A power system for a carbon neutral Europe

entsoe VISION

Webinar 1

Energy System Flexibility: the key for Renewable Integration

DAY 2, 11 OCTOBER, WEBINAR 1

#VisionEvent22

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Day 2, Webinar #1, 11 October

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A power system for a
carbon neutral Europe

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VISION

INTRODUCTION

Tahir Kapetanovic
Chair of SOC, ENTSO-E

ENTSO-E Vision for the future of the European Power System

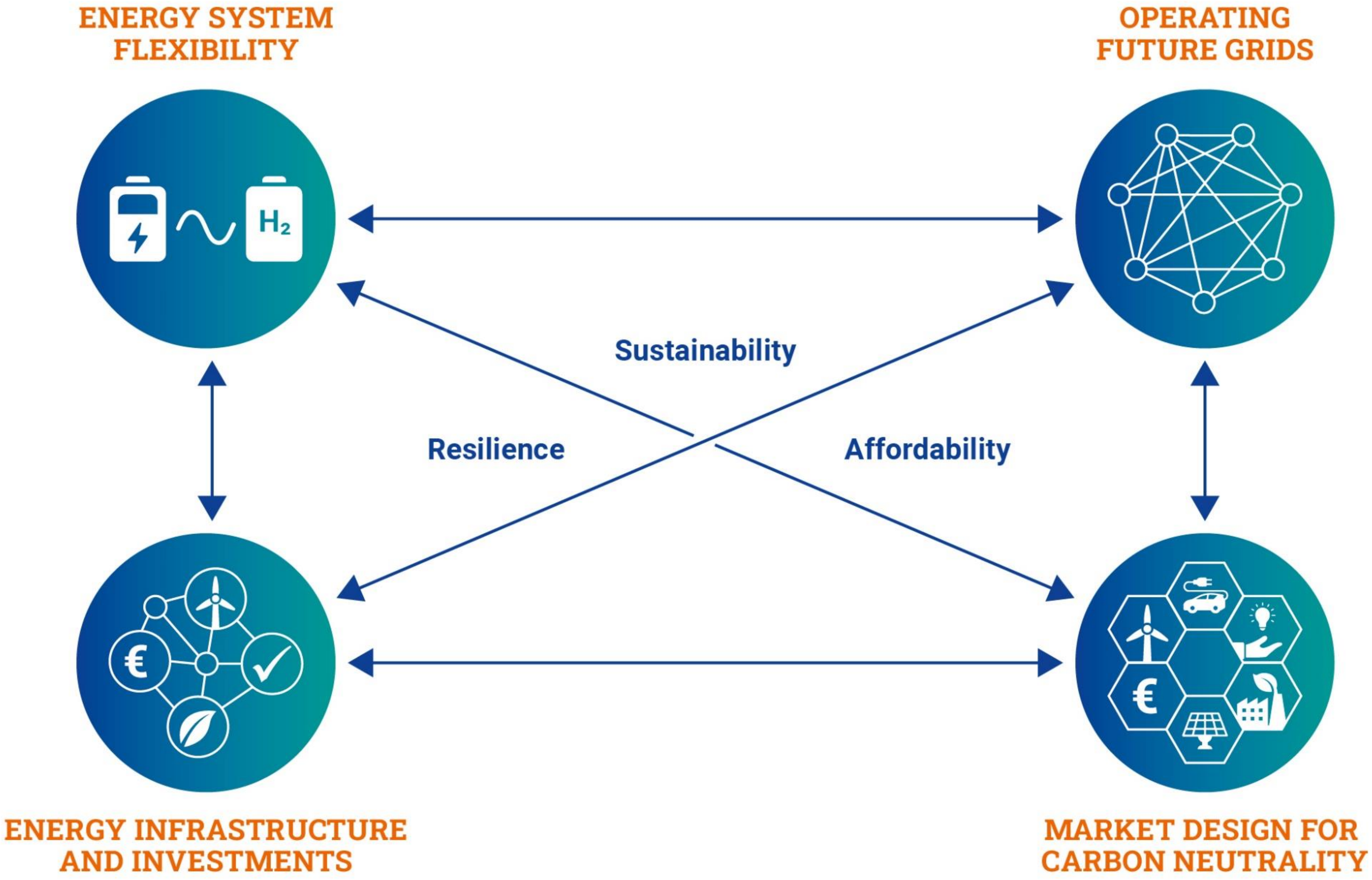
Guiding principle

- A shared political goal for a fully **carbon-neutral European economy**

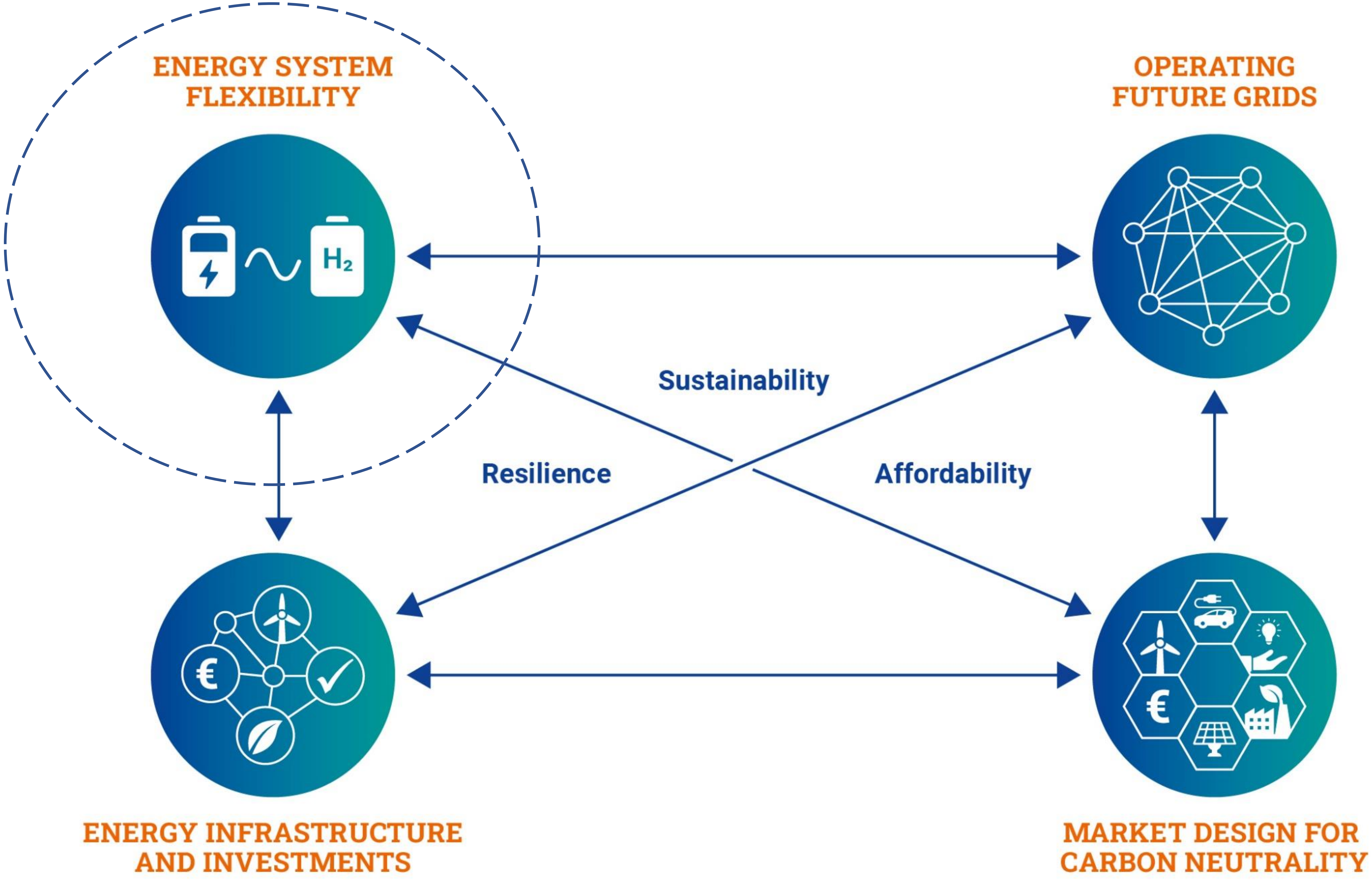
Our Vision

