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Key long-term planning considerations with a higher share of VRE

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Power system planning: Fundamentals

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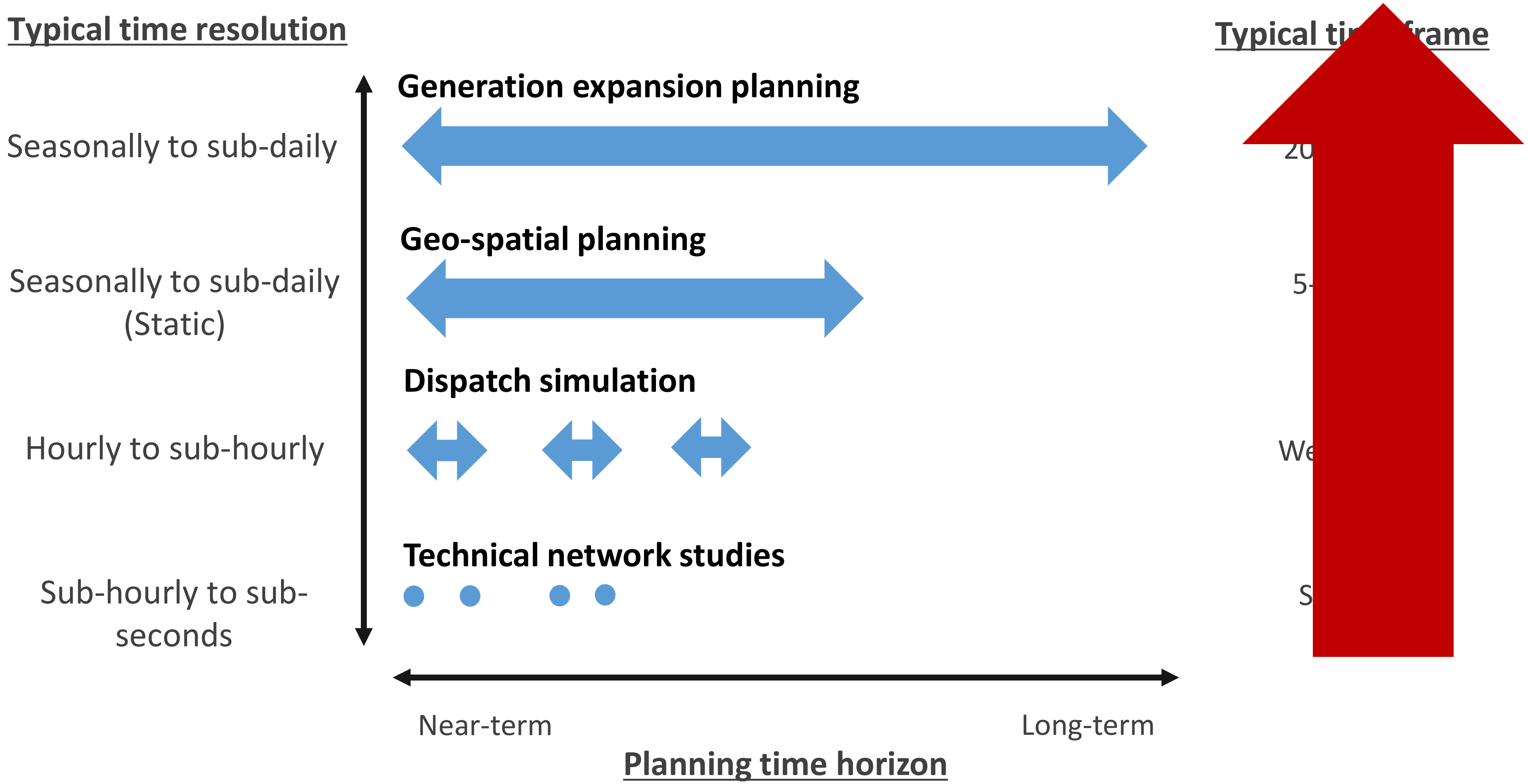
How much electricity demand will there be?

How much and what type of generation is needed to serve this demand?

What enhancements to the network are needed to ensure the reliable supply of electricity?

Energy/power system models are used to answer these questions while taking into account economic and technical consequences of alternative choices.

