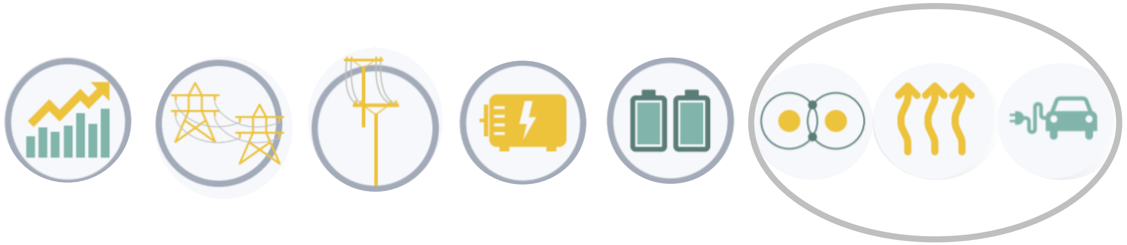
Power System Flexibility for the Energy Transition



Emanuele Taibi
Power Sector Transformation Strategies

LTES webinar, 21 March 2019, Bonn

Agenda

1. **Introduction to IRENA's work on power system flexibility**

2. **Power system flexibility for the energy transition**

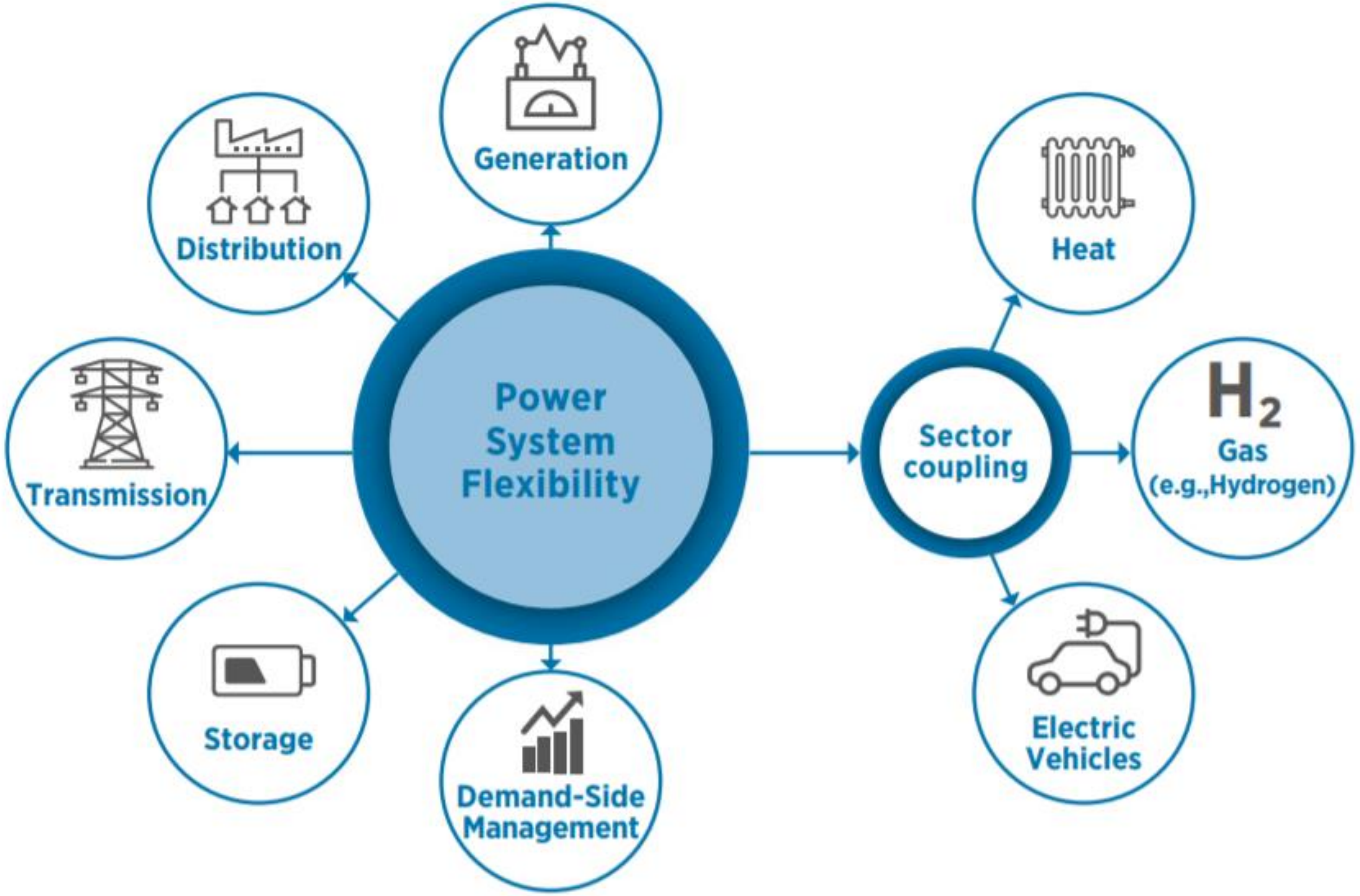
3. **The IRENA FlexTool**

Flexibility needs to be harnessed in all sectors of the energy system

Flexibility according to IRENA (2018):

"Flexibility is the capability of a power system to cope with the variability and uncertainty that VRE generation introduces into the system at different time scales, from very short to the long term, avoiding curtailment of VRE and reliably supplying all the demanded energy to customers"

- 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*

The need to complement long term with dispatch models

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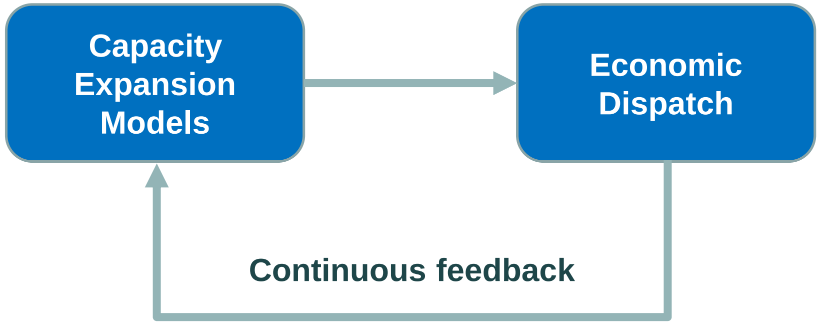
- » If we had unlimited computational power (maybe soon with quantum computers?) could be one single problem. Maybe deep learning can soon target such problems?
- » Most operational constraints are not included in capacity expansion models
- » Time granularity is reduced often without preserving chronology
- » Long-term capacity expansion models (CEM) cannot capture all the relevant variables with the degree of detail required – **Economic dispatch (ED) models are necessary to:**

1. Evaluate power system flexibility
2. Correctly represent Energy Storage
3. Analyse production costs and market prices
4. Add binding technical constraints (e.g. MSL, inertia)
5. …



