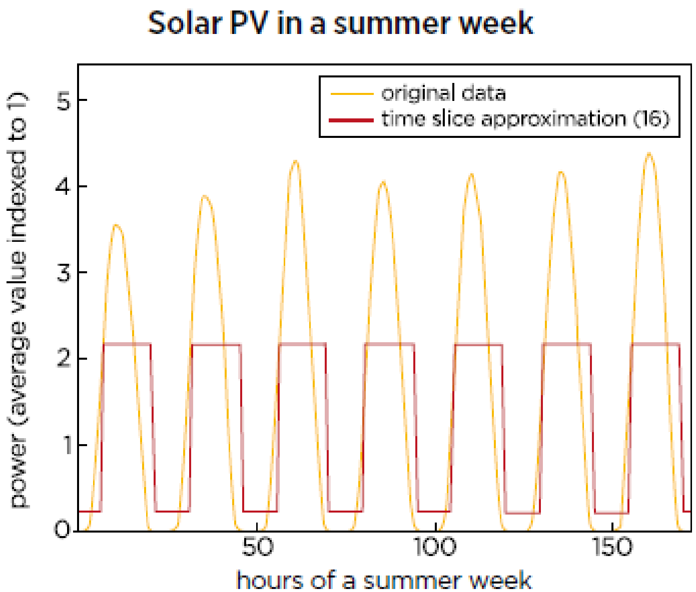
- Rapid cost reduction
- Firm capacity / capacity credit
- Flexibility
- Transmission investment needs
- Stability consideration

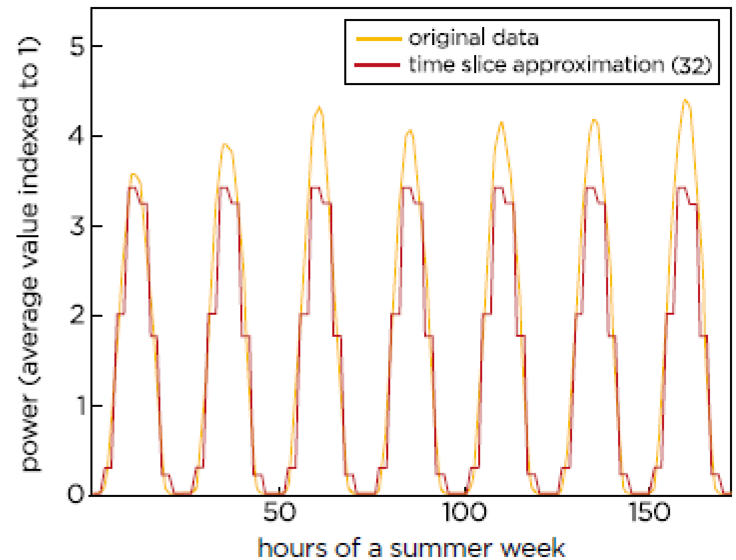
Typically not well covered in "traditional" generation expansion planning models and methodologies

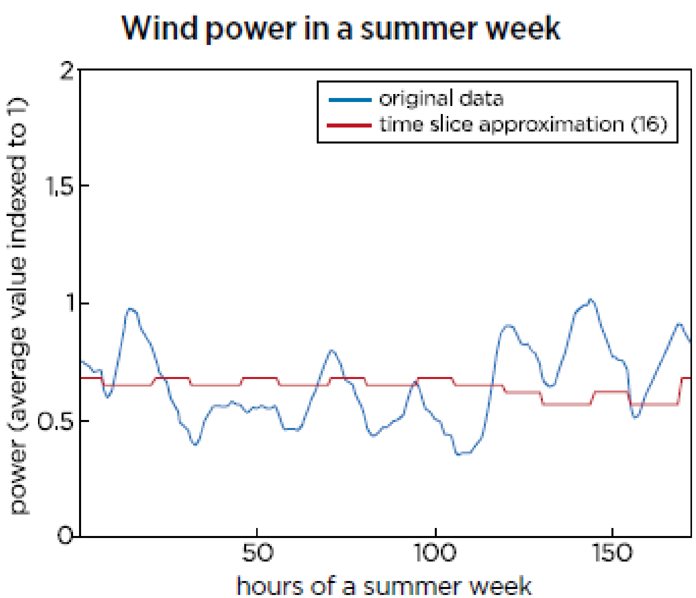
	Generation	Networks
Adequacy	**Firm capacity**	**Transmission capacity**
Security of operation	**Flexibility**	**Voltage control capability**
	Stability (frequency response and voltage response)	

Most relevant / High relevance / System-specific / Near-term relevance

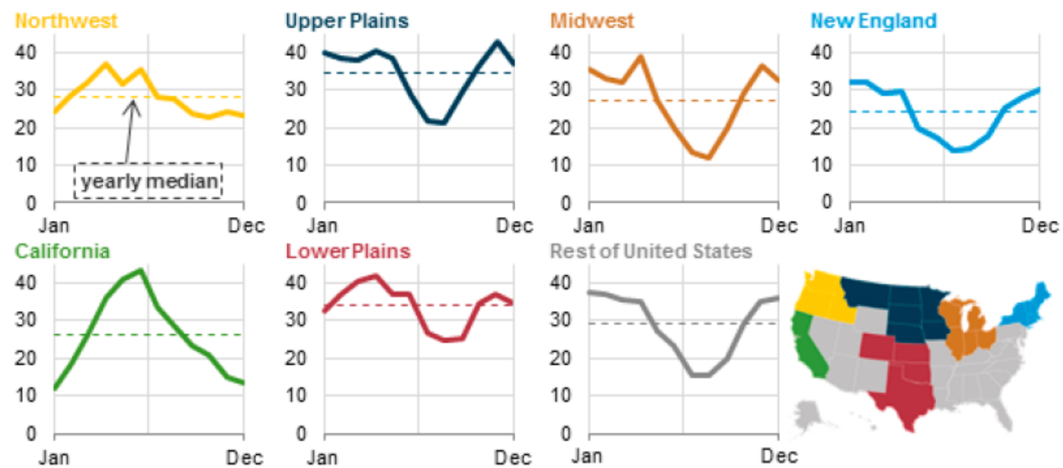
Checkpoint 1: Definition of time







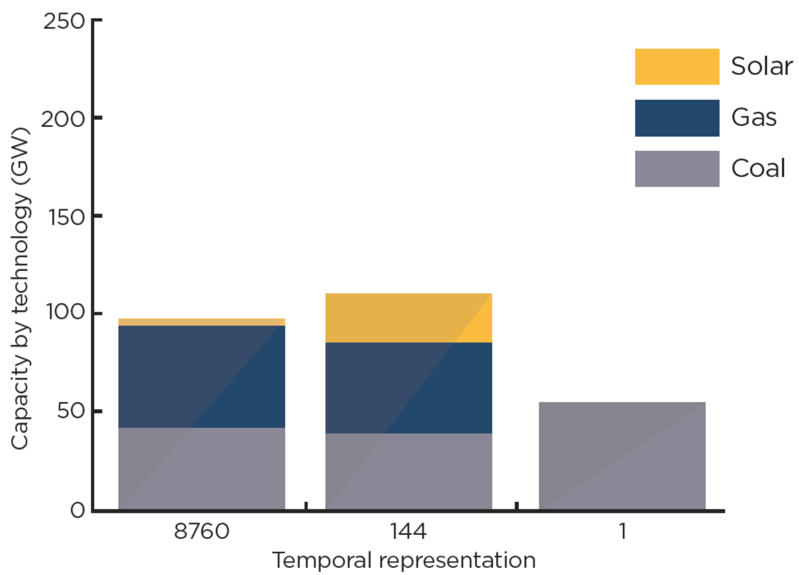
Source: Ueckerdt et al., 2016



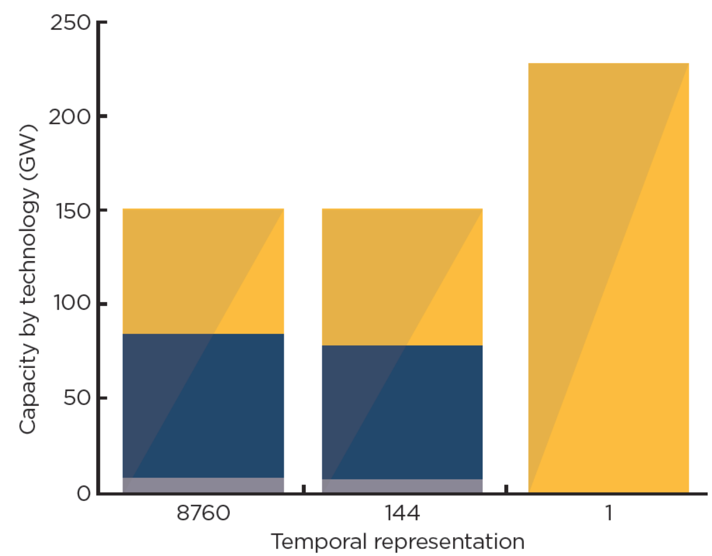
Source: EIA (2015)

The choice of the right temporal resolutions

The results of the analysis is highly dependent to the temporal resolution of the models



PV cost 1$/KW



PV cost 0.5 $/KW

(Source: Merrick, 2016)

Checkpoint 1: Definition of time

How?