Time dimensions of power sector planning



Source: IRENA

Generation capacity expansion planning

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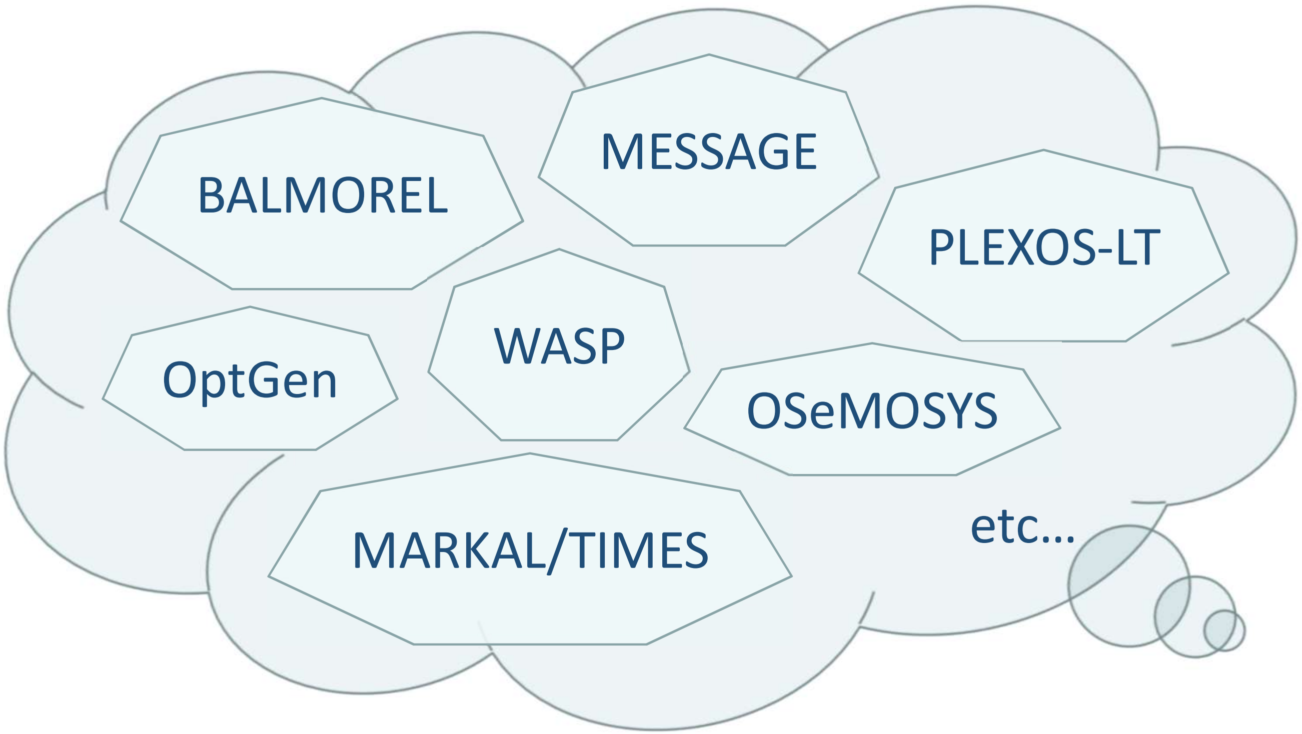
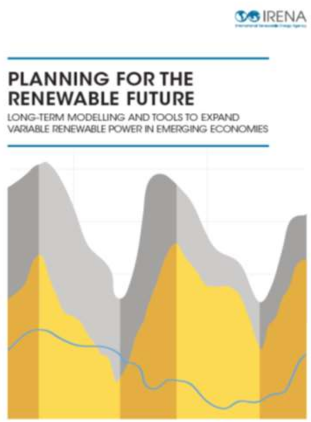
Commonly used modeling software



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



A wide spectrum of planning tools

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Long-term energy planning tools

Connolly et all (2010) – 37 tools

- Simulation
- Equilibrium
- Top-down
- Bottom-up
- Operation optimization
- Investment optimization

Long-term power sector planning tools

Af-Mercados EMI (2011) – 22 tools

- Dispatch included
- Objective function
- Network included
- Stochastics modelling
- Reliability considered
- Renewable energy variability
- Forecasting errors

A wide spectrum of planning tools

Long-term energy planning tools

Connolly et all (2010) – 37 tools

- Simulation
- Equilibrium
- Top-down
- **Bottom-up**
- **Operation optimization**
- **Investment optimization**

Long-term power sector planning tools

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Example of capacity expansion planning tools used by utilities in the MENA region

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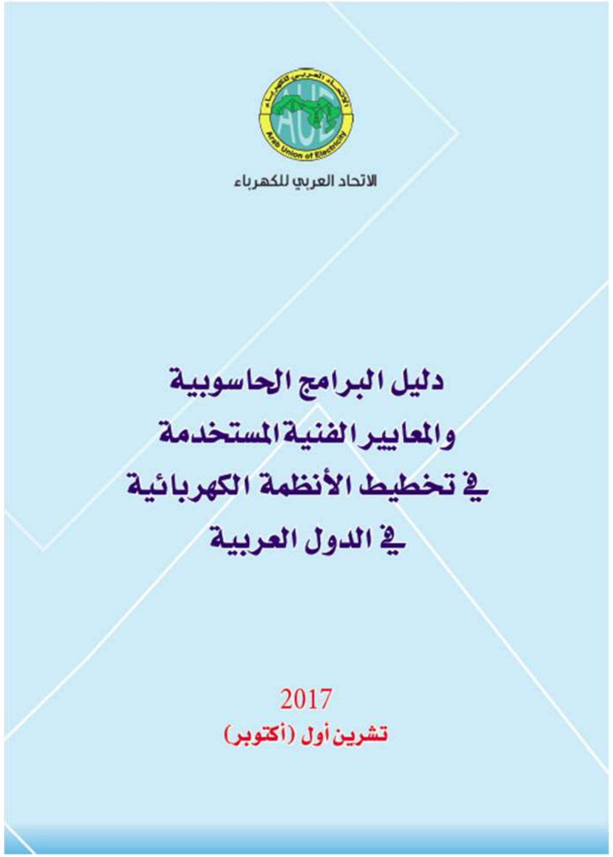
Tools [developer]	List of the countries that used the tool
Aurora [EPIS]	Oman
EGEAS [EPRI]	Egypt, Qatar
EMS - Economic Dispatch [Alstom - GE]	Bahrain
eterracommit [Alstom - GE]	Bahrain
NCP [PSR]	Morocco
OPTGEN [PSR]	Morocco
Ordina [Mercados]	Saudi Arabia
Promod [ABB]	Saudi Arabia
WASP [IAEA]	Algeria, Jordan, Libya, Saudi Arabia, Sudan, Tunis, UAE
***Not available**	Iraq, Syria, Palestine