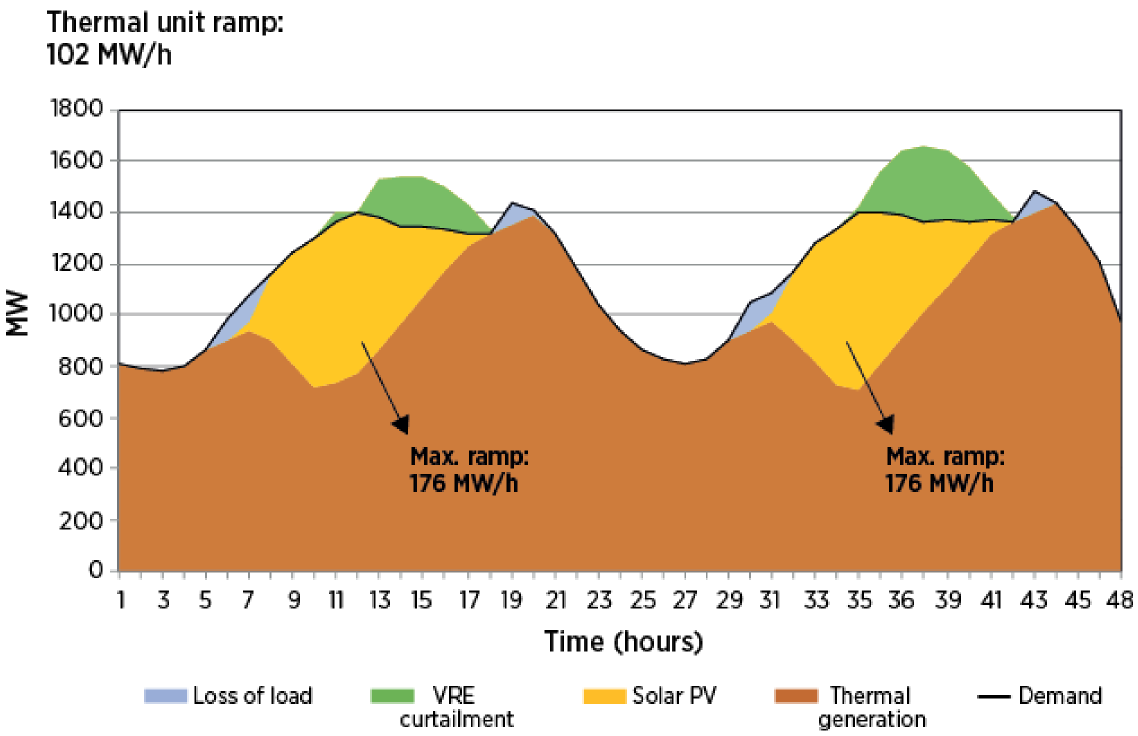
Contents lists available at ScienceDirect
Renewable and Sustainable Energy Reviews
journal homepage: www.elsevier.com/locate/rser
ELSEVIER

Integrating short term variations of the power system into integrated energy system models: A methodological review

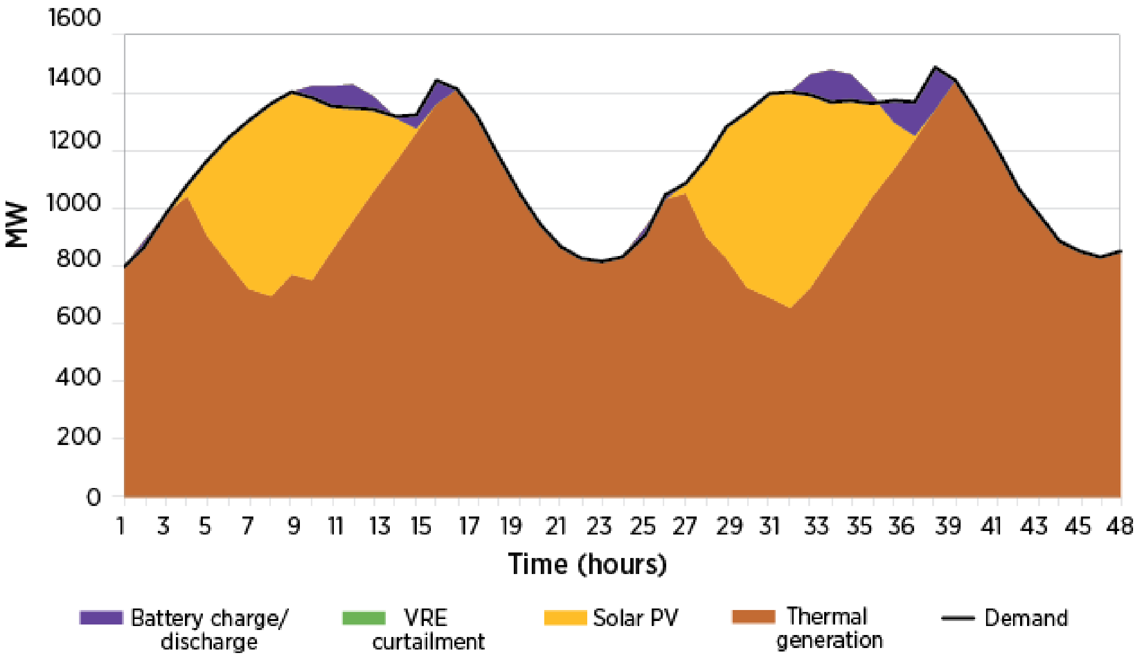
Seán Collins[a,b,c,*], John Paul Deane[a,b,c], Kris Poncelet[d,e,f], Evangelos Panos[g], Robert C. Pietzcker[h], Erik Delarue[d,e], Brian Pádraig Ó Gallachóir[a,b,c]

Example of insufficient flexibility and solutions

Insufficient ramping capability



Battery storage reducing ramps



Review of flexibility approaches

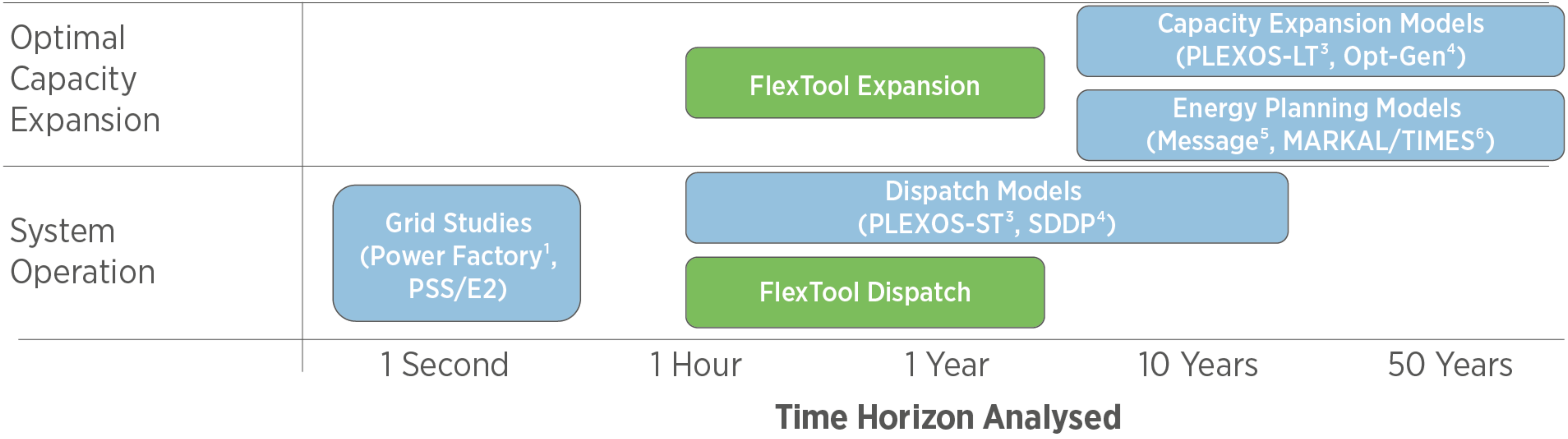
- Tier 1: **Tools with light data requirements**
  - Based on data such as the generation portfolio, interconnectors or other potential sources of flexibility
  - Require expert judgement
  - Examples: NREL System Evaluation, GIVAR charts (IEA)

- Tier 2: **Tools that calculate sufficiency of flexibility based on time series and more detailed unit data or based on a separate dispatch from an external tool**
  - Calculations performed in a spreadsheet without any type of optimisation
  - Examples: FAST2 (IEA), INFLEXION (EPRI)

- Tier 3: **Tools based on dispatch models**
  - IRENA FlexTool in this tier, including additionally a simplified capacity expansion problem
  - Other examples: FESTIV (NREL), RESOLVE (E3)

Power system modelling tools and the IRENA FlexTool

FlexTool in the planning process



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[5] Developed by the International Institute for Applied Systems Analysis (IIASA)
[6] Developed by the Programme of Energy Technology Systems Analysis (ETSAP)

Introduction to the IRENA FlexTool

- The **IRENA FlexTool** is a detailed but user-friendly tool that:
  - Analyse system operations using a time step that represent real world challenges (typically 1 hour and 1 year horizon) by solving a linearized economic dispatch problem
  - Carry out long-term analyses and propose possible flexibility solutions in a system with high VRE penetration: generation, transmission, storage…

Flexibility indicators	
Loss of load (terawatt-hours (TWh) and %)	VRE curtailment (TWh and %)
Reserves shortage (megawatts (MW))	Capacity inadequacy (MW)
Spillage (TWh)	

- 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

- **The IRENA FlexTool has become the only publicly and freely available tool that performs capacity expansion and dispatch with a focus on power system flexibility**

Use of the tool

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Primary: assesing flexibility of capacity expansion plans

Identify potential flexibility shortages in national electricity plans.