Representation of VRE generation in the model should be based on meteorological data

Data sources:

- Observation data
- Global re-analysis data

Check point 1

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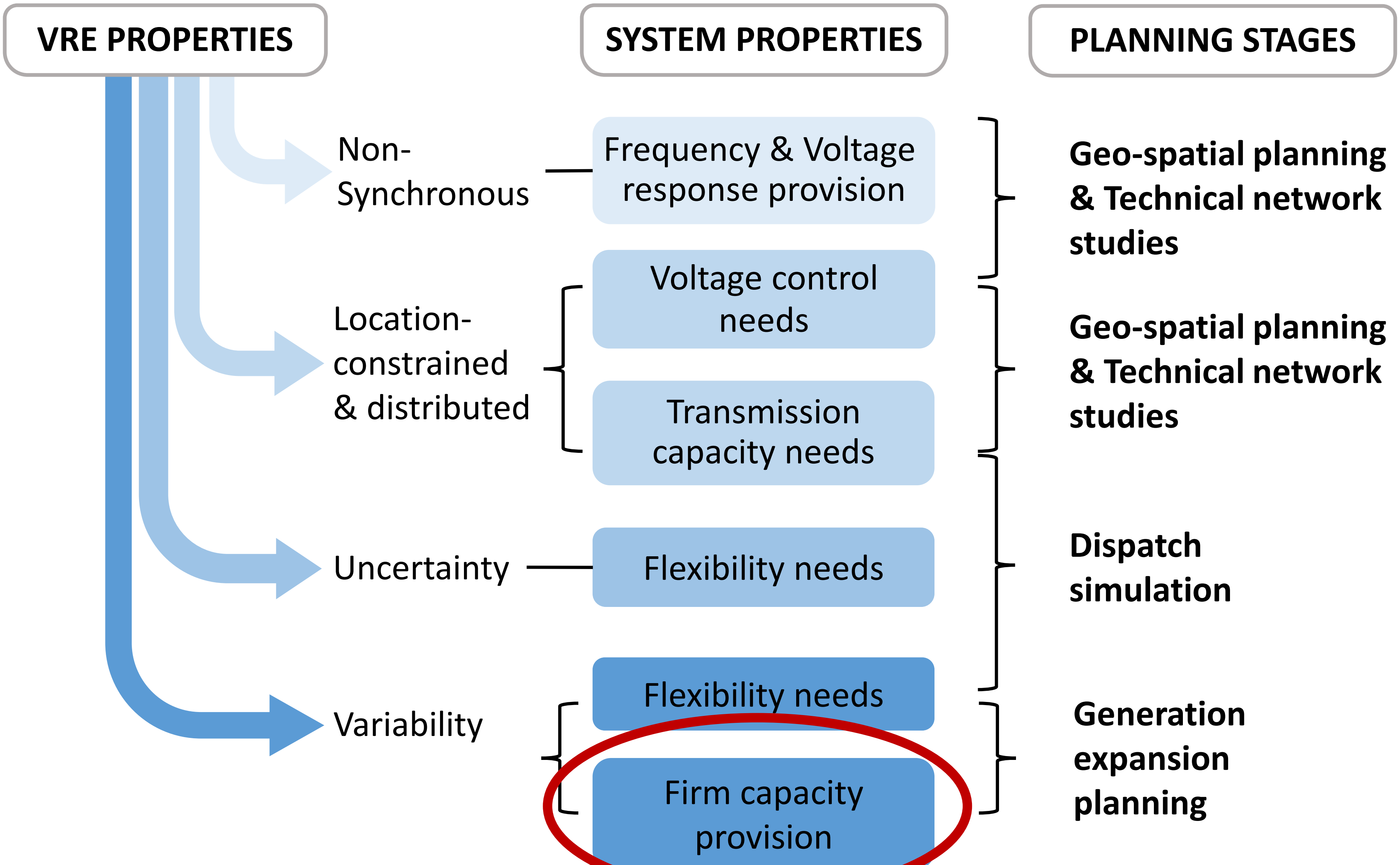
Does the model reflect the solar and wind variability based on meteorological data?

Check point 2: Adequate firm capacity



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

Variability – lack of correlation with demand

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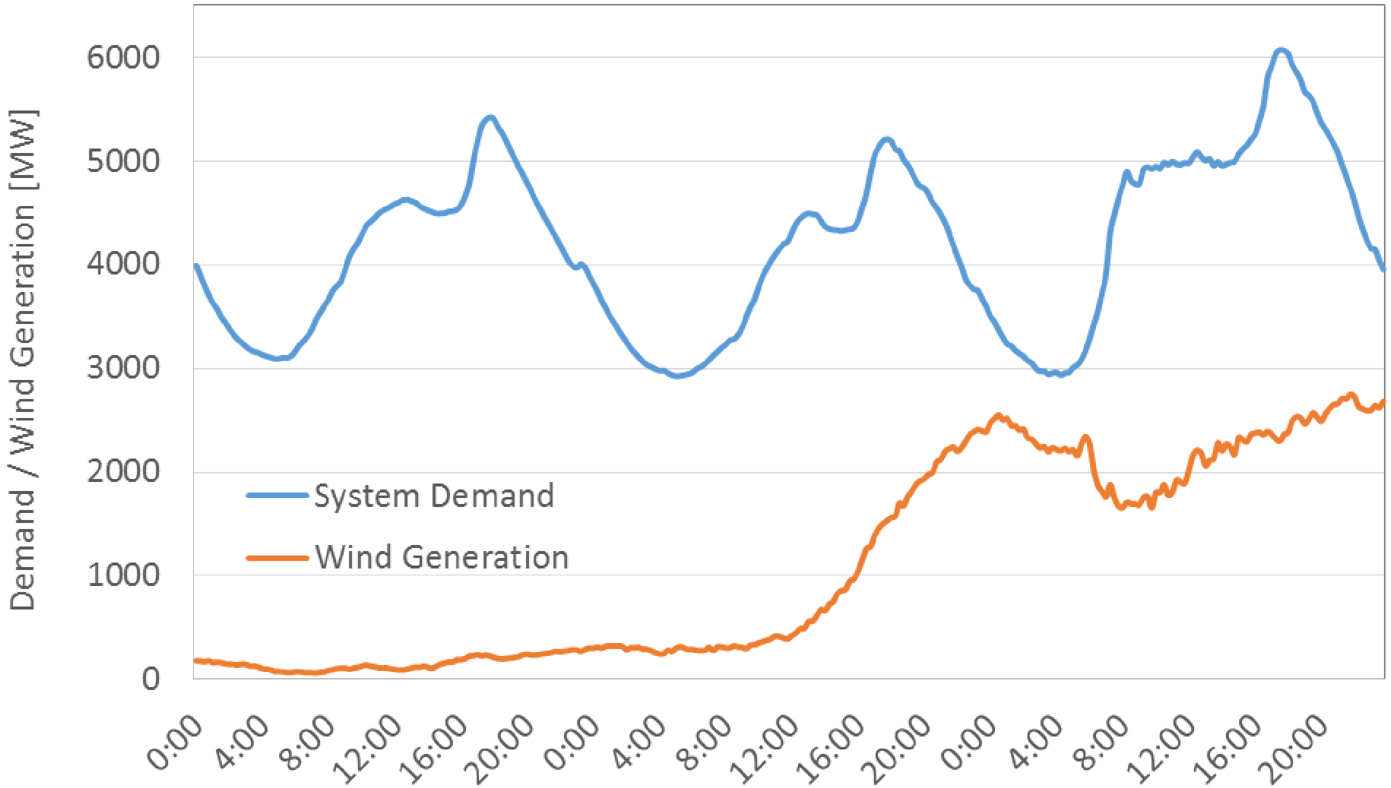

Good solar and good wind are not guaranteed when needed
Conventional generators are guaranteed to generate when needed

1 MW of VRE generators < 1 MW of conventional generators

Source: http://www.eirgridgroup.com

Variability – Key planning implications

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Does a system have sufficient generation to meet demand at all times?