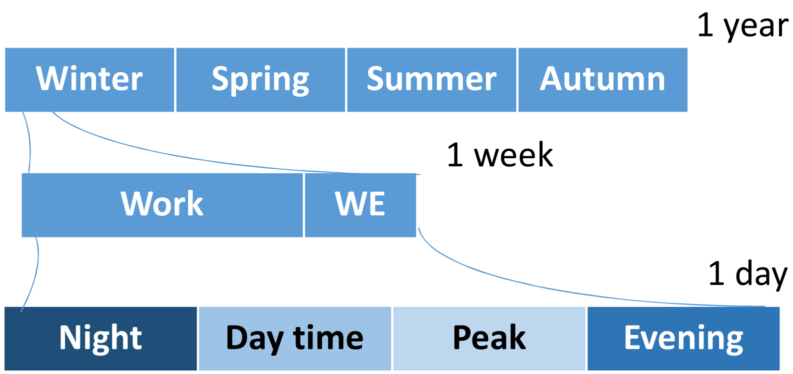


Example of the capacity expansion tools used by governments in the LAC region

- **MESSAGE, TIMES** (Argentina, Paraguay, Peru); **OptGen** (Bolivia, Colombia, Ecuador, Peru); **PET** (Chile); **PLEXOS** (Mexico); **WASP** (Uruguay)

Features of generation expansion planning model

- Long-planning horizon
- Capacity build up with time steps of 1-5 years
- Limited time resolution
- Limited spatial resolution



Total of 32 slices

Example of models with advanced approaches

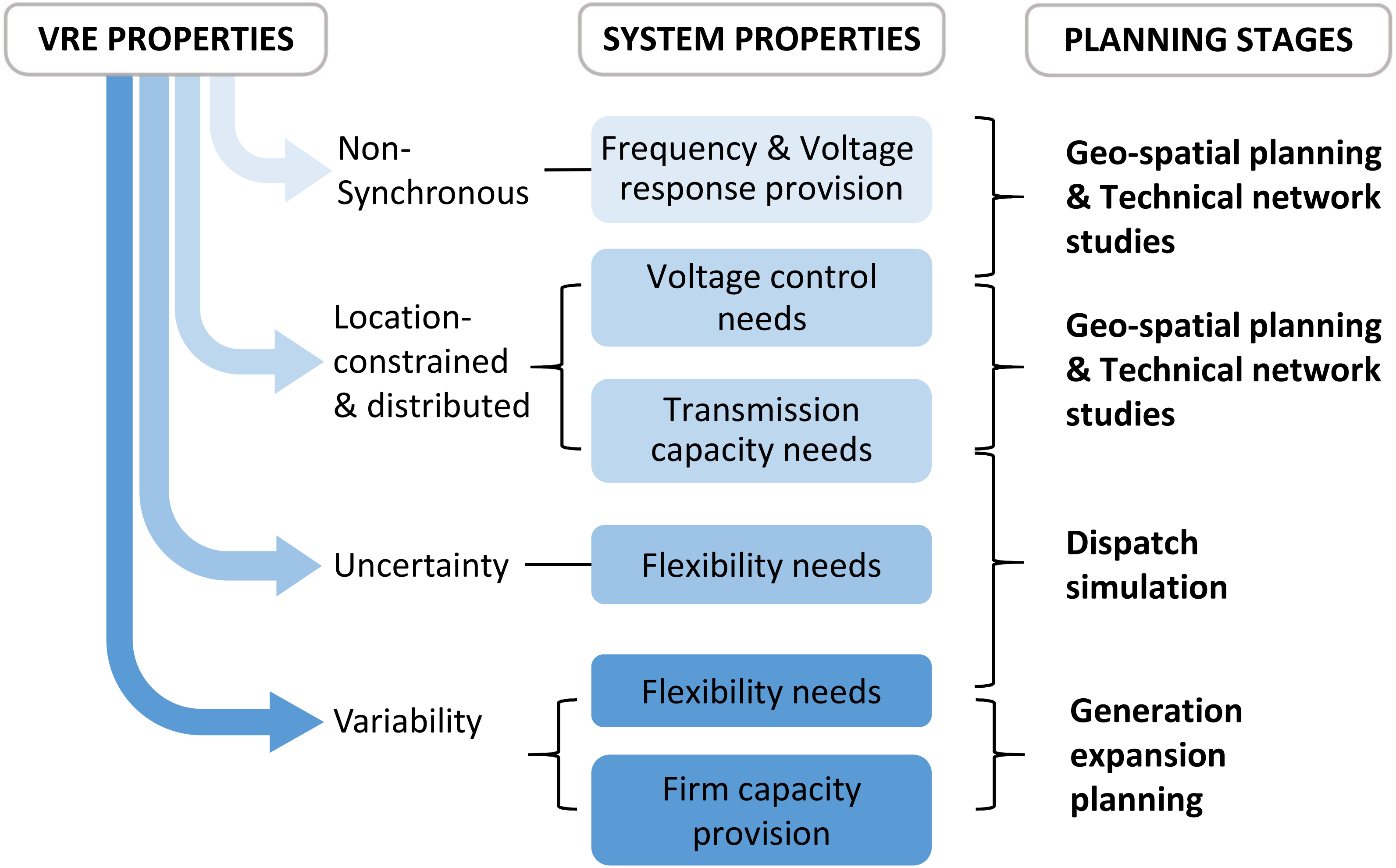
Model name	Region	No. of time slices
GEMS +CEEM	Germany	**432**
DIMENSION +INTRES	Europe	**192**
DIMENSION	Europe	**7200**
US-REGEN	US	**50**
LIMES-EU+	Europe & Middle East and North Africa	**49**
URBS-EU	Europe	**8064**
-	Texas (US)	**696**

Elements of system reliability

	Generation	Networks
Adequacy	Sufficient firm capacity	Sufficient and reliable transport and distribution capacity
Security	Flexibility of the system Stability (Robustness to contingency)	Voltage control capability Stability (Robustness to contingency)

Generation from VRE generators is variable, uncertain, location-constrained, non-synchronous, and often distributed (connected to distribution grid).