Study operations during non-average years, *e.g.*, dry years.

Capacity expansion plans from national authorities and from IRENA REmap are the ideal starting point

Secondary: cost-efficient additional investments

Identify the least-cost mix of solutions to flexibility shortages.

Study additional investments that can minimise total system cost (CAPEX + OPEX)

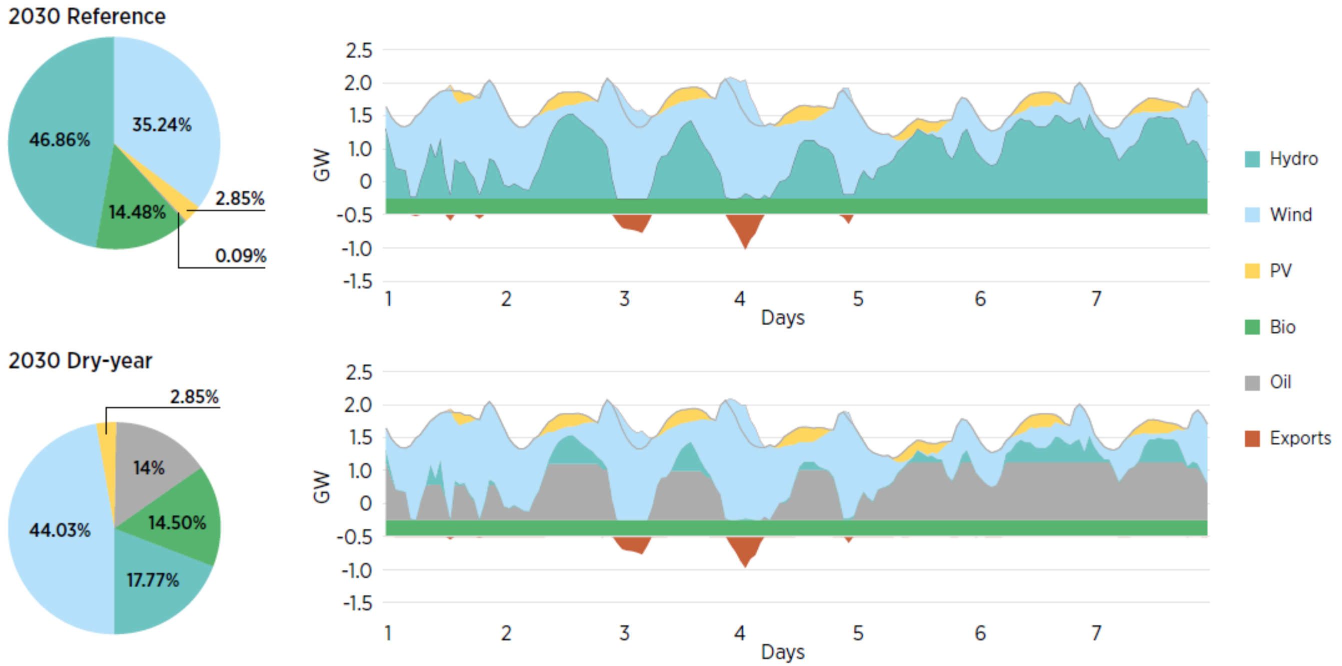
Tertiary: higher VRE shares

Run sensitivity analysis to see the effect of additional VRE deployment on flexibility.

Identify threshold after which flexibility shortages start appearing (and solutions)

1) Flexibility assessment for Uruguay’s 2030 power system

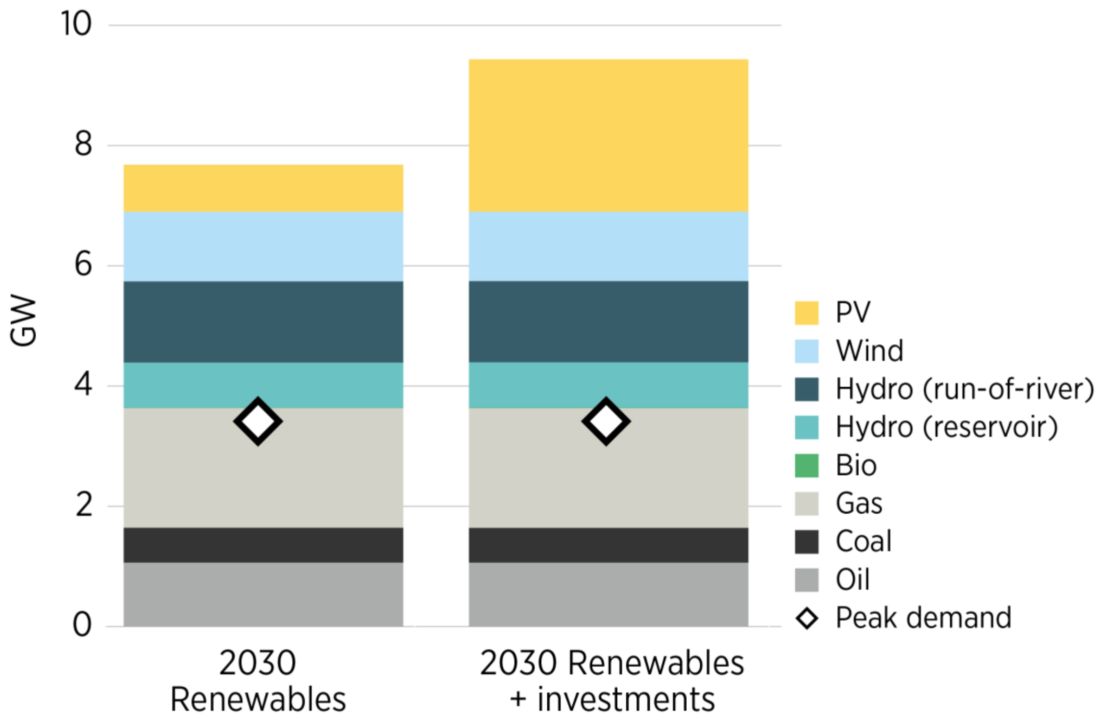
- No flexibility issues identified in 2030 even if the year considered has low hydro inflows (dry year scenario)
- Reference year is 100% RE while dry year 86%
- Excess VRE generation of 25% in reference and 8% in dry year
- Options to reduce curtailment:
  - Active cross border market with Argentina or Brazil is in place to export
  - Explore sector coupling such as power to gas, power to heat or electric vehicles
- **MIEM sees the FlexTool as a useful complement to their current planning tools, as a tool that provides further insight on flexibility of the power system**