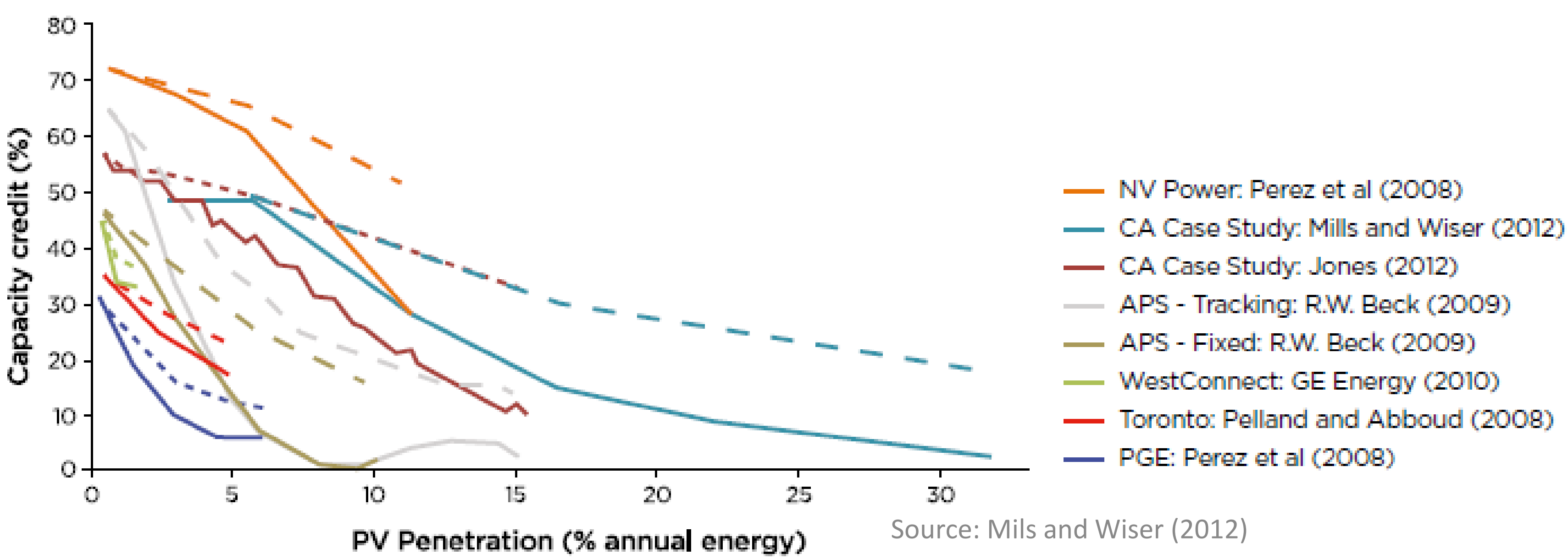
Indicators to measure how well VRE generation matches demand:

- **Firm capacity:** *"the amount of power generation that can be guaranteed to meet demand at any given time, even under adverse conditions"* (EIA)
- **Capacity credit:** The fraction of VRE capacity that can be relied upon as firm capacity

"the amount of additional load that can be served at the target reliability level with the addition of the generator in question" (Holttinen et al. 2009)

Planning for adequate firm capacity

- A system needs to have sufficient generation capacity even during the time of high demand / low solar availability
- How much renewable energy contributes to **firm capacity** and to **planning reserve margin** needs to be evaluated
- Lower capacity credit means lower utilization of the rest of the system



Source: Mils and Wiser (2012)

Representing adequate firm capacity

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How are the capacity credits estimated and used in the modelling tools?

Detailed methodology based on reliability

- Using the probabilistic reliability indicators

Simplified methodologies

- Capacity factor during the peak hours
- Rule-of-thumb

US system operators (in 2012)	
Reliability based	9
Statistical analysis	6
Peak hours	10
Rule-of-thumb	1

Source: Rogers and Porter (2012)

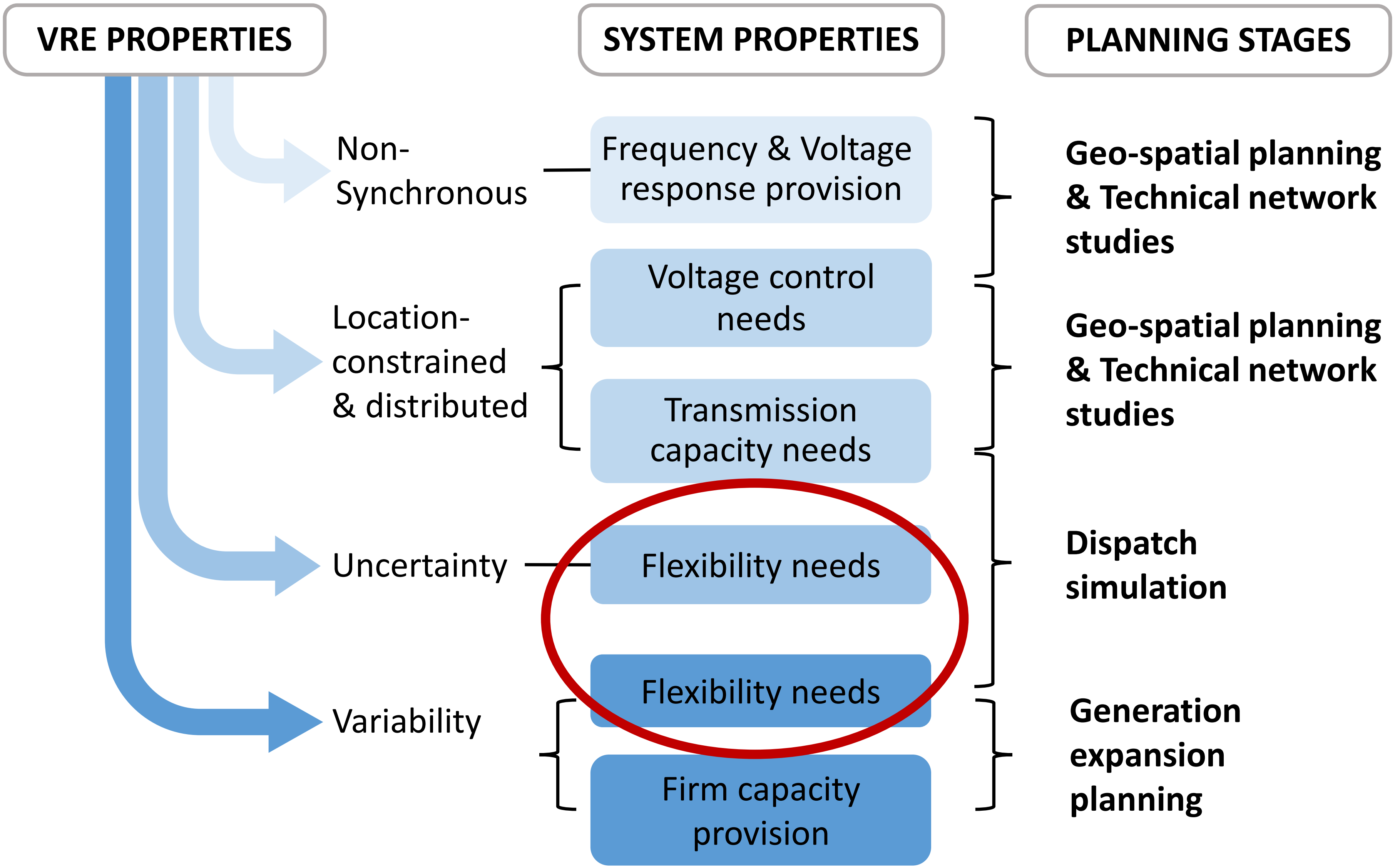
EU system operators (in 2014)	
Reliability based	2
Rule-of-thumb	8

Source: CEER (2014)

Check point 2

Is the **capacity credit** of VRE reflected in the reserve margin requirement in the model, so that long-term generation plans ensure the sufficient generation at all times?

Check point 3: Flexibility needs



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

Flexibility

Flexibility requirements

» Variability - fast changing VRE output → increase in ramping capability may be required

» Uncertainty – forecast and estimation errors → increase in operational reserve may be required