Tools for different stages



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

Elements of system reliability: Impacts of VRE

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	Generation	Networks
Adequacy	Variability reduces contribution to firm capacity	Location-constraints may require grid extension and reinforcement
Security	Variability and limited predictability requires system to follow residual load Lack of inertia and governor response may pose the technical limit to VRE penetration	Location-constraints may change voltage control requirements Distribution level connection may affect voltages and protection system coordination RE's behavior during fault may affect system stability

VRE: Long-term investment implications

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

Most relevant	(red)	System-specific	(light orange)
High relevance	(orange)	Near-term relevance	(light blue)

Key features of solar and wind

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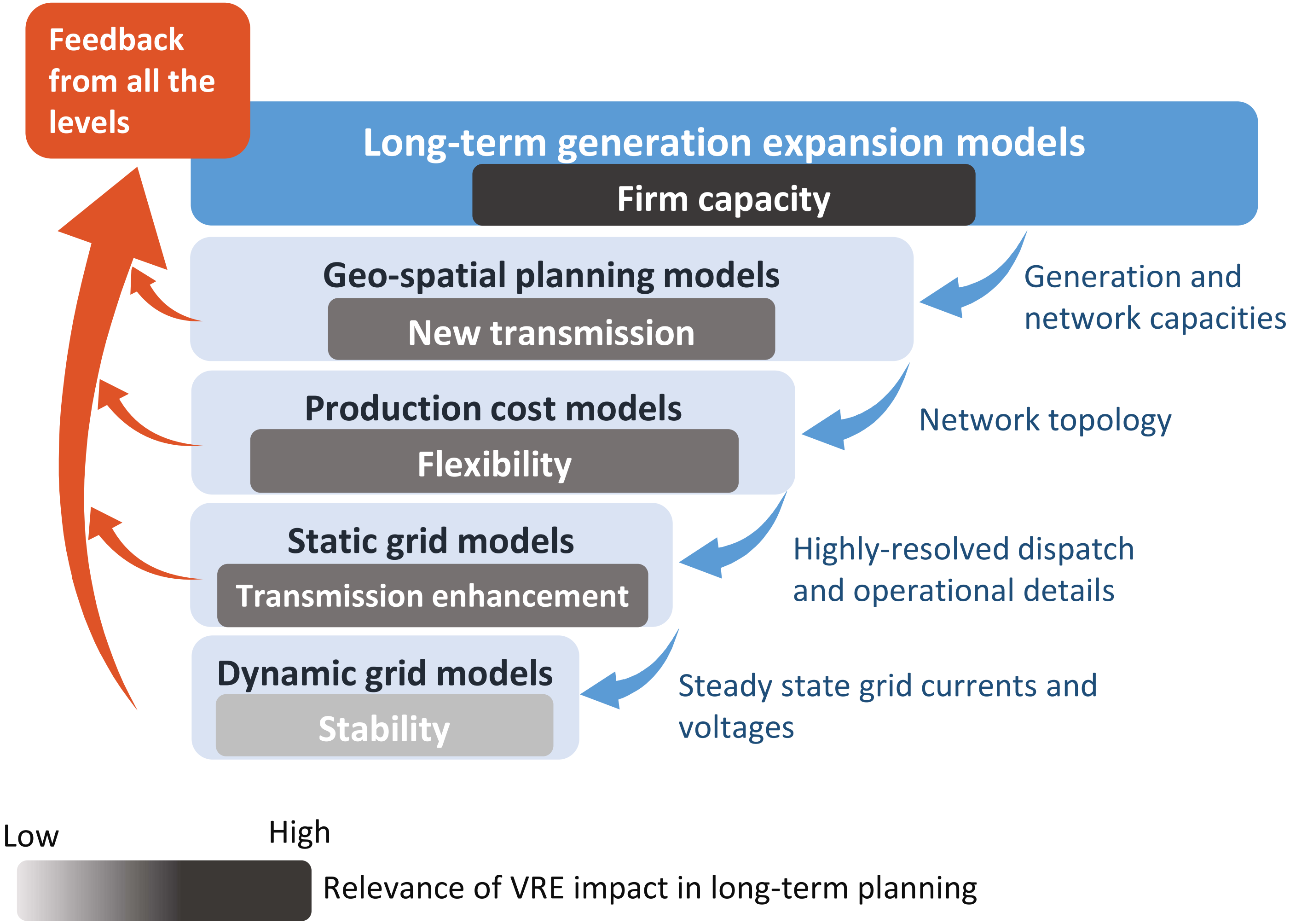
- » Rapid cost reduction
- » Firm capacity / capacity credit
- » Flexibility
- » Transmission investment needs
- » Stability consideration

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

Application of planning tools … with VRE



It is important to do it right from the beginning!