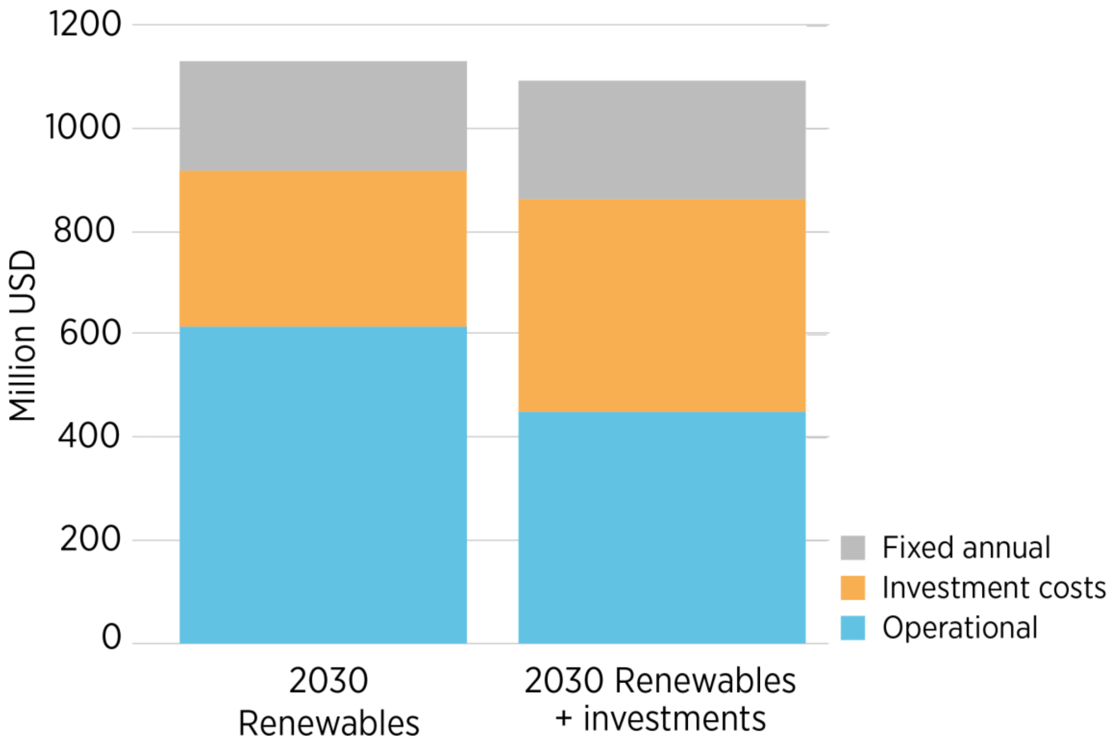
	2030 Reference		2030 Dry Year	
	Total (GWh)	Peak (MW)	Total (GWh)	Peak (MW)
Curtailment*	1 920	2 397	609	1 102.7
Loss of load	0	0	0	0
Spillage	0	0	0	0
Reserves inadequacy	0	0	0	0

2) Cost-effective additional investments

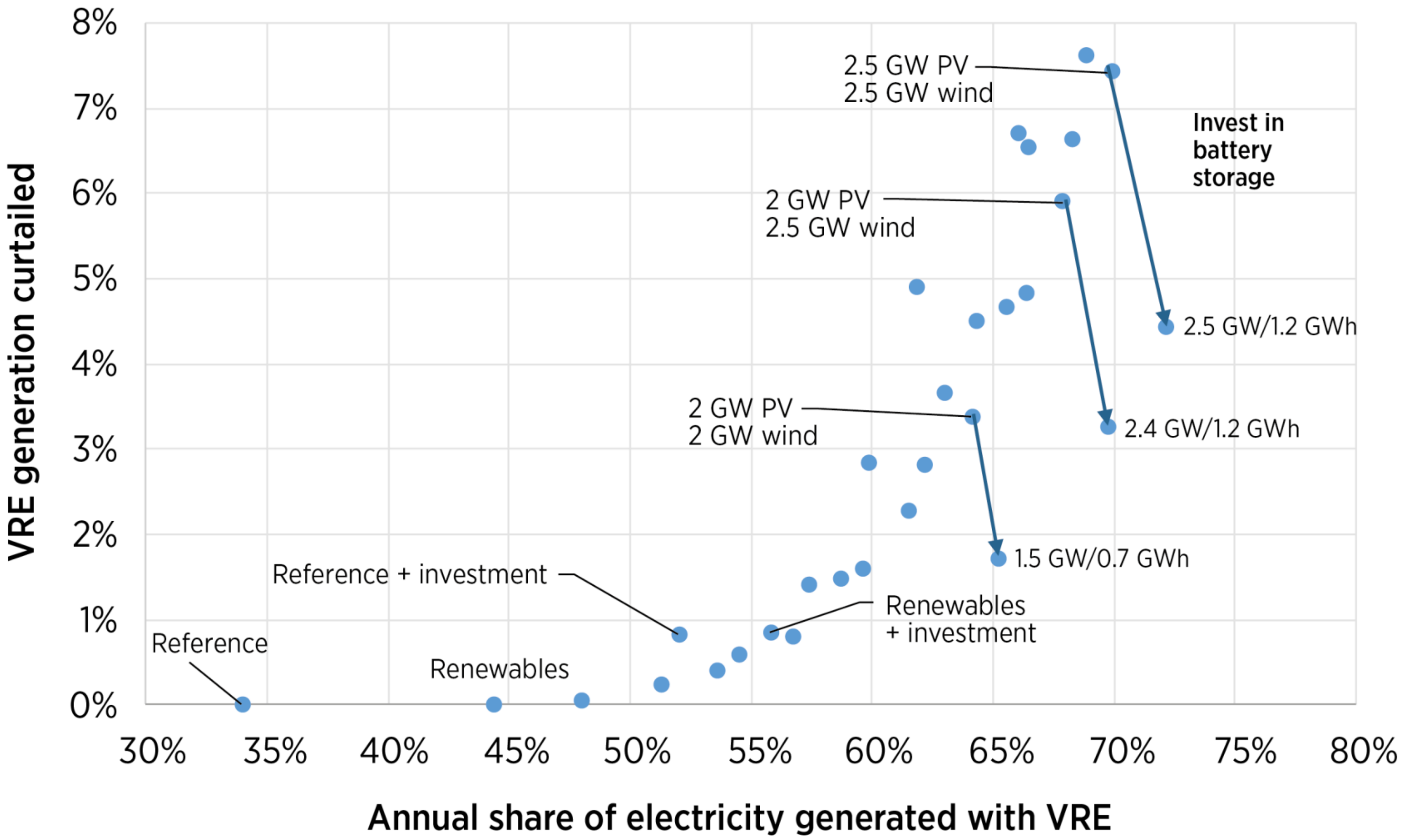
Additional investments



Higher CAPEX, lower OPEX



3) Sensitivity analysis for higher VRE



Conclusions

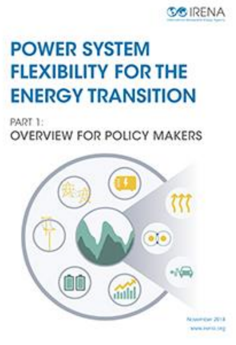
- The steep decrease in the cost of renewable energy together with the need for full decarbonisation of the energy system are leading to high shares of Variable Renewable Energy in the power sector
  - REmap estimates that RE generation will account for over 85% of total electricity generation by 2050, 2/3 being VRE

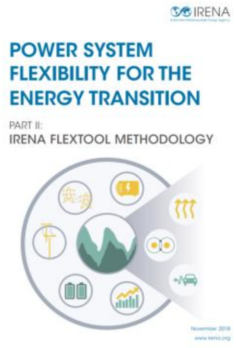
- VRE resources are characterized by variability and uncertainty that require changes in power systems
  - Increasing flexibility will be required to integrate large shares of VRE in power systems
  - Start by improving and unlocking operational flexibility before investing in new assets

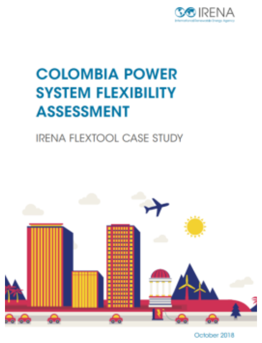
- Flexibility has to be harnessed in every energy sector and not only in the power sector
  - Sector coupling will be a relevant source of flexibility

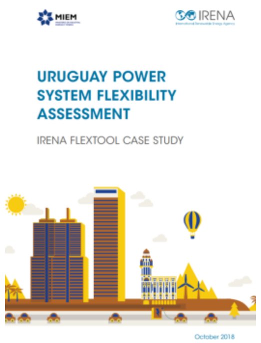
- IRENA has developed the IRENA FlexTool with VTT research in order to help Members in the transition towards a high RE system, by analyzing the flexibility of the power system and proposing a mix of solutions