Flexibility sources

» Ramp rate

» Minimum load levels

» Start-up times

» Storage

» Interconnectors

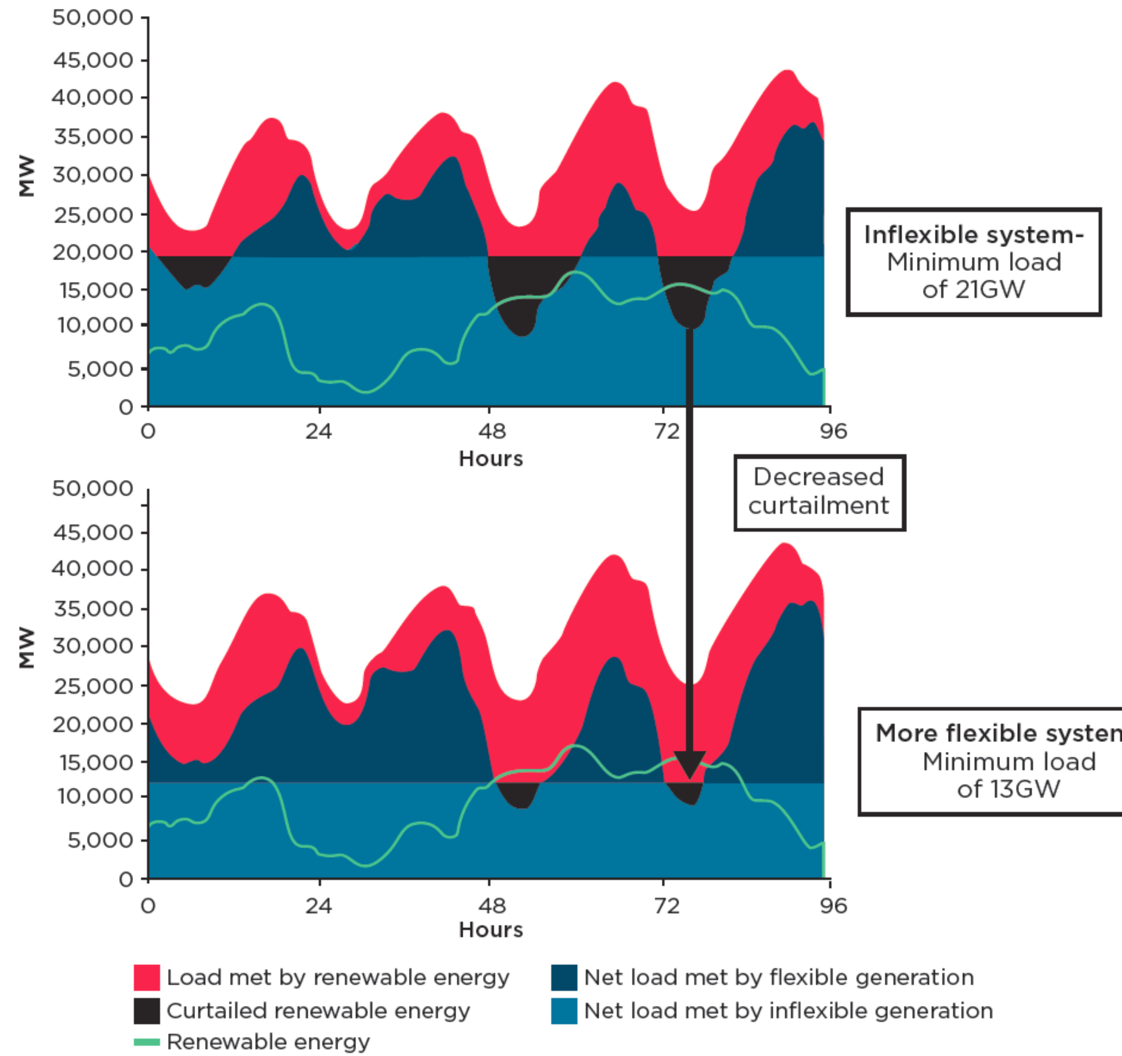
» Demand response

→ Lack of flexibility would result in inefficient operation of power systems

Planning and modelling flexibility

How are they covered in the modelling tools?

- **Flexibility parameters of various technologies**
- **Flexibility supply needs to be matched with the demand for flexibility**
- **A separate flexibility analysis may be required using a dispatch simulation tool**



Source: Denholm, P., Hand, M. (2011)

IRENA flexibility tool

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- Capacity expansion + dispatch optimization tool
- Assessment flexibility needs of a given capacity mix

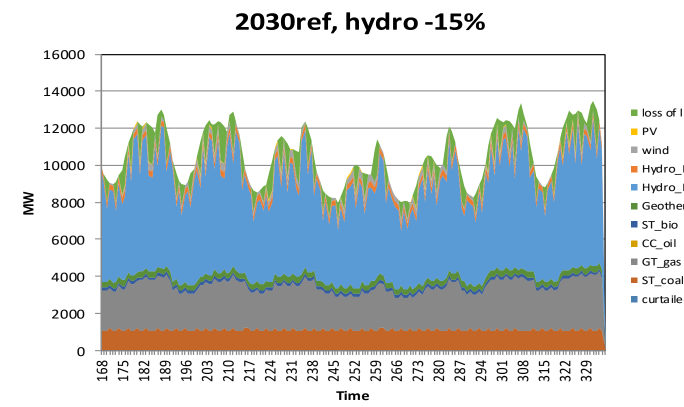
1. Input
- Estimated generation mix at 2030

2. Run the model
- Run dispatch
- New investments disabled

3. Results
- Identify flexibility shortages
- Check if any other issues

4. Alternative run
- Same input data, allow investments
- Get least cost flexibility solutions

- Flexibility metrics – loss of load, curtailment
- Flexibility options - Transmission investment, batteries, DSM, investment in new capacity



Power system flexibility enablers in the energy sector

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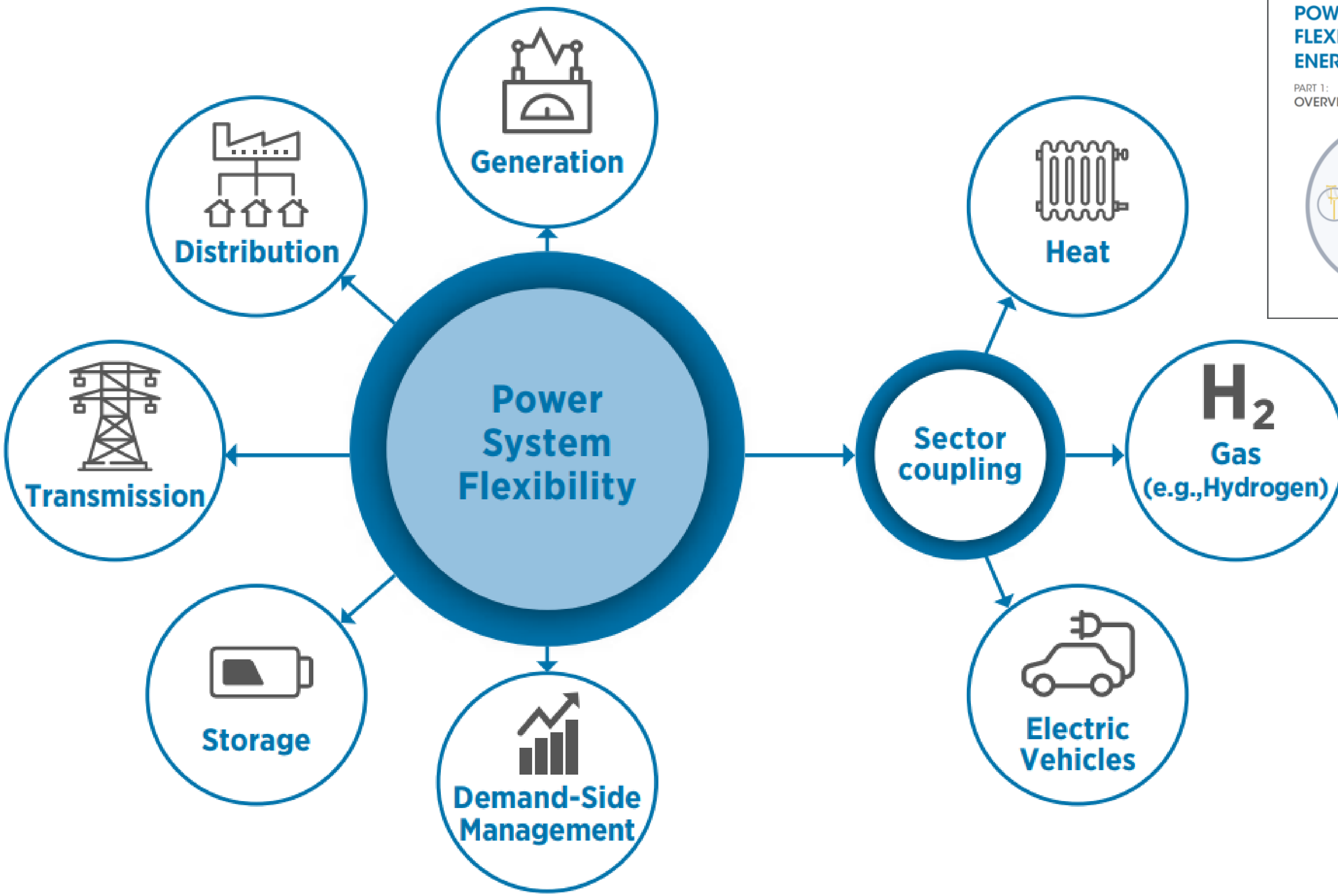