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How?

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

How can generation expansion models incorporate these feedbacks?

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- Creation of a “super model”?
- Model coupling?
- Simplified representation of the key elements in a simplified manner?
  - Input data preparation (better temporal and spatial resolution RE generation data)
  - Model constraints

To be addressed in the open discussions of this workshop

Notes on choice of software

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

The choice of software is often 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

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

Check point 1

» Fast cost reduction

» Firm capacity / capacity credit

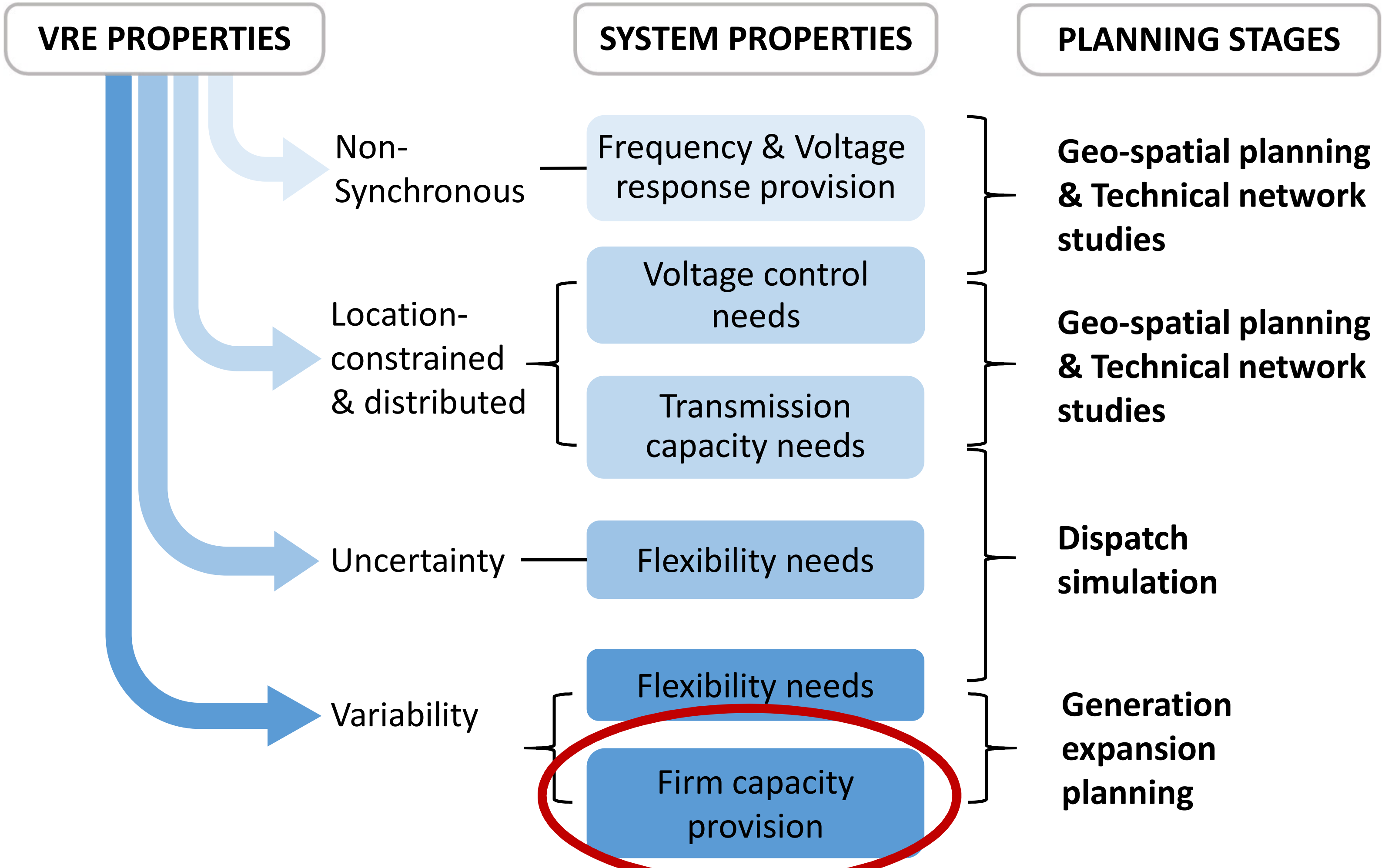
» Flexibility

» 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.