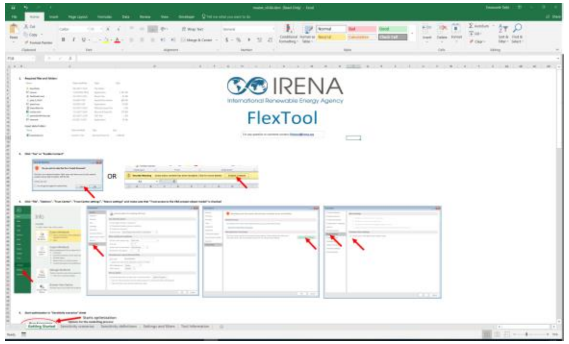
- IRENA is engaging with Member Countries to carry out flexibility assessments. Additionally, trainings can be organised to learn how to use the IRENA FlexTool for national planning purposes











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The flexibility package, including reports, country studies and the IRENA FlexTool are available at

http://irena.org/publications/2018/Nov/Power-system-flexibility-for-the-energy-transition

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BACKUP

Overview of Flexibility workstream

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Report Title	Type of content	Format	Target audience
Power system flexibility for the energy transition, ***Part I: Overview for policy makers***	Discussion on role of flexibility	Brief report	Policy makers
Power system flexibility for the energy transition, ***Part II: IRENA FlexTool methodology***	Technical description of method behind the new IRENA FlexTool	Detailed report	Power system modellers, energy planners, power system operators, academia
FlexTool case studies on **Colombia, Panama, Thailand, Uruguay**	Summary of engagement and analysis	Brochure, communication-oriented	Policy makers, energy planners, general public

Innovation unlocking flexibility across whole power system

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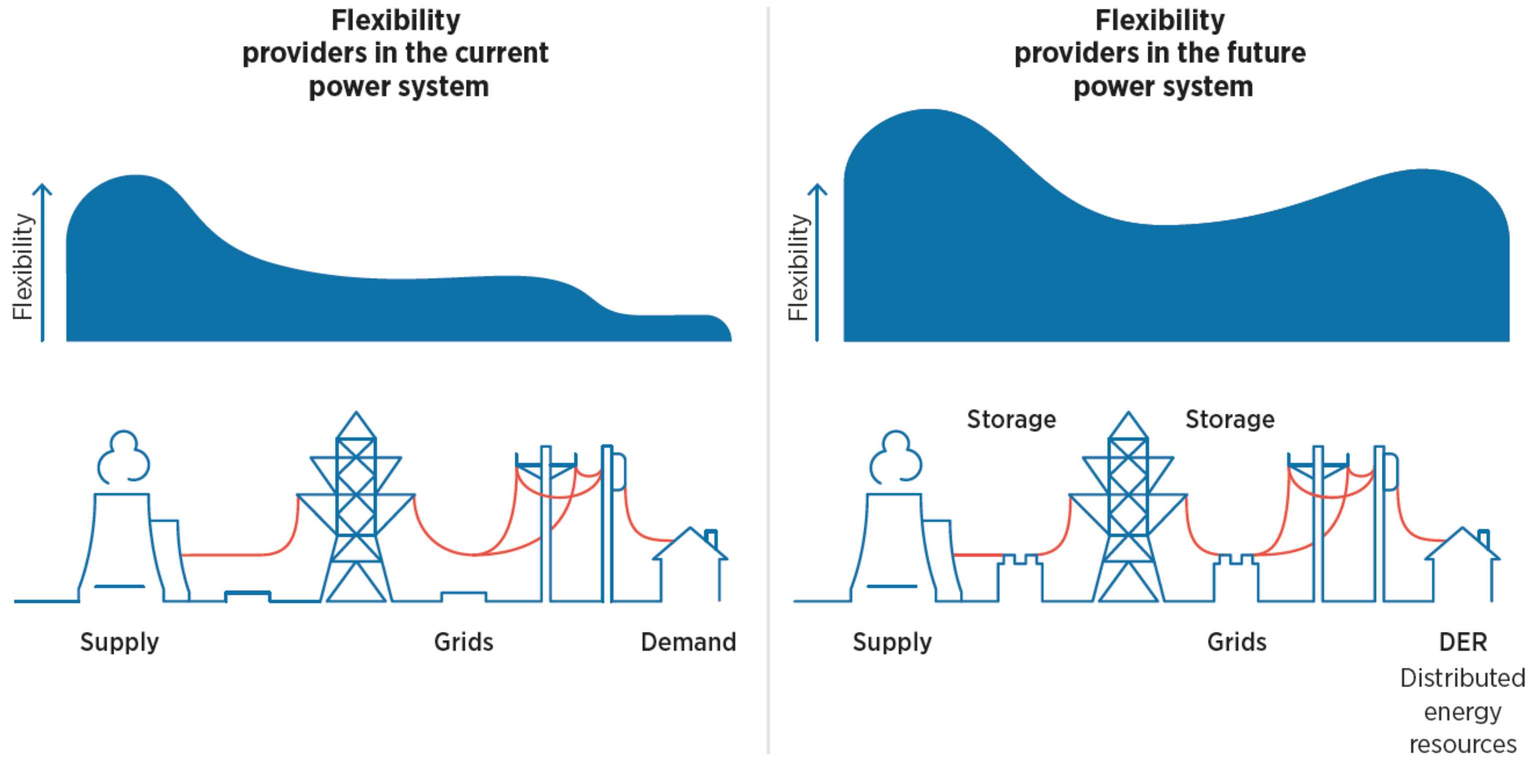


Flexibility sources:
- Flexible generation

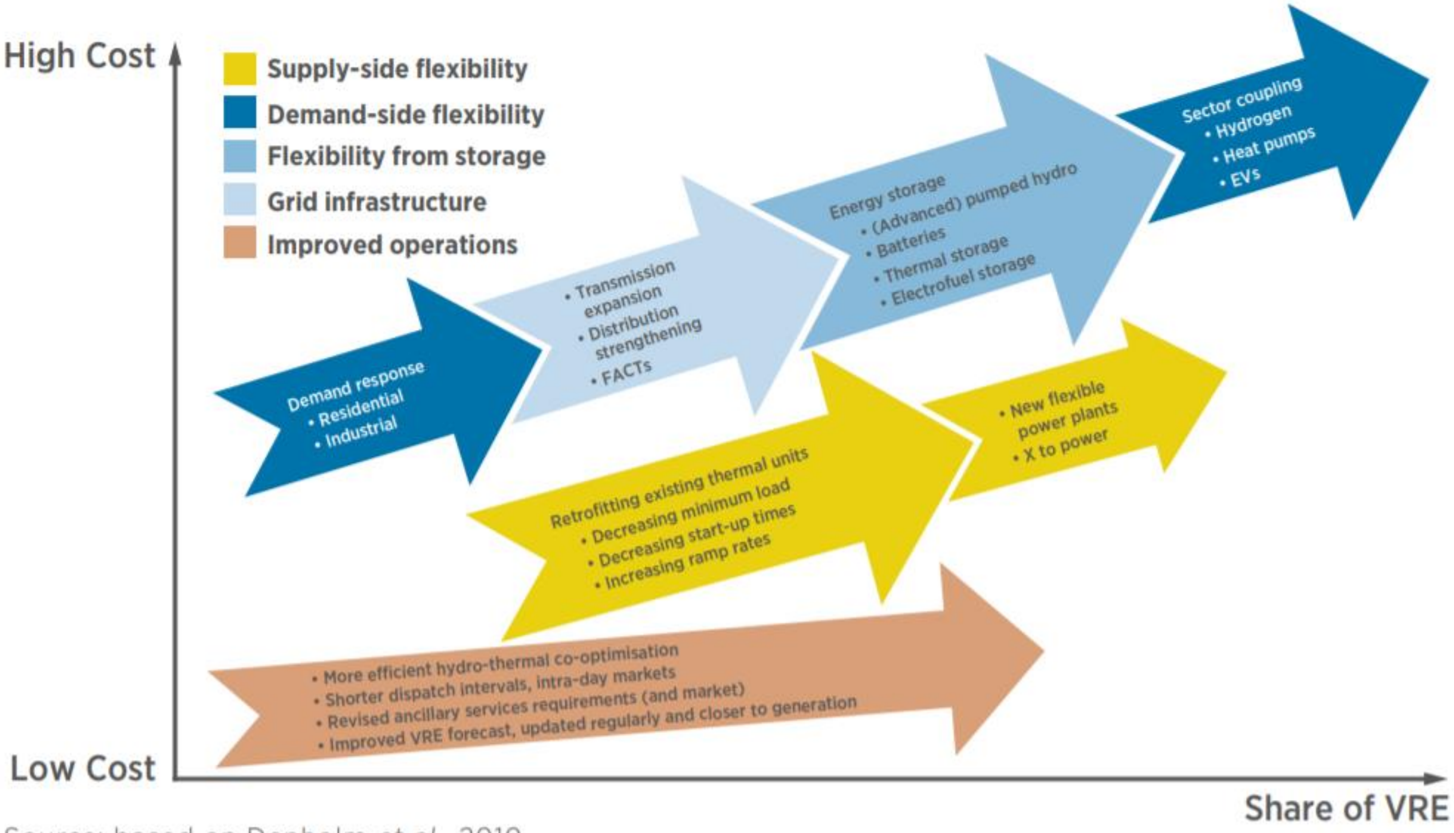
Flexibility sources:
- Flexible generation
- Regional interconnections and markets
- Demand response
- Storage
- Power-to-X