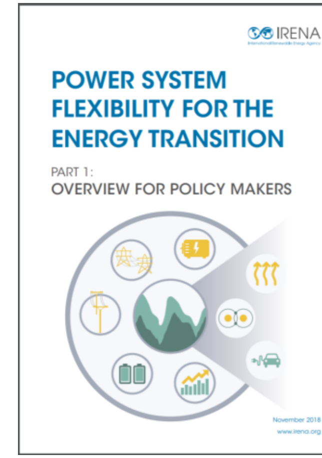

Impacts of VRE at various time scales and relevant flexibility solutions

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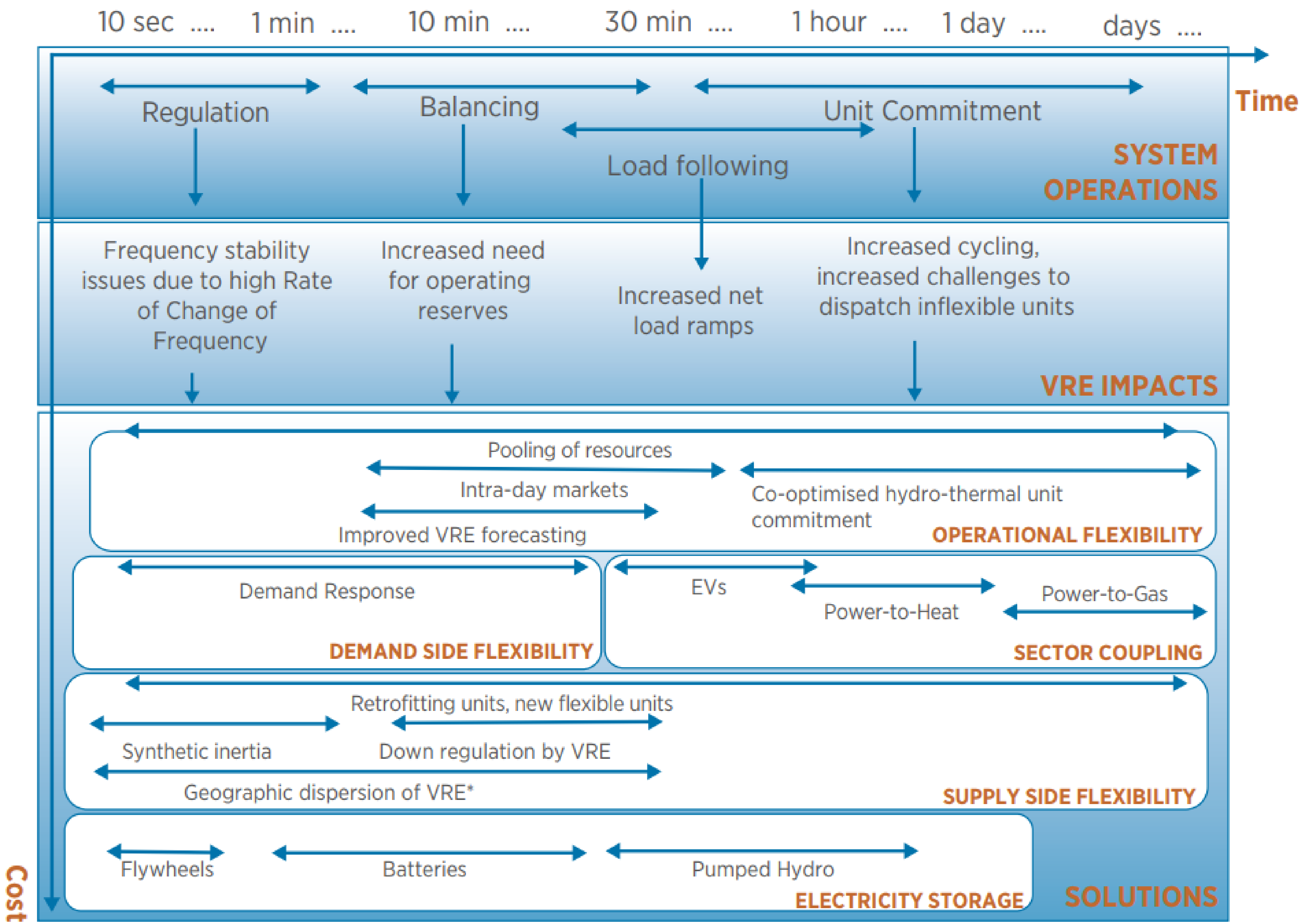
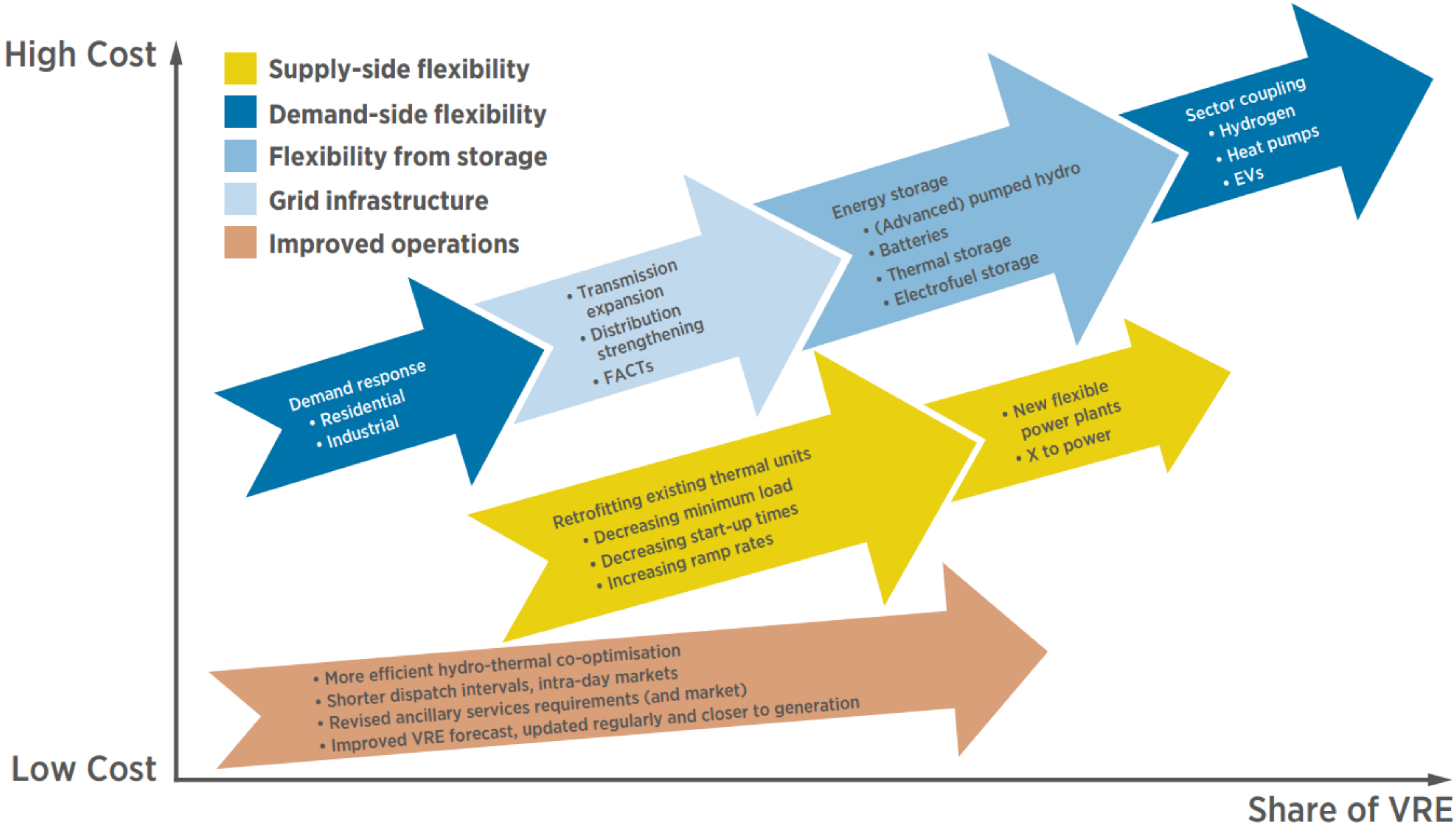


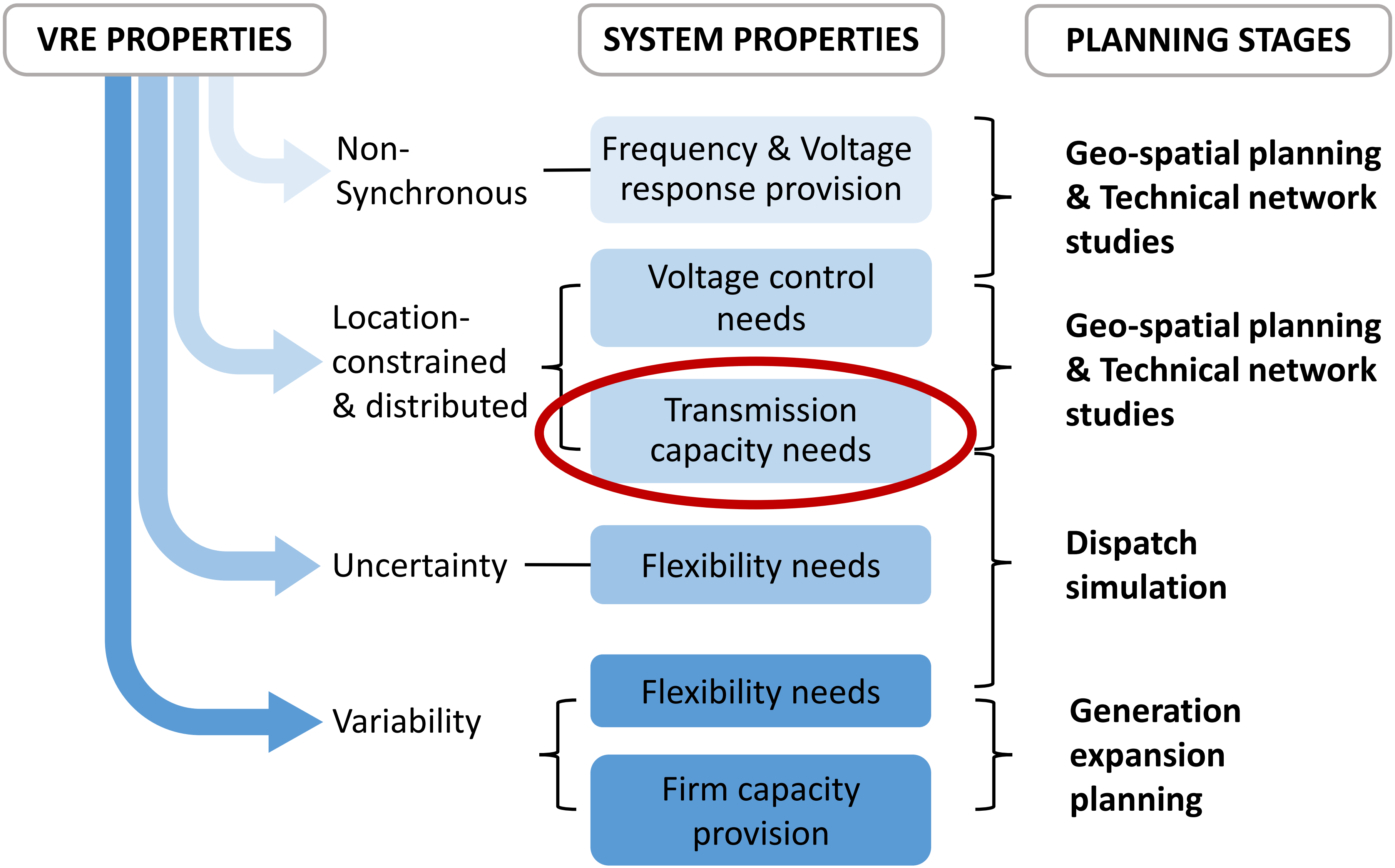
Technical options to increase system flexibility



Check point 3

Is the flexibility of a power system properly represented in the model? Do we know how much flexibility would be needed and how much would be met by what?