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

Check point 2-1

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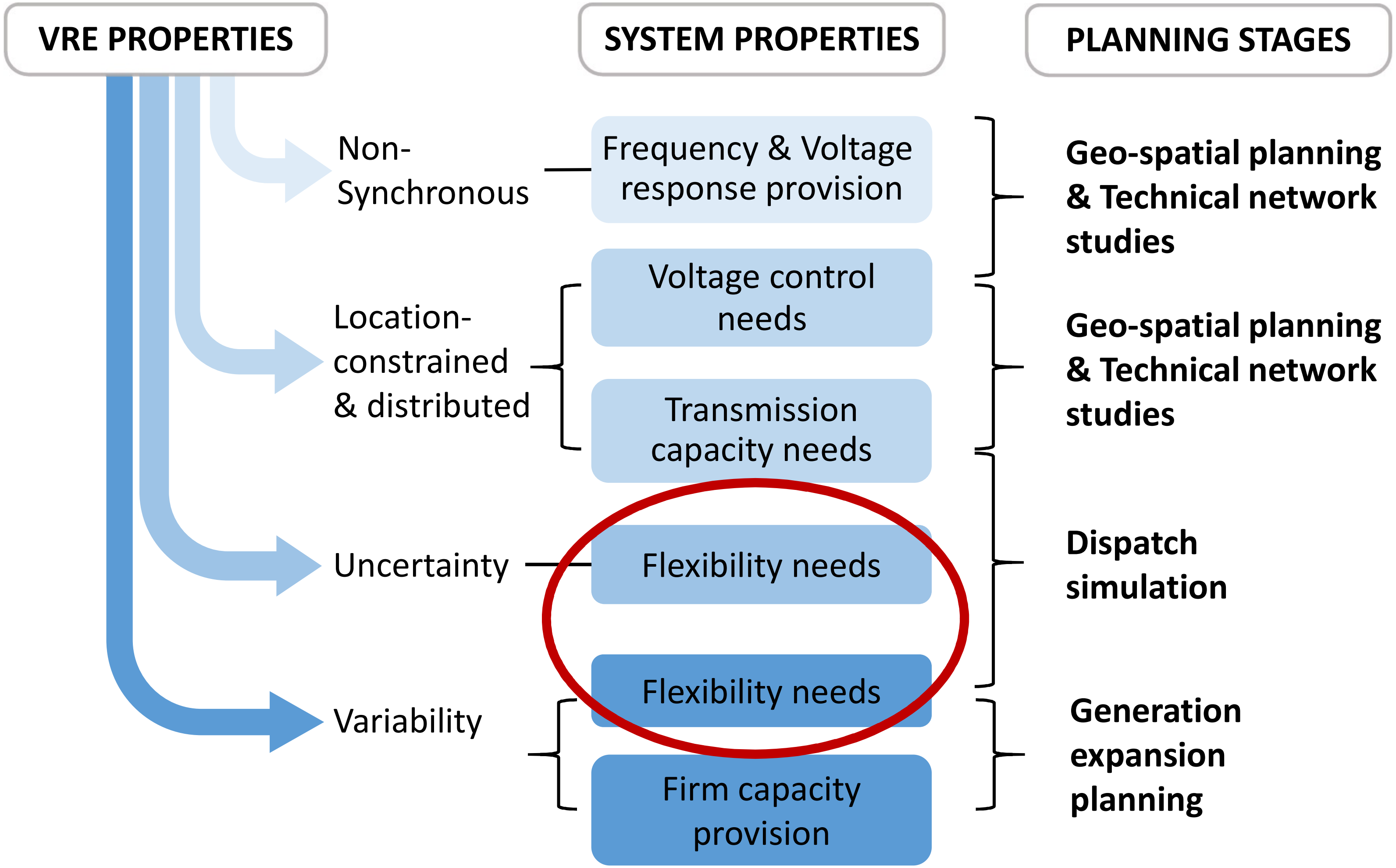
Does the model reflect the solar and wind variability based on meteorological data?

Check point 2-2

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

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

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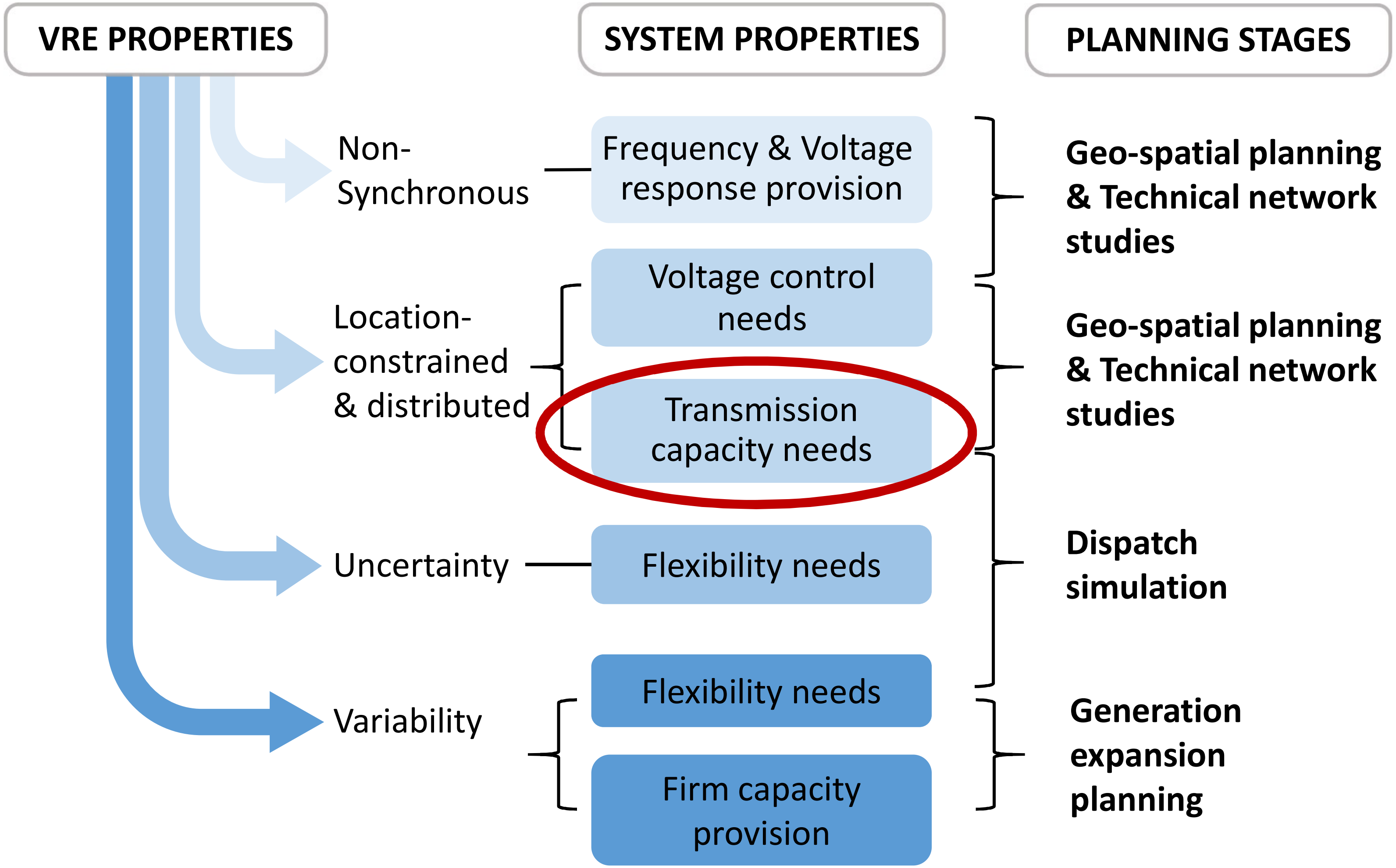

Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies

Check point 4

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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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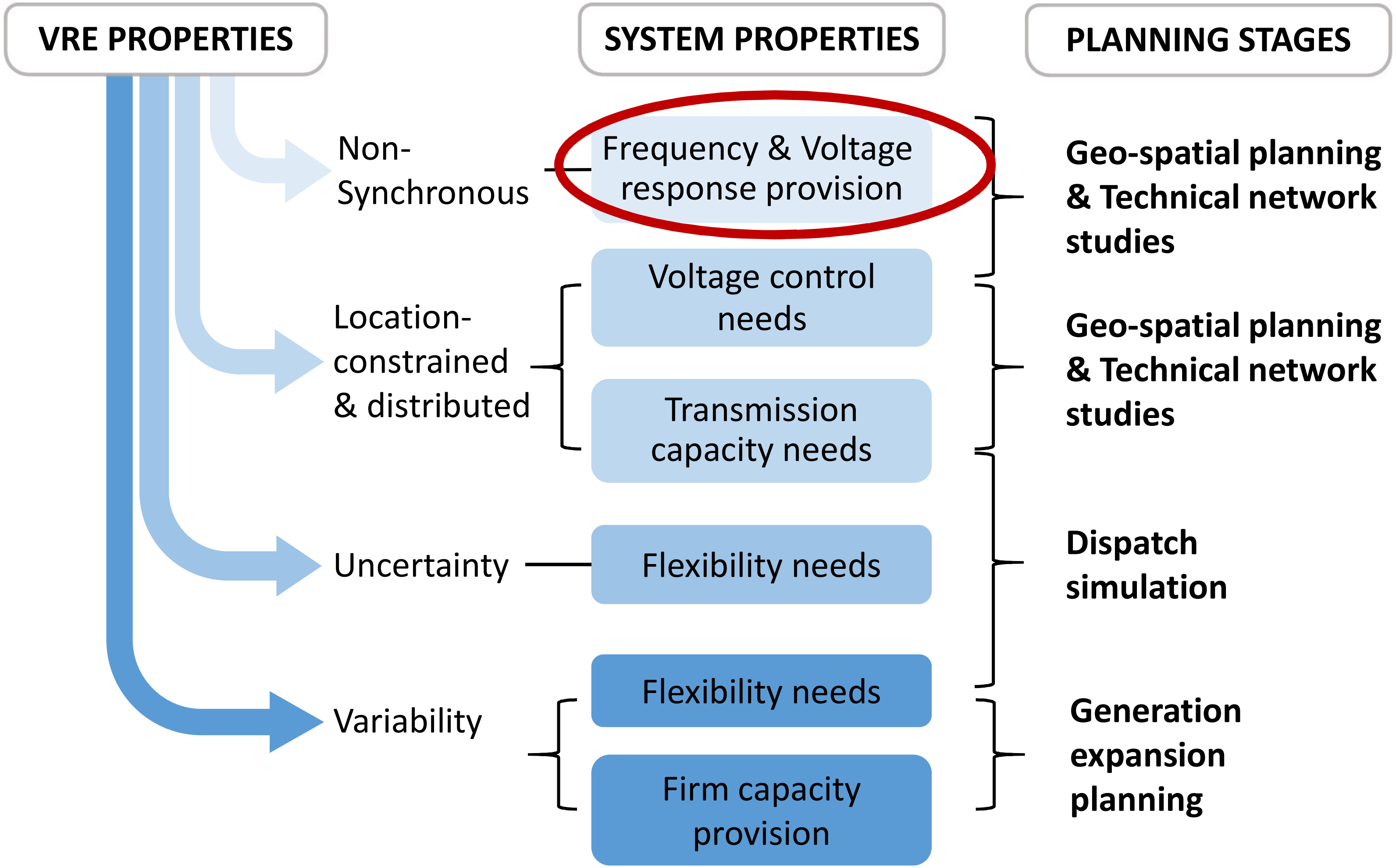
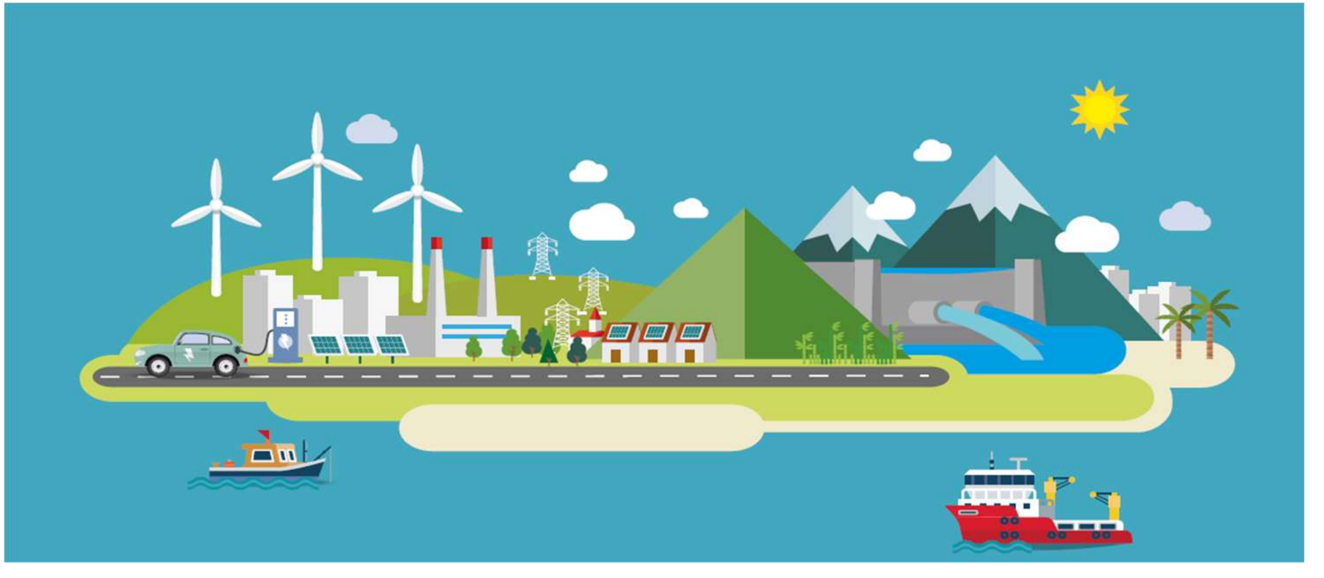