- A **comprehensive analysis** of what is necessary to achieve a power system fit for a carbon-neutral Europe
- As a contribution to the debate on the **European Energy Transition**
- Including **TSOs shared intelligence** on trends, scenarios, challenges, technology & innovation

A Vision based on 4 Key “Building Blocks”



A Vision based on 4 Key “Building Blocks”



Presentations by ENTSO-E Vision Project Members

Energy System Flexibility

DAY 2, 11 OCTOBER, WEBINAR 1 #VisionEvent22

A power system for a carbon neutral Europe

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ENERGY SYSTEM FLEXIBILITY

Danny Klaar, Mario Sisinni

ENTSO-E Vision Project Team Members

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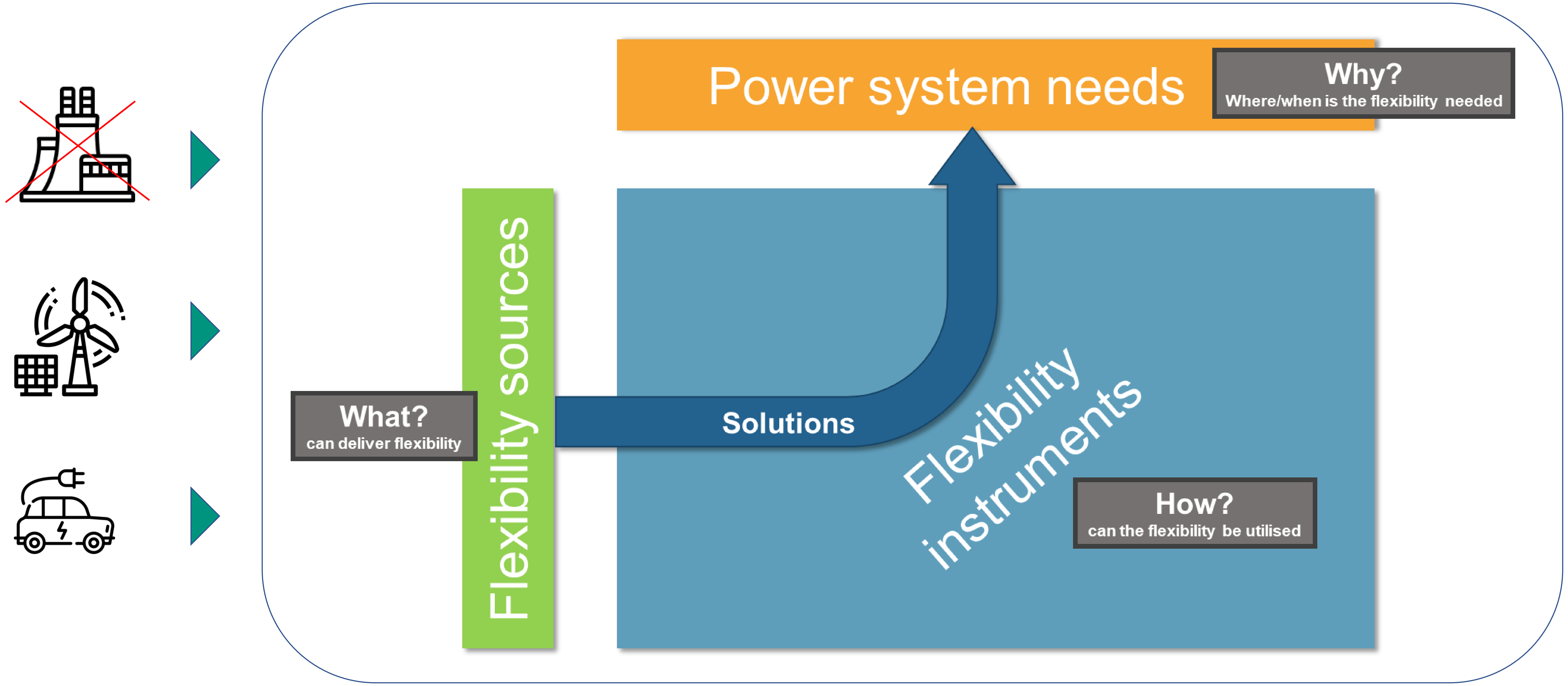
Energy System Flexibility – a definition