A combination of solutions is needed

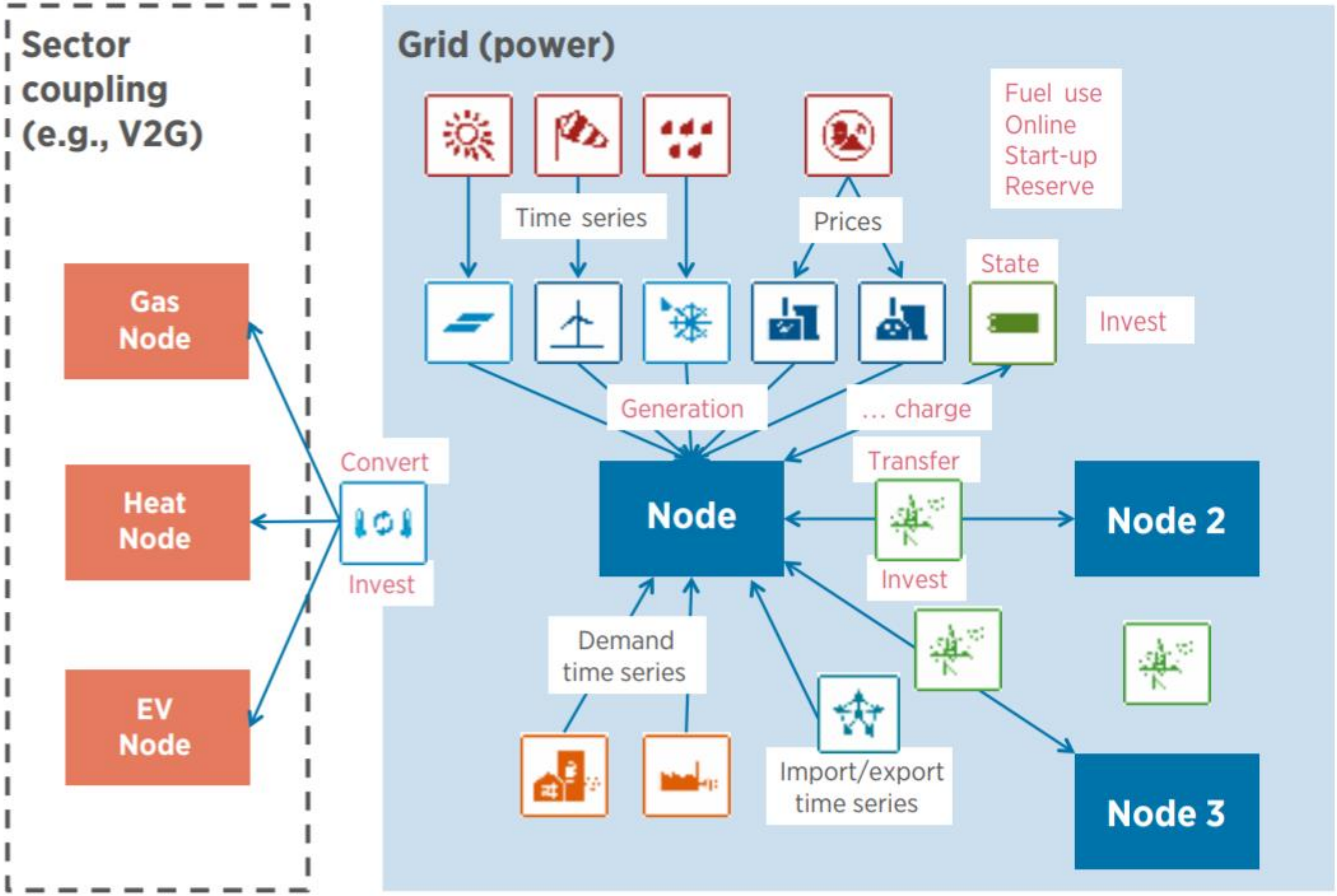
» Besides applicability, the optimal choice of solutions needs to consider costs

» Improving operations is the cheapest solution and usually a very effective one

» A combination of solutions of various costs is needed to facilitate high shares of VRE



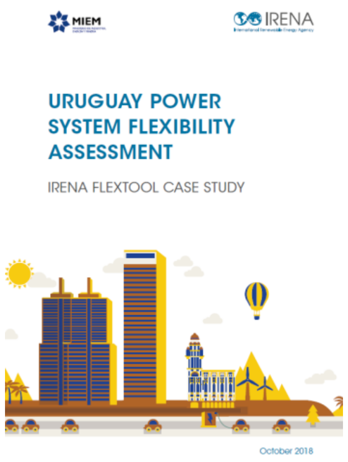
Source: based on Denholm *et al.*, 2010

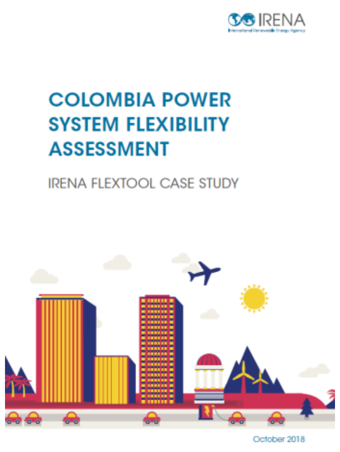

Sector coupling (e.g., V2G)
Gas Node
Heat Node
EV Node
Convert
Invest
Grid (power)
Time series
Prices
Fuel use
Online
Start-up
Reserve
State
Invest
Generation
... charge
Transfer
Node
Node 2
Invest
Demand time series
Import/export time series
Node 3