Check point 4: Transmission capacity



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

Location specificity

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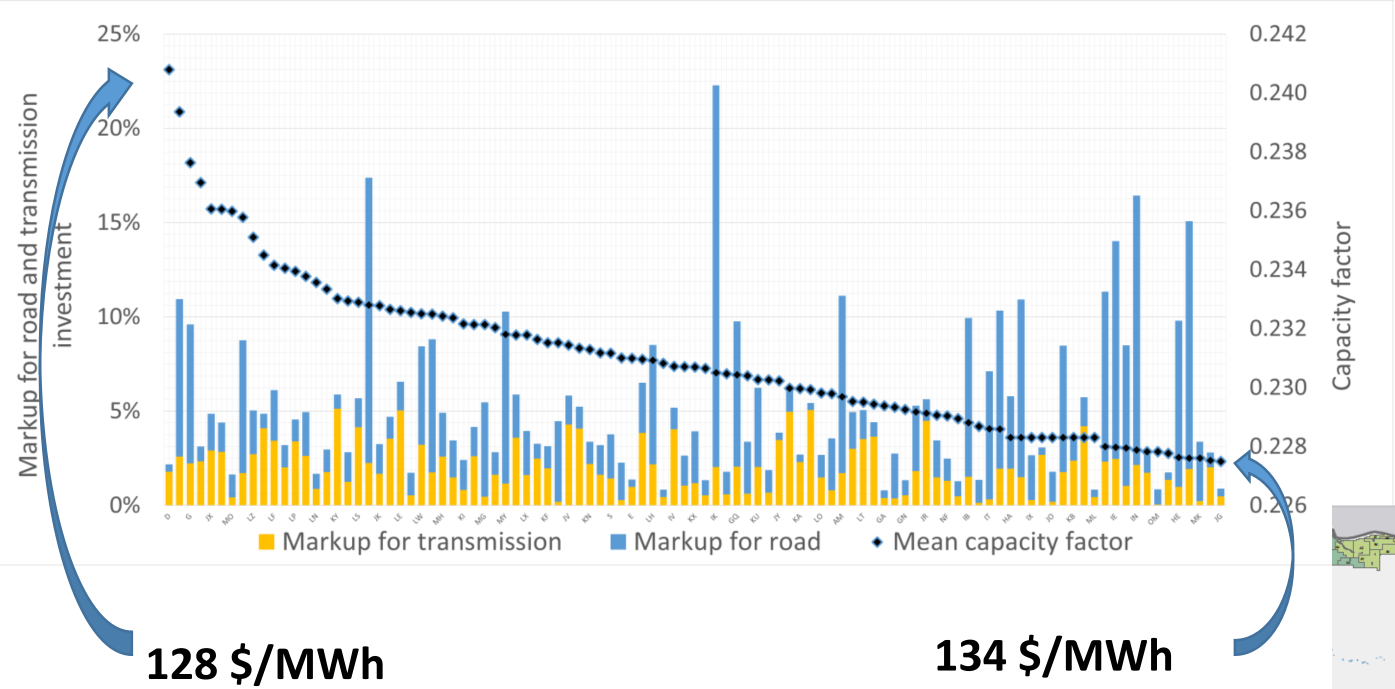
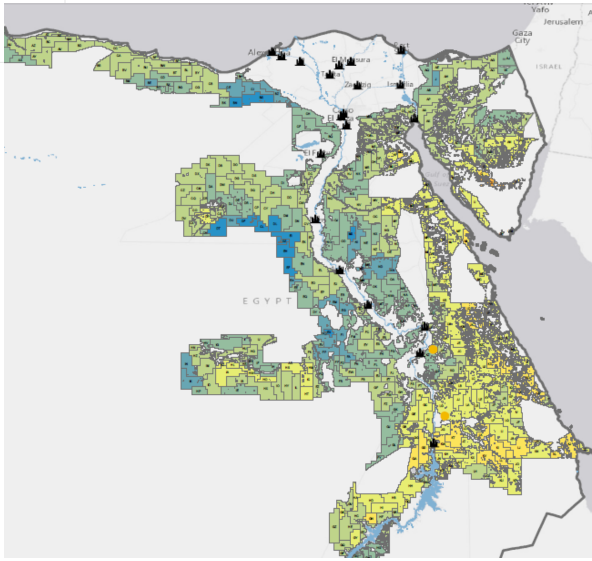


Egypt, PV zones



Source: Lawrence Berkley National Lab, MapRE

Key planning implication:

- **Trade-off between resource quality and transmission investment**

Planning and modelling transmission capacity

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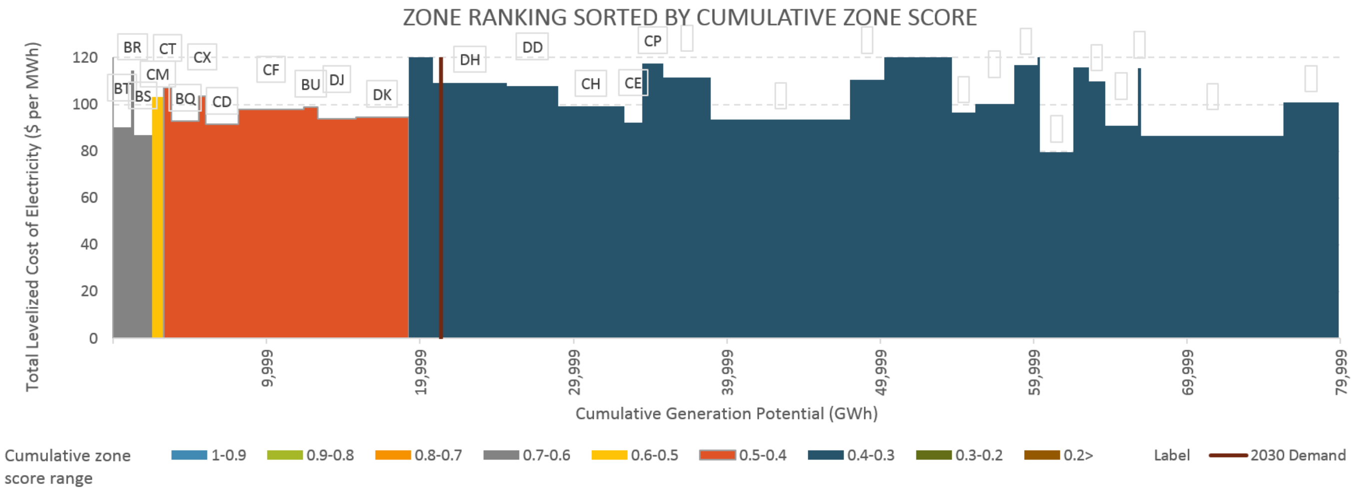
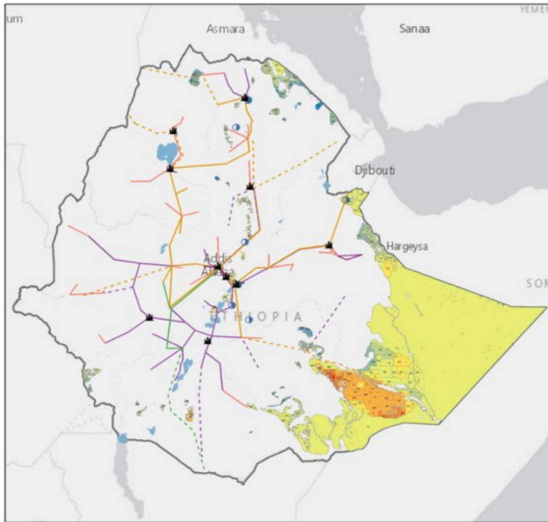
- Are transmission investment needs taken into account?
- To which degree site specificity of generation and transmission sites are taken into account?

How are they covered in the modelling tools?

Cost mark up to generation investment

Site specific representation of generation and transmission





Check point 4

Is the trade-off between resource quality and transmission investment needs analyzed in the model? Is the resource quality assessed using the geo-referenced data?