Flexibility refers to the ability of the power system to cope with variability and uncertainty in generation, demand and grid availability



Power System Needs

- Balance energy flows
- Ensure resource adequacy
- Manage loads
- Optimal use of resources
- Stabilize the grid
- Minimize curtailments
- Increase resilience
- Address partial grid defection

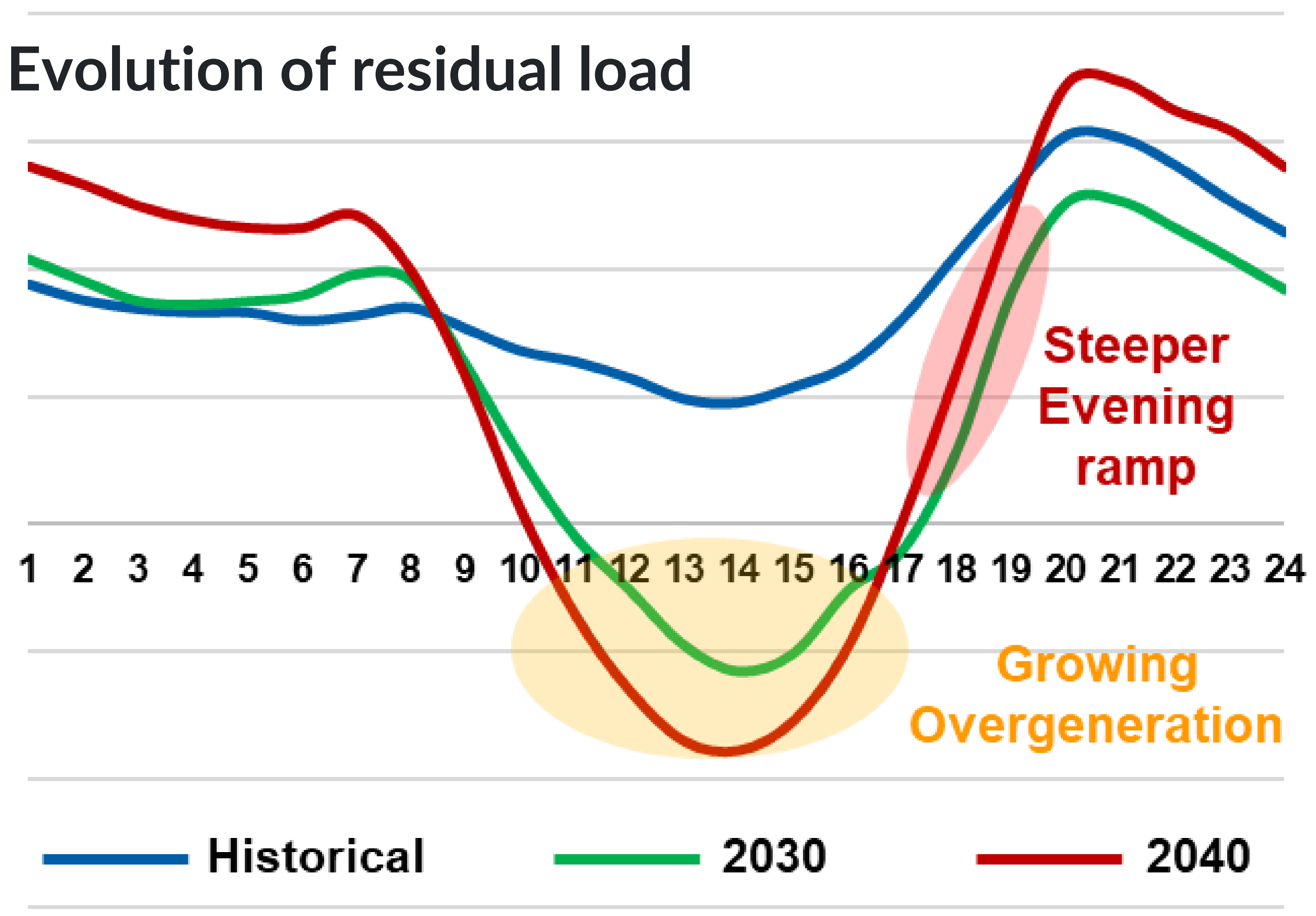
In a fully carbon neutral system, based on electrified consumption and variable RES, flexibility will be essential to complement the variability of both generation and demand and to address the increase of system complexity