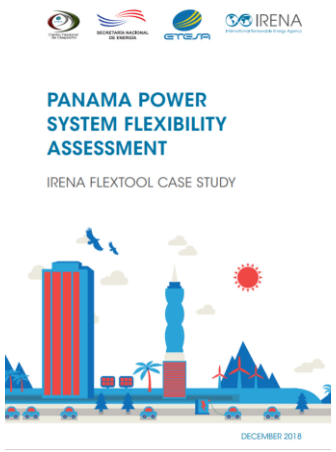
Current case studies and future work

Country analysis completed

- Uruguay
- Colombia
- Panama
- Thailand *(under finalization)*





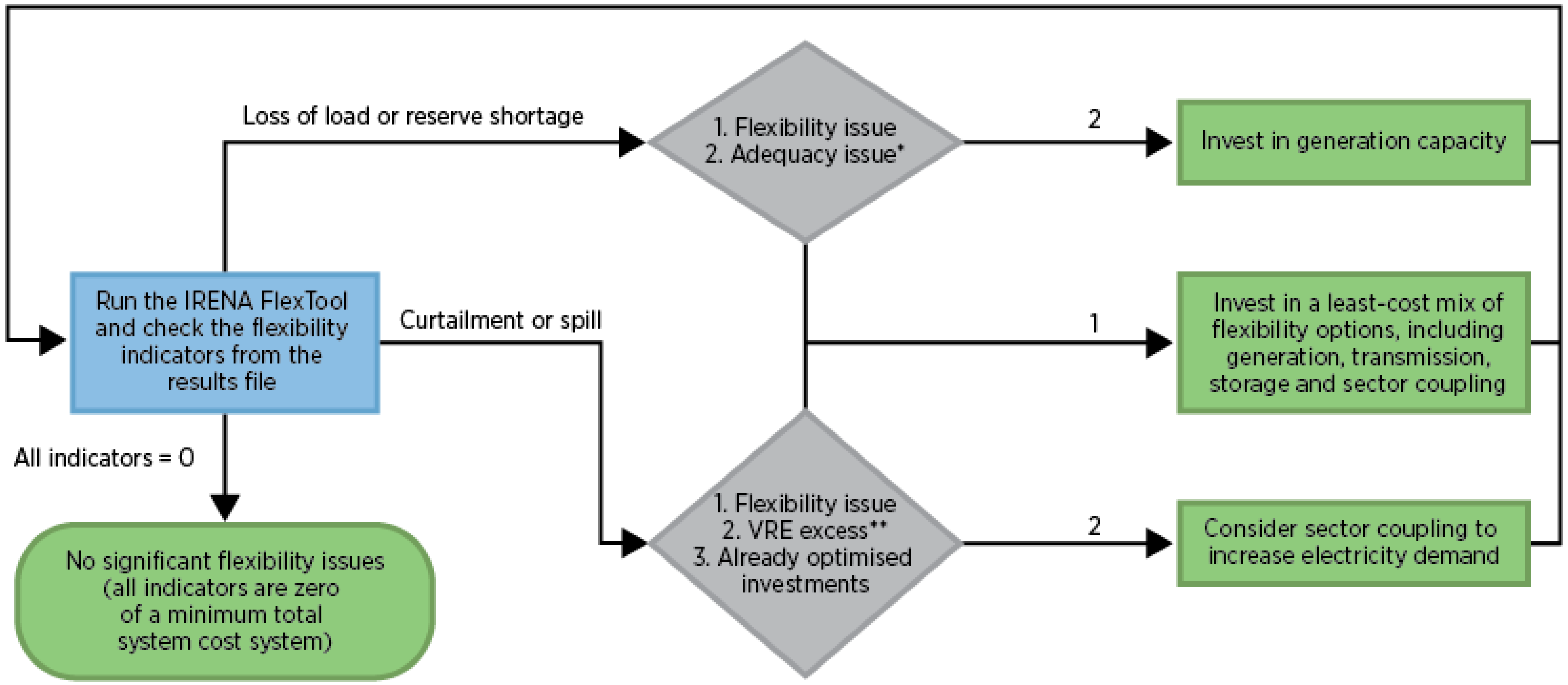


Outputs of the case studies

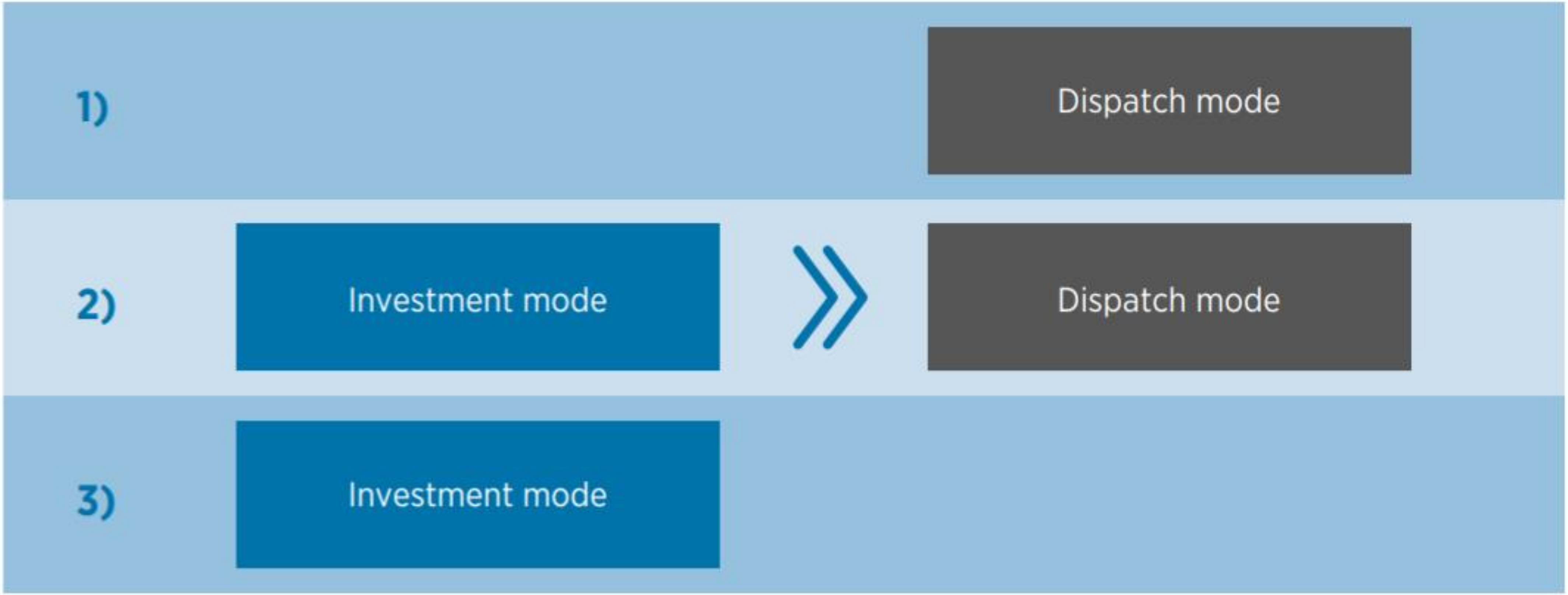
- The IRENA FlexTool model
- Slide deck with the main results
- 8-pages IRENA publication

Upcoming flexibility assessments using the IRENA FlexTool

- **Flexibility of power-to-hydrogen and power-to-heat**
- **Regional flexibility analysis for Central America and South-East Asia**
- **Several countries expressed interest in performing a FlexTool analysis during the following events**
  - **Sixteenth meeting of the IRENA council (dedicated lunch event to launch the reports and FlexTool)**
  - **Second Energy Planners Forum in Santiago de Chile (dedicated session)**
  - **South East Europe workshop on grid integration of variable renewable energy sources (dedicated session)**


Loss of load or reserve shortage
1. Flexibility issue
2. Adequacy issue*
2
Invest in generation capacity
Run the IRENA FlexTool and check the flexibility indicators from the results file
Curtailment or spill
1
Invest in a least-cost mix of flexibility options, including generation, transmission, storage and sector coupling
All indicators = 0
1. Flexibility issue
2. VRE excess**
3. Already optimised investments
2
Consider sector coupling to increase electricity demand
No significant flexibility issues (all indicators are zero of a minimum total system cost system)

Flexibility indicators	
Loss of load (terawatt-hours (TWh) and %)	VRE curtailment (TWh and %)
Reserves shortage (megawatts (MW))	Capacity inadequacy (MW)
Spillage (TWh)	
Dispatch per generator and per node	
Transmission between nodes (and utilisation factor of lines)	
Costs	
OPEX	**CAPEX**
Fuel costs	Generation investments
Cost of carbon dioxide emissions	Transmission investments
Operation and maintenance costs	Storage investments
Cost of loss of load	Sector coupling investments (e.g., heat pumps)
Cost of curtailment	
Electricity price per node (marginal price)	
Ramping information (one-hour and four-hour ramps)	
Investments (invested transmission, generation, storage or sector coupling capacity)	
Other (e.g., dispatch and costs from other energy sectors)	