Check point 5: stability constraints

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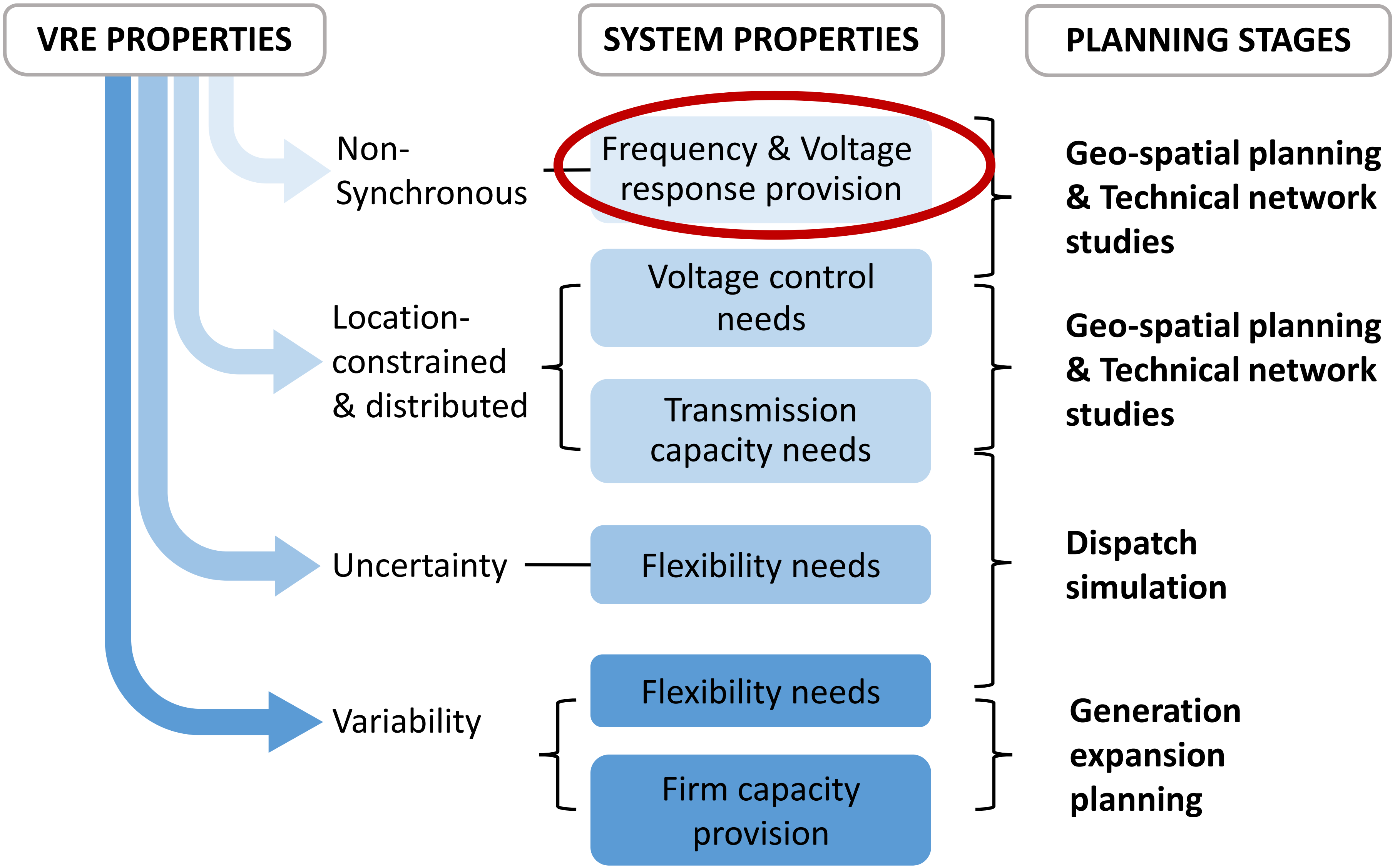

Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies

Non-synchronous interface with gird

Operating a system with a higher share of non-synchronous generators (e.g., solar PV) is a challenge as a system requires synchronous generators to provide frequency and voltage response after a contingency event (within a second) to gain **stability** in a system

How are they covered in the modelling tools?

Putting a hard constraint on instantaneous penetration limits - it can be rule of thumb or based on a full dynamic study

Check point 5

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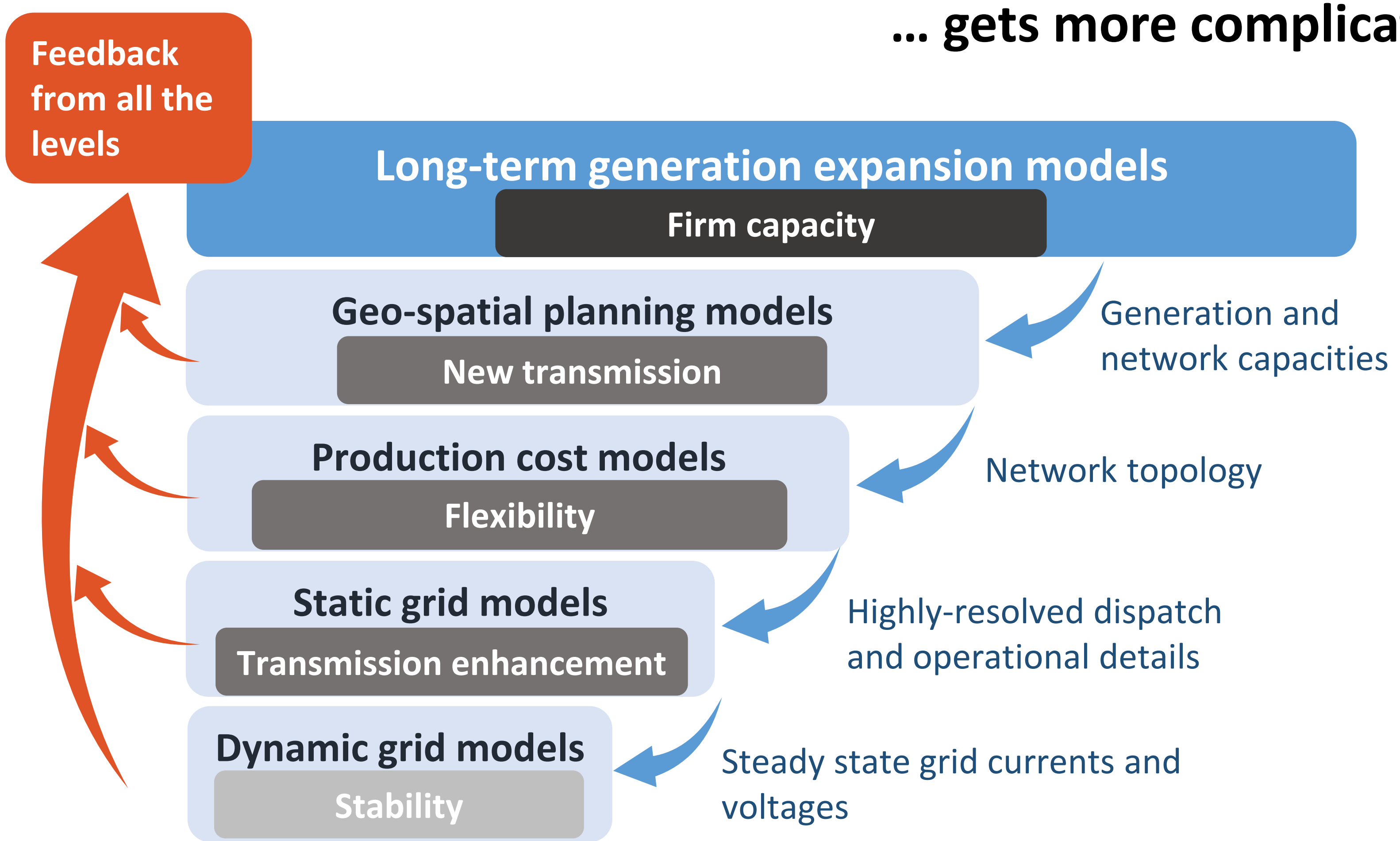
Do we expect a technical limit to instantaneous penetration of solar and wind? If so, is it a hard limit, or depending on institutional arrangements? Are these limits modelled as scenarios?