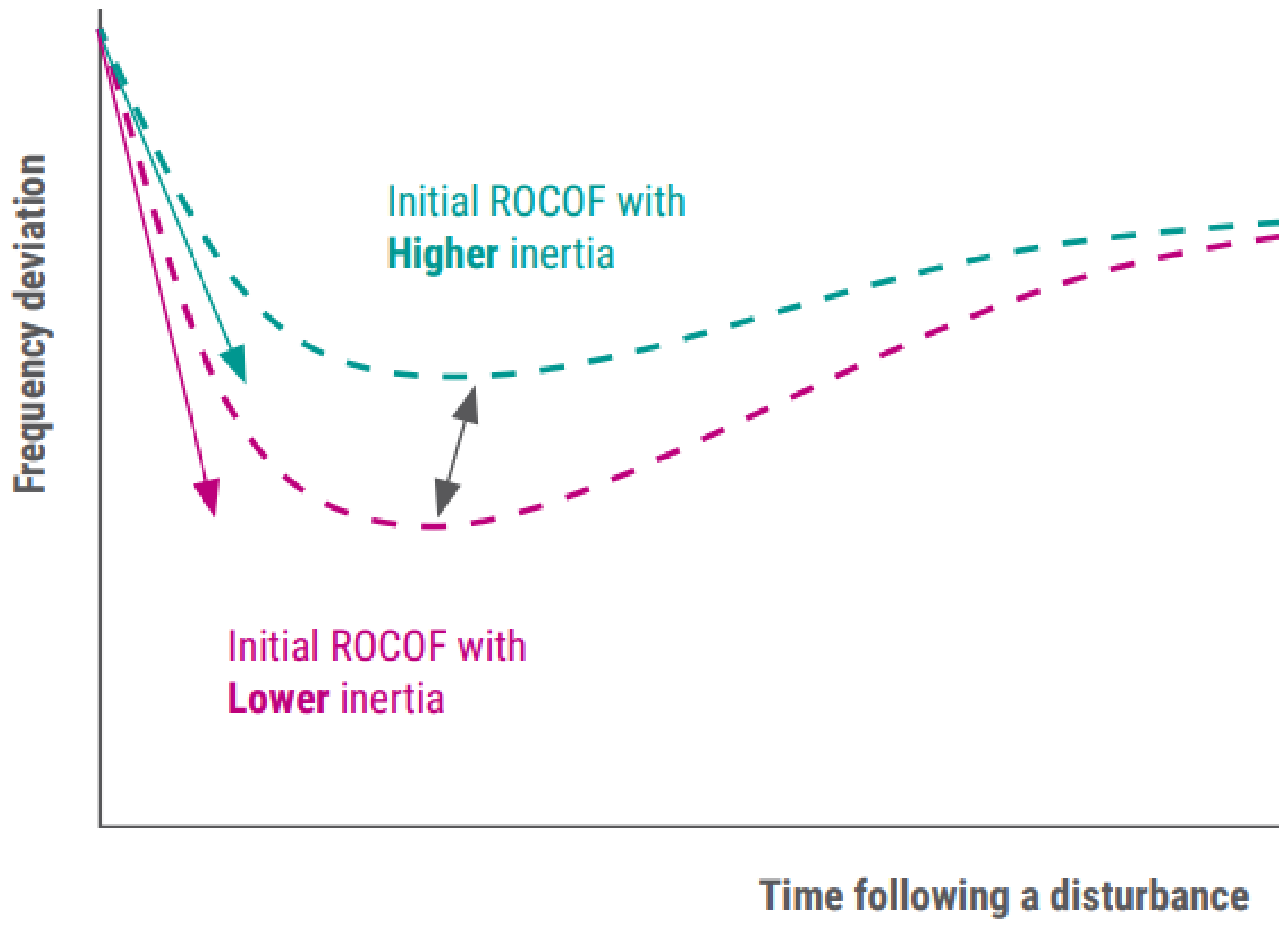
Flexibility needs will evolve both in nature and volume

Flexibility needs can be classified in:

- ***Short duration flexibility***

(From milliseconds up to a few hours, to balance the system within the day and ensure system stability)

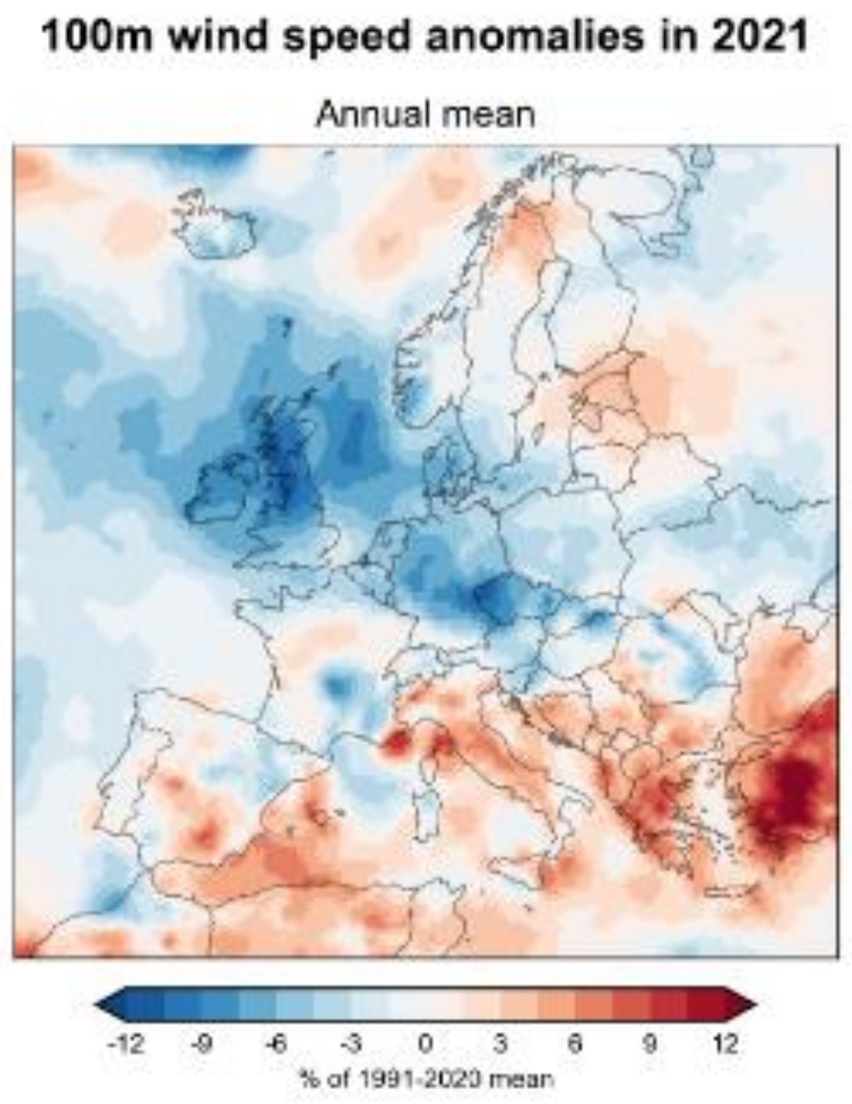




- ***Long duration flexibility***

(Up to several weeks, to compensate for long events such as periods with shortage of wind/solar and hydro generation)

In 2021, parts of northwestern and central Europe experienced some of the lowest annual average wind speeds since at least 1979.