Source: IRENA (2017), Planning for the Renewable Future: Long-term modelling and tools to expand variable renewable power in emerging economies

Check point 5

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?



Next sessions

- » Input presentations
  - » Relevance of the each of the five concepts to VRE and long-term planning
  - » Modelling approaches
- » Country experiences
  - » Moderated discussion based on the survey
  - » Possible gaps

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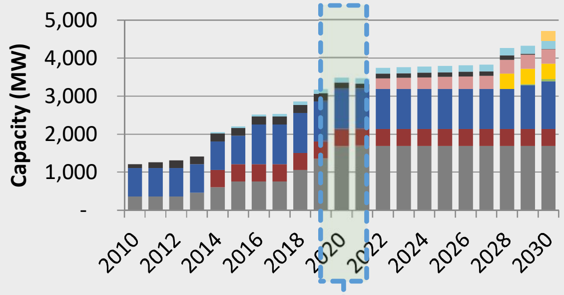
Power system planning: Scopes of analysis

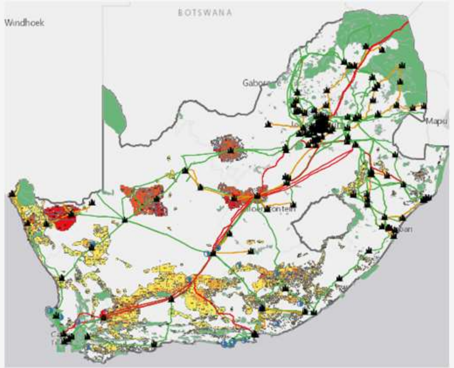
Capacity expansion planning

- Ministry of Energy
- Utility
- Planning agency



Geo-spatial planning

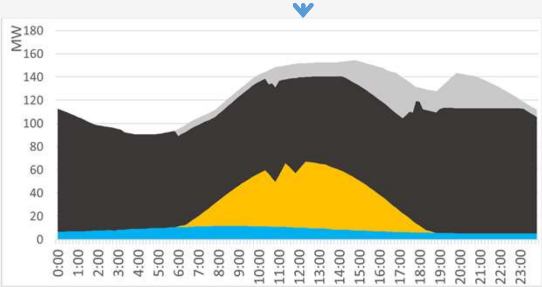
- Government planning office
- Planning agency
- Utility
- TSO



Snapshot of one year

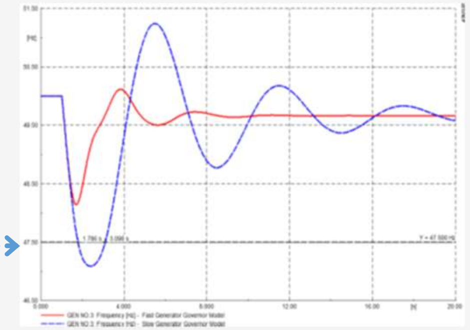
Dispatch simulation

- Utility
- Regulators
- TSO



Technical network studies

- TSO
- Regulator
- Project developer



Snapshot of one moment

Long-term energy planning with VRE

… gets more complicated