Long-term energy planning with VRE

… gets more complicated



Low High

Relevance of VRE impact in long-term planning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Thank you
Asami Miketa, Amiketa@irena.org

Solar PV Cost Trends

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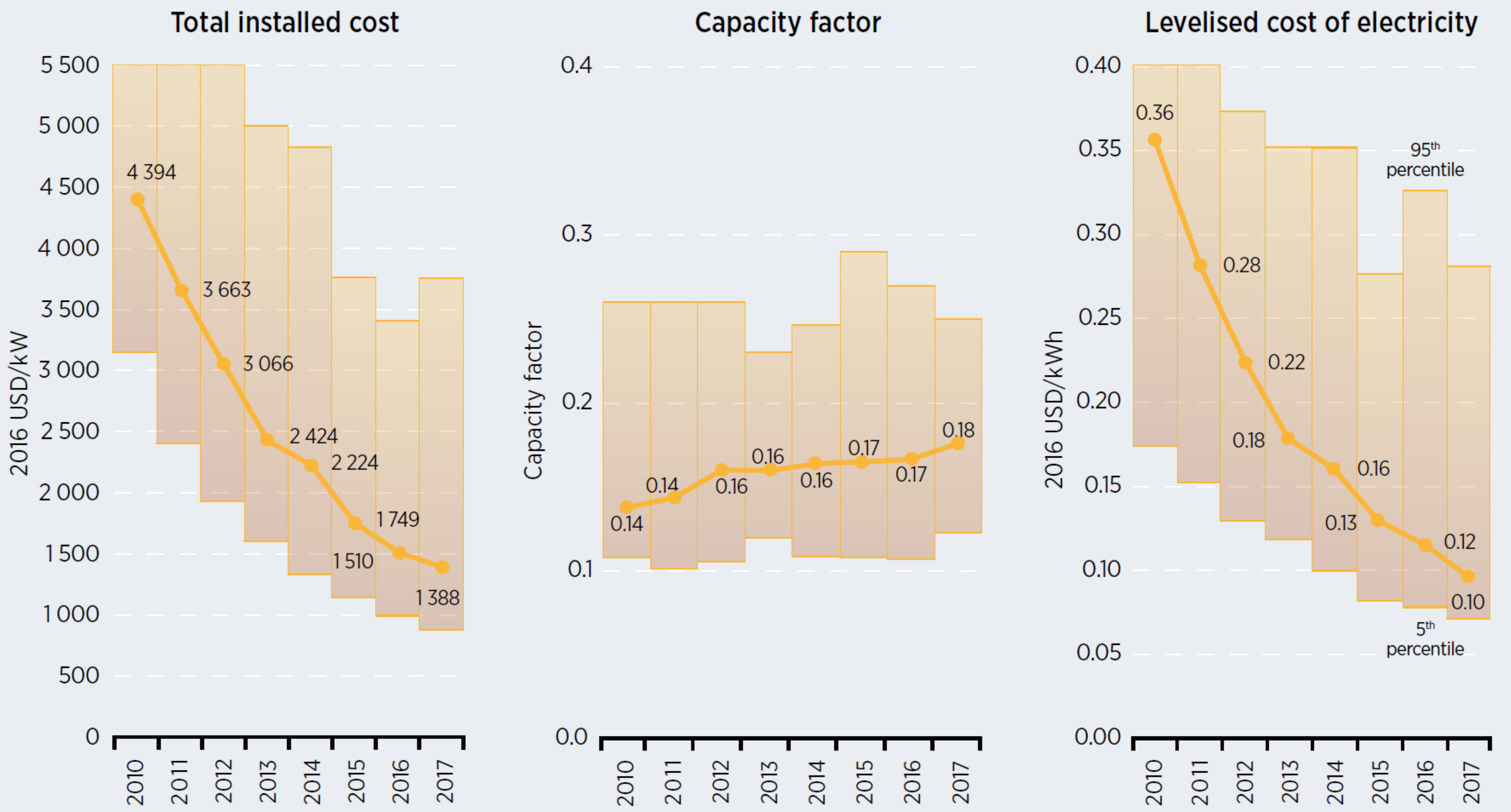
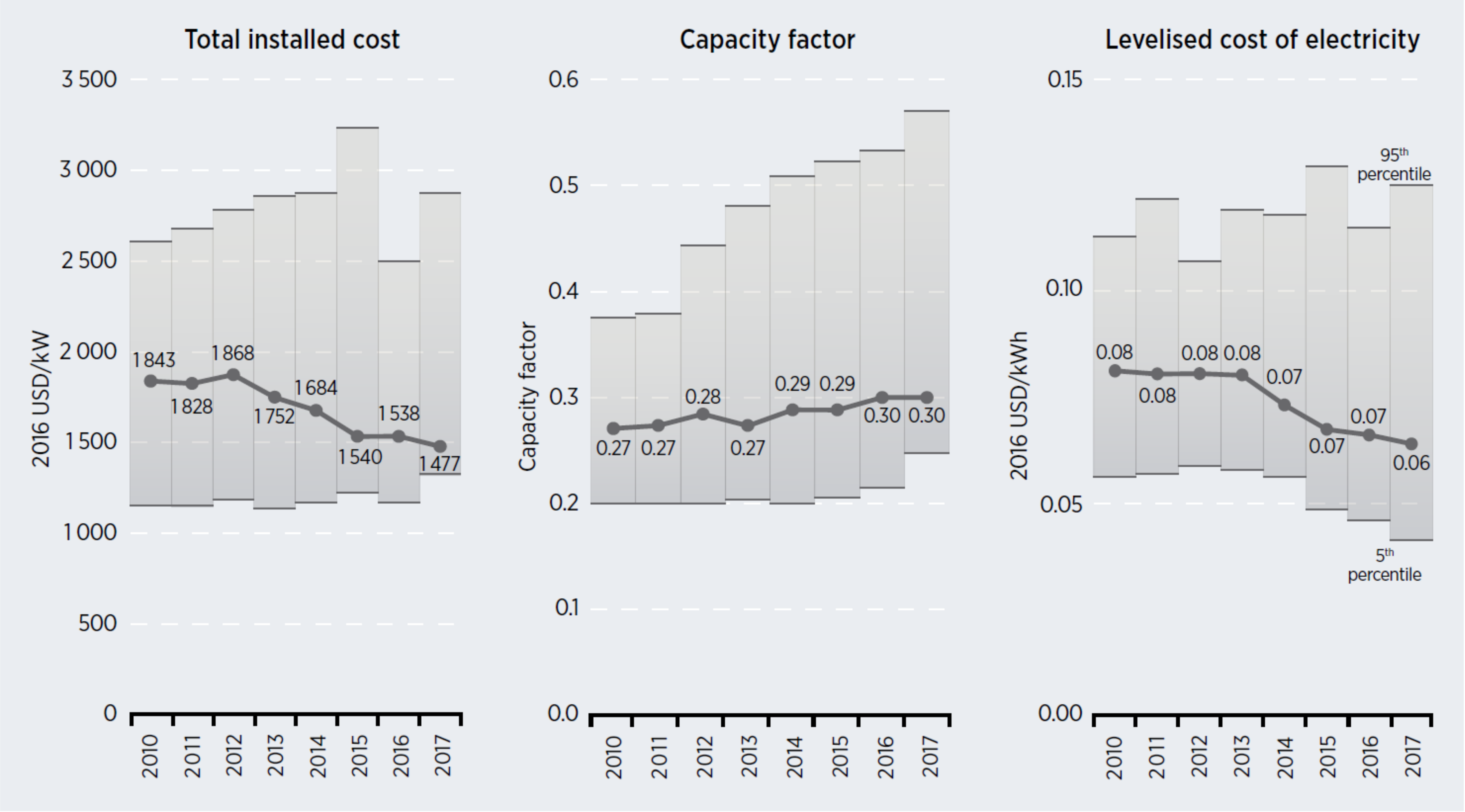


Onshore Wind Cost Trends



Source: IRENA Renewable Cost Database.

Firm capacity / capacity credits

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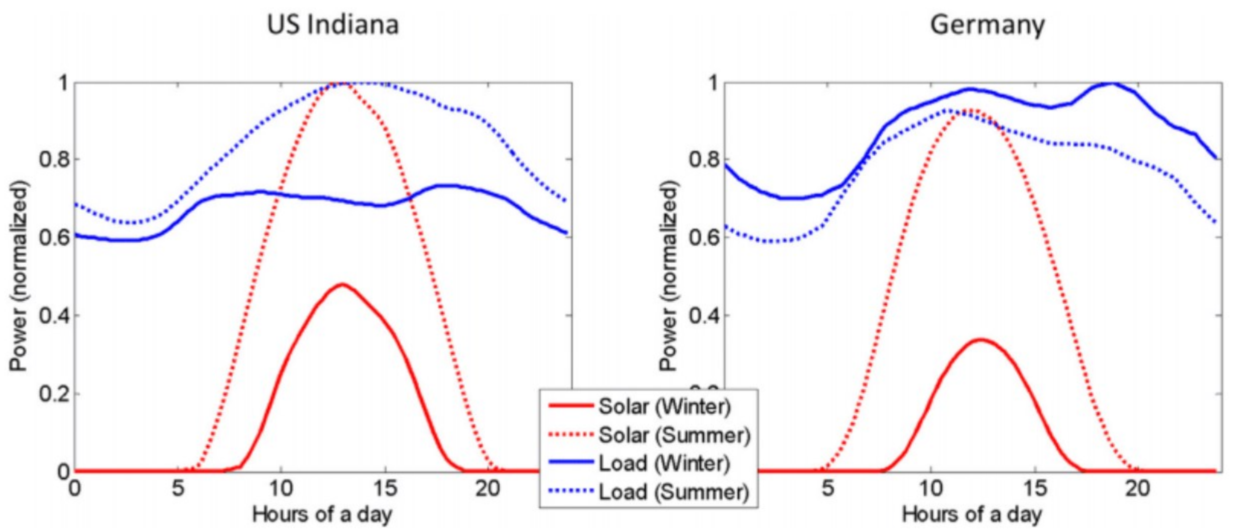
Driven by temporal correlation of VRE and load pattern

Sun is not guaranteed to shine when needed
Conventional generators are guaranteed to generate when needed

1 MW of solar generators < 1 MW of conventional generators
→ Lower **capacity credit**



Higher capacity credit

Lower capacity credit