Quantifying all types of flexibility

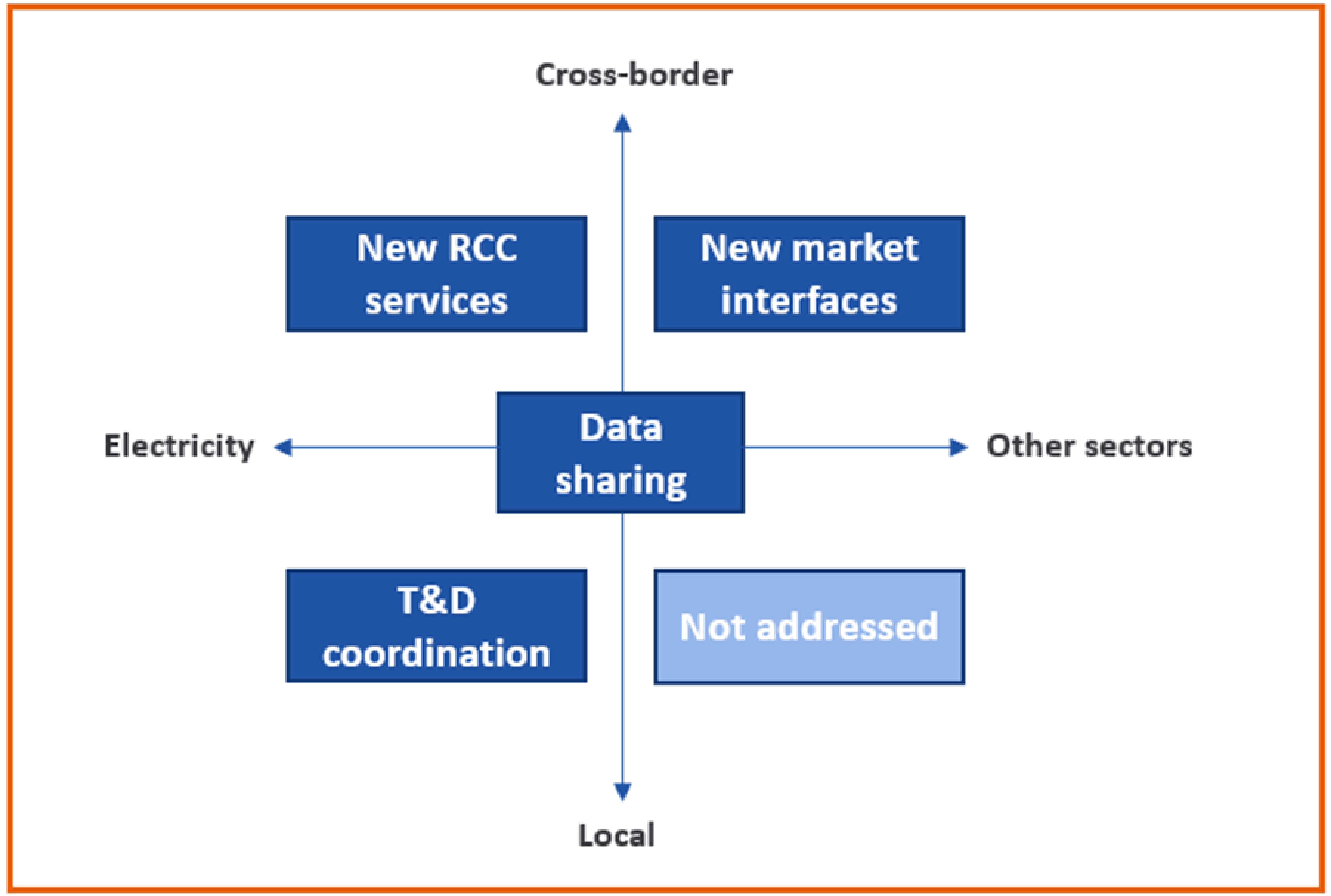
Accurately quantifying all types of flexibility needs across time and space will become an essential tool to guide a cost-efficient deployment of flexibility resources

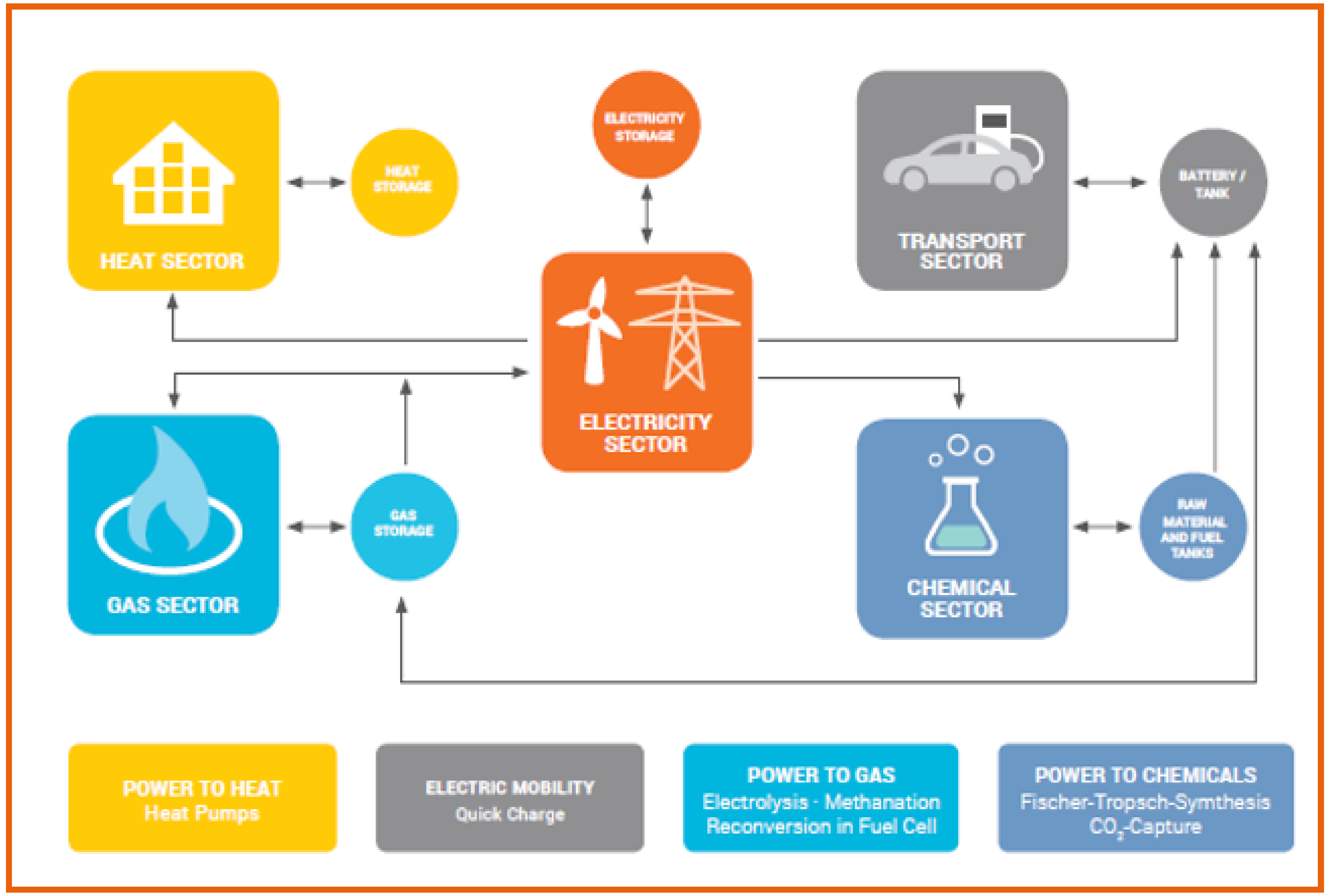
Some countries are already running some national analysis on flexibility needs, but pan-European assessments, capable of including national specificities, will be needed.