1)
Dispatch mode
2)
Investment mode
Dispatch mode
3)
Investment mode

IRENA FlexTool: scope and limitations

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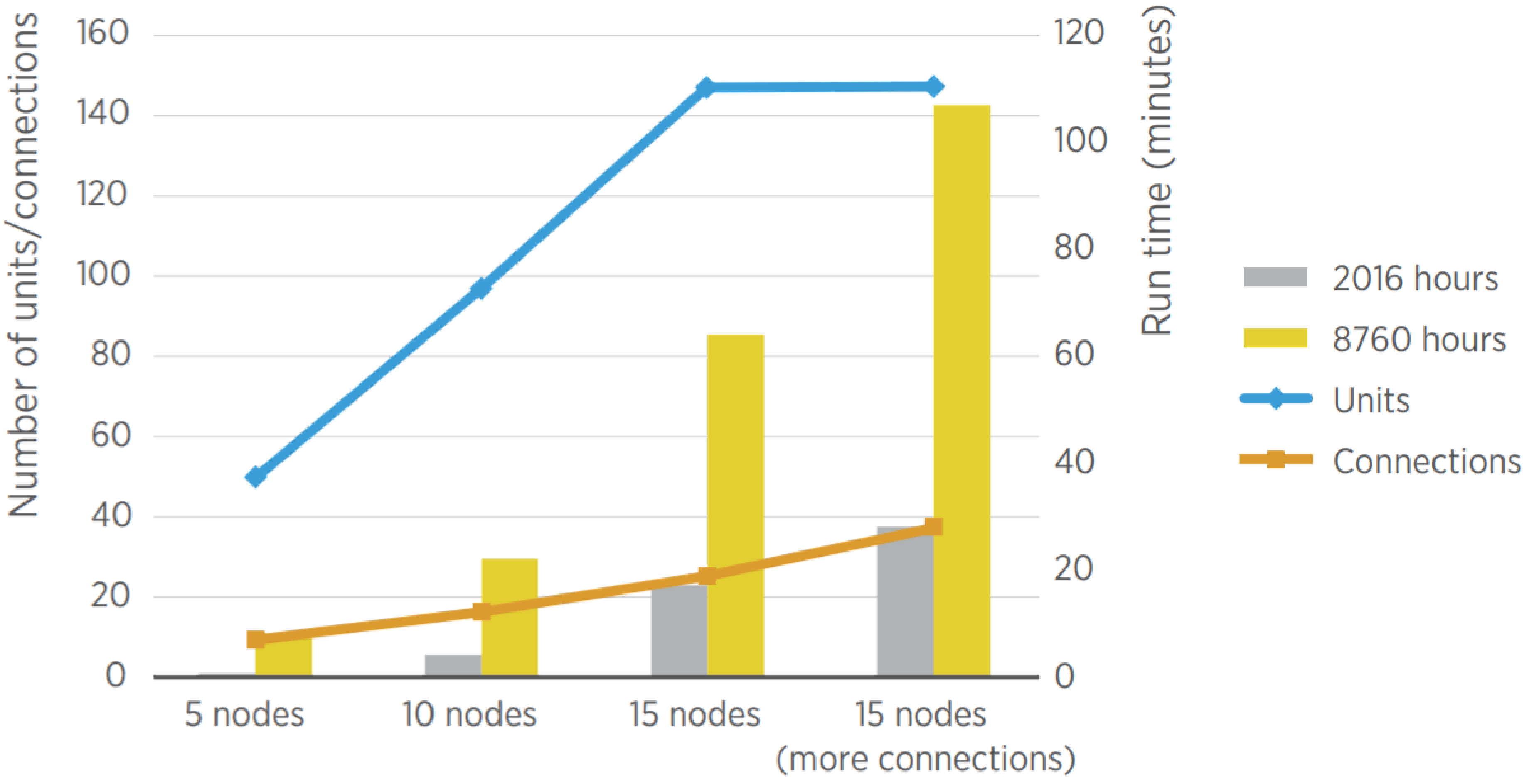
Type of flexibility issues checked

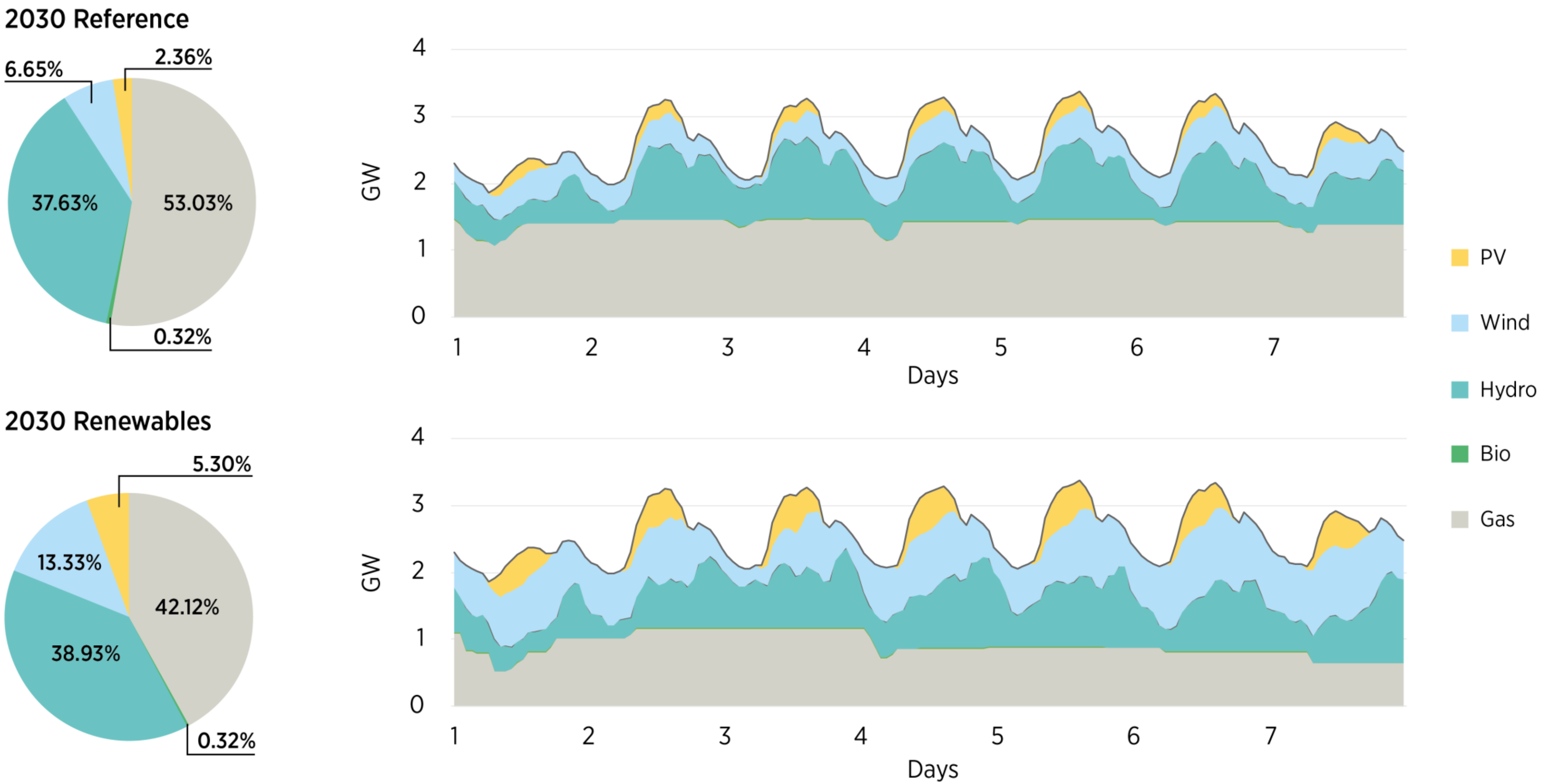
- Loss of load
- Reserves' shortage
- Insufficient ramp rate
- Curtailments of VRE generation
- Spilling of hydro power
- Transmission congestion

FlexTool does not consider

- Frequency and voltage
- Stability
- Distribution grid
- Start-up time of thermal power plants
- Integers for unit commitment or investment
- Transmission is in nominal power capacity (no AC, no Kirchhoff laws)



Number of units/connections
160
140
120
100
80
60
40
20
0
Run time (minutes)
120
100
80
60
40
20
0
5 nodes
10 nodes
15 nodes
15 nodes (more connections)
2016 hours
8760 hours
Units
Connections


2030 Reference
6.65%
2.36%
37.63%
53.03%
0.32%
2030 Renewables
5.30%
13.33%
42.12%
38.93%
0.32%
GW
0
1
2
3
4
1
2
3
4
5
6
7
Days
PV
Wind
Hydro
Bio
Gas