VISION RECOMMENDATION

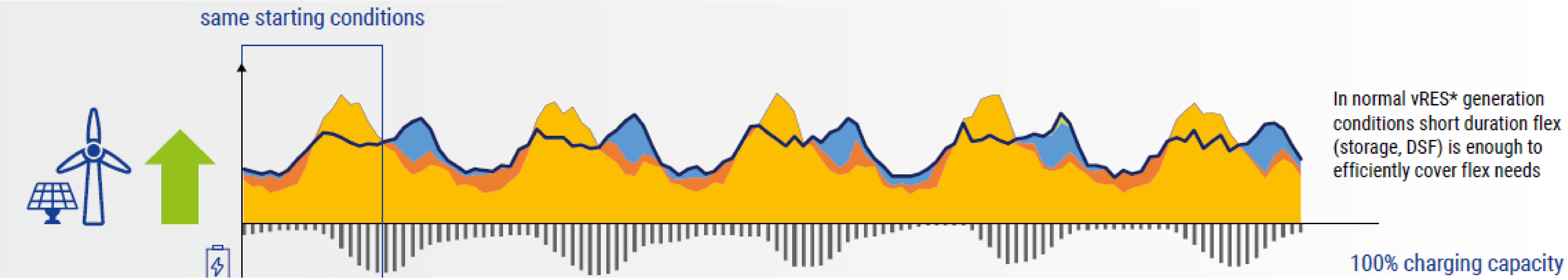
ENTSO-E shall produce with relevant stakeholders a pan-European assessment of flexibility needs for the whole timespan of the energy transition, to guide a cost-efficient deployment of flexibility resources

A wider portfolio of flexibility resources

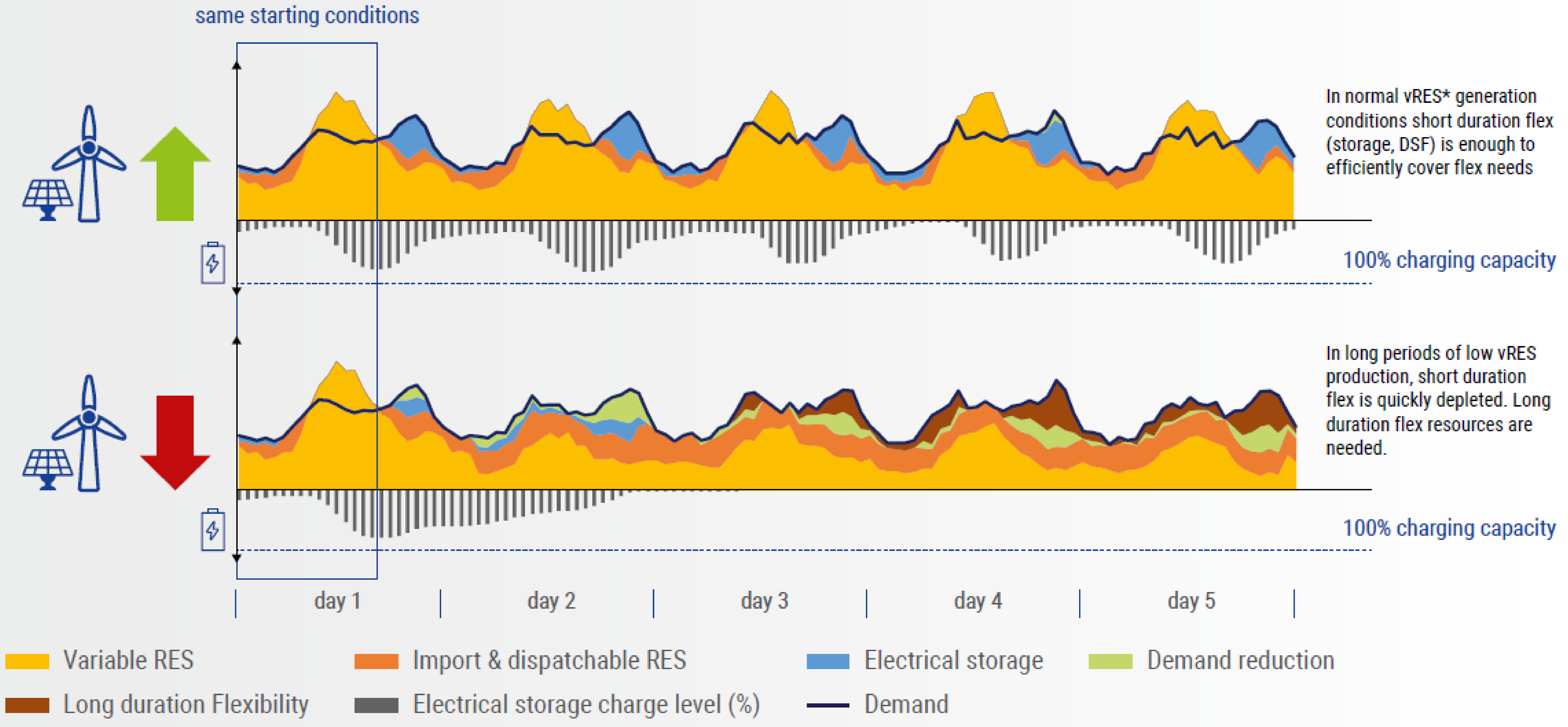




Most suitable and cost-efficient flexibility resources



Most suitable and cost-efficient flexibility resources



* vRES = Variable Renewable Energy Sources, characterised by their intermittent and weather-dependent nature

Flexibility matrix – Introduction

	Need / Source	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	↓	↓	↓	↓	↓
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

↓ Phase-out by 2050 ● Most promising ○ Contributing

Legend

↓ Resources expected to be phased-out by 2050

● Most promising resources to cover needs / for wider diffusion vs today

○ Other resources contributing to covering needs / which diffusion is subject to technological developments or national/regional specificities

Flexibility matrix – Introduction

	Need / Source	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
		Long-duration	Short-duration			
Generation	Fossil thermal generation					⬇
Generation	Hydrogen power generation	●				○
Generation	Dispatchable RES (hydro, bio)	●	○	○	○	●
Generation	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
Demand	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
Storage	Supercapacitators			○		
Storage	Hydro pumping storage	○	●	●	●	●
Storage	Flywheels			○		
Storage	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
Coupling	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
Grid	Grid flexibilities (power flow, voltage control)		●	●	●	●

⬇ Phase-out by 2050 ● Most promising ○ Contributing

- This is a high-level, qualitative and non-exhaustive analysis of flexibility resources, to be used as **starting point for discussion**
- Since **no single recipe for all Europe is expected**, it is likely that the matrix would differ at national/regional level
- A number of European countries foresee also **nuclear power** generation as a non-renewable but carbon-free source of energy, and its inclusion in the mix should partially decrease some of the flexibility needs. This is why nuclear has not been included in the matrix

Flexibility matrix – Focus on generation cluster

	Source \ Need	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	↓	↓	↓	↓	↓
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

↓ Phase-out by 2050 ● Most promising ○ Contributing

- **Fossil thermal generation** is expected to be progressively phased-out in line with national strategies
- **Carbon Capture and Storage (CCS)** applied to thermal generation is not foreseen to have major diffusion in the long-term (*see also Game Changers webinar*)
- **Hydrogen power generation** is among the most promising resources of long-duration flexibility
- Further diffusion of **dispatchable RES** is subject to geographical/country specificities
- **Variable RES** are expected to growingly contribute to covering a wide range of flexibility services

Flexibility matrix – Focus on demand cluster

	Source \ Need	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	↓	↓	↓	↓	↓
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

↓ Phase-out by 2050 ● Most promising ○ Contributing

- Both **small and large-scale Demand Side Response** are among the most promising resources to cover a wide range of short-duration flexibility services. They will also contribute to covering long-duration needs

- Going forward, the **collaboration between TSOs and DSOs** will be essential to ensure an efficient deployment of DSR resources

Flexibility matrix – Focus on storage cluster

	Need / Source	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	⬇	⬇	⬇	⬇	⬇
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

⬇ Phase-out by 2050 ● Most promising ○ Contributing

- **Both mall scale and utility scale batteries** and **hydro pumping storage** are among the most promising resources to cover short duration flexibility needs
- **Supercapacitors** and **flywheels** could contribute to cover stability/inertia needs. Their diffusion will be subject to technological developments/national strategies
- **Mechanical storage (LAES/CAES)** and **thermal storage systems** include several technologies capable of contributing to short duration and long duration flexibility needs, but would require further technological developments

Flexibility matrix – Focus on sector coupling cluster

	Source \ Need	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	↓	↓	↓	↓	↓
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

↓ Phase-out by 2050 ● Most promising ○ Contributing

- As also reported in the TYNPD scenarios, in the medium/long- term **electrolysers fed by renwable electricity** will be largely used to meet hydrogen and green fuels demand
- As controllable loads, **electrolysers** could also provide short-duration flexibility services. This includes converting the surplus of RES generation into hydrogen, in line with energy efficiency principles
- Diffusion of **Power-to-Heat** technologies will be highly dependent on national strategies (e.g. development of district heating)

Flexibility matrix – Focus on grid cluster

	Need / Source	Periods of vRES shortage	Balancing/ congestion management	Stability/ intertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	⬇	⬇	⬇	⬇	⬇
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

⬇ Phase-out by 2050 ● Most promising ○ Contributing

- The **electricity network** will first play a key role in enabling the exchange of both energy and flexibility resources within the full European "System of Systems", thus reducing the overall amount of flexibility requirements to be covered
- **Grid flexibilities** include a wide range of technologies which allow TSOs to optimize power flows and make a more efficient use of existing capacity

Flexibility matrix – Focus on short-duration needs/resources

	Need / Source	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	↓	↓	↓	↓	↓
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

↓ Phase-out by 2050 ● Most promising ○ Contributing

- The portfolio of resources able to cover short-duration flexibility needs **includes several promising technologies** for wider diffusion vs. today
- Among them, **Demand Side resources** and **Electrical storage systems** (batteries and hydro pumping) have significant potential to become providers of carbon neutral short duration flexibility

Flexibility matrix – Focus on long-duration needs/resources

	Source \ Need	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	⬇	⬇	⬇	⬇	⬇
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

⬇ Phase-out by 2050 ● Most promising ○ Contributing

- There are **very few potential resources** of carbon-neutral long duration flexibility.
- **Dispatchable RES** (**hydro, bio, geothermal**) are among the promising ones, but their further development is subject to national specificities and strategies
- The most promising solution could be **hydrogen** – produced from carbon neutral generation, stored, and subsequently used for power generation when required by the system
- Other **alternatives** could emerge assuming that further technological progress is made to decrease their cost and improve their capacity to store energy

Flexibility matrix – Conclusions

	Source \ Need	Periods of vRES shortage	Balancing/ congestion management	Stability/ inertia	Voltage control	Reliability/ restoration
Generation	Fossil thermal generation	⬇	⬇	⬇	⬇	⬇
	Hydrogen power generation	●				○
	Dispatchable RES (hydro, bio)	●	○	○	○	●
	Variable generation		●	●	●	○
Demand	Smart charging EVs/small DSR	○	●	●	○	○
	Large DSR	○	●	●	○	●
Storage	Chemical batteries/V2G		●	●	●	●
	Supercapacitators			○		
	Hydro pumping storage	○	●	●	●	●
	Flywheels			○		
	LAES/CAES, thermal storage	○	○	○		
Coupling	Power-to-hydrogen		●	○	○	
	Power-to-heat		○	○		
Grid	Interconnections (incl. HVDC & conversion stations)	●	●	○	●	○
	Grid flexibilities (power flow, voltage control)		●	●	●	●

⬇ Phase-out by 2050 ● Most promising ○ Contributing

- To enable a secure transition towards carbon neutrality the **deployment** of both short and long duration flexibility resources will need to be **coordinated** with the **integration of weather-dependent renewable generation sources** and the **phase-out of fossil-fuel generation**

VISION RECOMMENDATION

Appropriate market mechanisms should be developed to ensure that both short and long duration flexibility resources are timely deployed and efficiently procured where and when needed

Flexibility across functions

Ensuring a cost-efficient deployment, procurement and use of flexibility is a cross-function exercise!

Planning: In line with the Energy Efficiency first principle, flexibility solutions are assessed to complement traditional grid investments

Operations: enhanced observability and controllability enable leaner and automated procedures in all timeframes

Market design: clear market-based mechanisms and price signals ensure a timely deployment and an efficient procurement of flexibility resources

For further information don't miss the next dedicated webinars!!!

Summary of conclusions and recommendations

- In a **fully carbon neutral system**, based on electrified consumption and variable RES, **flexibility will be essential** to complement the variability of both generation and demand and to address the increase of system complexity
- Different resources will be needed to cover the **different types of flexibility needs**.
  - **Demand Side sources and electrical storage** have good potential to become significant providers of carbon neutral **short duration flexibilities.** Cooperation between TSOs and DSOs will be essential to unlock their potential.
  - There are **very few potential sources** of carbon-neutral **long duration flexibilities.** The most promising are **carbon-free dispatchable generation** (mainly hydroelectric) and **high energy density storage** (hydrogen, other new technologies).
- To **access and coordinate** the portfolios of flexibility sources across voltage levels, national borders and sector integration, the future will clearly be a **system of systems**.
- **Grid development and interconnections** will be key to mitigate overall flexibility needs, as **national and regional variations** should partly offset each other.
- A number of European countries foresee also **nuclear power generation** as a non-renewable but carbon-free source of energy, and its inclusion in the mix should **partially decrease some flexibility needs**.

ENTSO-E shall produce with relevant stakeholders a pan-European assessment of flexibility needs for the whole timespan of the energy transition, to guide a cost-efficient deployment of flexibility resources.

Appropriate market mechanisms should be developed to ensure that both short and long duration flexibility resources are timely deployed and efficiently procured where and when needed

ASK YOUR QUESTIONS ONLINE WITH SLIDO

Day 2, Webinar #1, 11 October

Scan

Code #6646755

A power system for a
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entsoe VISION

REACTIONS FROM KEY STAKEHOLDERS

Moderated by: Bruno Gouverneur

Head of Operations, ENTSO-E

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A power system for a carbon neutral Europe

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CONCLUDING REMARKS

Damian Cortinas

ENTSO-E Vision Project Manager, ENTSO-E

DAY 2, 10 OCTOBER, WEBINAR 1 #VisionEvent22

Our Vision – what the future will look like

In a fully carbon-neutral economy, **electricity** will be the main and most efficient energy carrier, and it will need to be coupled with other energy sectors. The system of the future will be based on 3 key elements, all **essential** for a sustainable, resilient and affordable power system:

- **Carbon Neutral Energy Sources**, providing the bulk of the power generation, and for the most part weather-dependent.
- **System Flexibility Resources**, to efficiently complement the variability of generation and consumption, and to address the increase in overall system complexity.
- The **Power Grid**, connecting generators, consumers and flexibility resources across Europe, and enabling a fully integrated European Energy Market.

The future power system in Europe will be:

- A **System of Systems**, which will need strong cooperation between transmission and distribution, and amongst different energy systems. All operators will be key enablers and facilitators to make this future energy system work.
- At the same time more **European** and more **Local**, with TSOs providing a critical interface between both dimensions.

Our Vision – how do we get there

A Power System for a Carbon Neutral Europe is within our reach

Four key elements will need to change to make this new reality possible:

- The development of significant system **flexibilities**, both short and long duration, that will need to be timed with the phase-out of fossil fuel generation.
- An **operation** of the system that will rise up to the challenge of this much more dynamic System of Systems, including the management of flexibilities, through innovation and cooperation.
- A regulatory framework, planning and permitting procedures that will facilitate the timely deployment of the necessary **investments**, and encourage efficiency and innovation.
- A **market design** that must evolve to allocate value where it will be most needed for the energy system, while reflecting different consumers needs and preferences.

The scale of change is such that **we need to act now**.
To transform this vision into reality as soon as possible, we will need a strong cooperation across the whole energy industry, and a permanent dialogue with consumers, stakeholders and public authorities

TSOs, through ENTSO-E, propose this work as a basis to start building this future together

COME BACK
AFTER THE BREAK!